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Relationships are powerful

Rel [231x536]ationships are the food of life. Therefore, in order to nourish ourselves, we must surround ourselves with healthy relationships. You are responsible for the success of your own relationships. Both our practices and our families are the products of a series of inherited patterns: the negative ones that we can choose to observe and change, and the positive ones that we can grow and make stronger. Even if you came from a dysfunctional family (and who didn’t?), the relationships outside of our blood ties, the ones we forge as independent adults, are 100% of our own choosing.

In my life, I feel that the most important relationship is that of marriage, and an important component of marriage that we can take into every relationship we have is to make sure you always keep a sense of humor. Understand that each person has other issues happening in their lives that they must deal with outside the relationship you have with them. The high energy word to keep in mind when you’re in a relationship is kindness. If we are anything less than kind, unpleasant emotions will surface faster than a flash flood. Good relationships are about giving and receiving warmth, understanding, acceptance, fun, sincerity, and trust, as well as having respect for ourselves and for our partners in every relationship.

Although it sounds wonderful, this is no easy undertaking. I deal with patients from every walk of life—from the wealthy to the poor, the highly educated to the deeply undereducated—and I treat them all with respect. As a professional, it is my duty to maintain positive relationships with my patients even when my warmth and kindness is not reciprocated. However, I find that many of my patients are indeed grateful when I provide them with needed care, since these services add value to their lives.

Every person we meet shows us how well-connected we are with our unconscious mind, because we notice qualities in other people that we either have resolved, or not resolved within ourselves. We can actually feel the energy exchange in a relationship because we feel good, or not so good, when we’re in the company of another person. The value we place on our relationships is reflected in the type of people we surround ourselves with at work and at home. Good relationships are like little homes, complete with healing powers and the promise of sanctuary.

Our relationship with our children also holds a key to better relationships with others, especially by showing the importance of good communication. By both teaching and learning the best way to communicate, we can ensure healthy relationships at both home and work.

Strong relationships focus on how we can help and interact with our partners in the relationship. We must keep in mind that sometimes life can be challenging. Convincing people that the best way to increase the quality of their lives is to do something that will enhance another person’s life can be difficult.

In the movie An Officer and a Gentleman the principal character starts out with the “me” attitude and through a series of events appears to become “human.” He eventually helps a fellow cadet finish an obstacle course and his superiors feel he had finally earned the title an officer and a gentleman. We must all reach out unselfishly to help others overcome the obstacles that keep them from being successful in developing as many strong relationships as possible. As Ben Sweetland said, “We cannot hold a torch to light another’s path without brightening our own.”

Roger D. Winland, DDS, MS, MAGD
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Taking an excellent impression is essential for a well-fitting restoration. This column examines several factors that must be present for an impression to be successful.

**Healthy tissue**

It is much easier to impress a preparation accurately if the gingiva is healthy. This concept should be common sense. However, laboratories receive numerous impressions that were obviously taken in a sea of blood; such efforts are an exercise in futility. Any inflammation and/or infection should be resolved before attempting to take an impression for a definitive restoration. If the cause of the soft tissue problem is a current restoration that is not tissue-friendly, a well-fitting provisional should be fabricated. Once the tissue heals, the impression can be taken.

An exception to this rule occurs when the tissue does not respond positively to a provisional, no matter how well it fits. In these cases, you may want to try fabricating a new provisional from another material, such as switching from a conventional bis-acryl to Tuff-Temp (Pulpdent Products), which is stated by the manufacturer to be a “rubberized-urethane” and free from bisphenol A (BPA). You may proceed with the definitive crown but plan on provisional cementation. This is a riskier option, since once the tissue heals, it may also shrink and expose your margins. Of course, in some cases, no matter how diligent you are, the tissue may never return to absolute health. Patients should be informed of this possibility upfront, or they may end up less than satisfied.

Another cause of inflamed tissue is haphazard subgingival tooth preparation. If you indiscriminately enter the sulcus with a coarse diamond bur without regard for the tissue, the damage you cause may never resolve completely. Subgingival preparation should always be done carefully. Either place an instrument between the gingiva and the diamond bur, or use pack cord to move the tissue away from the tooth.

In addition, there should be an adequate width of attached gingiva adjacent to any crown destined for subgingival placement. Without attached gingiva, subgingival preparations and impressions are precarious at best. Referring the patient for a graft is the standard of care in this situation.

Finally, biologic width goes hand-in-hand with an adequate band of attached gingiva. If a previously placed restoration has violated the biologic width, it must be re-established before you can hope for gingival rejuvenation.

**Gentle retraction**

Even though it is possible to successfully expose margins using electrosurgery or a laser, most dentists still rely on retraction cord. It’s not high tech, it’s not sexy, and it’s tedious to place—but it works, and it’s relatively inexpensive.

Cord is meant to move tissue laterally, away from the tooth, not necessarily apically. However, the tissue typically moves in an apical direction during this lateral movement. One should not jam the cord down deep into the sulcus, but rather place it gently without using much force. One way to refine your cord packing skills is to perform this procedure on a patient who has not been anesthetized.

The goal of cord placement is not to search for the epithelial attachment. The goal is to expose tooth structure for access during tooth preparation and to expose margins when taking an impression.

Paste-type retraction materials can be used as an alternative to cord when taking an impression. Approximately seven years ago, the gingival retraction/hemostatic paste market was launched with the introduction of Expasyl (Kerr Dental), which had no competition for a number of years. This monopoly was broken in 2011 with the introduction of Traxodent (Premier Dental Products, Co.). 3M ESPE has also entered the field with Retraction Capsule, and Centrix just brought out its newest product, Access Edge.

The advantages of these clay-like materials are ease of use and speed of delivery, with virtually no trauma to the tissue. However, while these products are reasonably effective hemostatic agents, their tissue retraction function falls somewhat short of cord.
Margin placement
New ceramic materials such as Lava Plus (3M ESPE) and e.max (Ivoclar Vivadent, Inc.) are much less opaque than ceramometal or even some of the original metal-free systems such as Inceram Alumina (Vident). This increased translucency means you don’t have to bury margins to keep them out of view. When your preparation margins can be equigingival or just slightly subgingival, the tissue has a lower chance of being insulted and the impression is easier to capture.

Proper impression tray
With the wide variety of impression trays on the market, you can probably find one to fit almost any patient. Whichever brand you choose, your success rate will increase if the tray is rigid rather than flexible. It is also important that the tray does not touch the teeth. A custom tray remains the best choice for multiple tooth impressions; however, a full-arch stock tray also can be successful.

One of the new ones on the market is HeatWave (Clinician’s Choice Dental Products, Inc.), a thermoplastic tray that can be modified to fit a patient’s mouth more precisely by heating it in very hot water and molding the flanges and the palate if necessary. While the thermo-forming property still doesn’t match a custom tray, it is faster and less of a hassle.

Accurate impression material
We are blessed to have a wide variety of excellent materials at our disposal. This column reviewed some of the crucial properties of impression materials in 2010. Suffice to say that although versatile vinyl polysiloxane materials will perform very well for most dentists, Aquasil Ultra (Dentsply Caulk) remains the only product in this category with a REALITY 5-Star rating. On the other hand, polyether materials still have their fans; one such material, Impregum Soft (3M ESPE), has also earned a 5-Star rating.

Digital impressions
This new world of impression taking will include digital devices. These items still command a pretty high price; however, it is the author’s belief that the main reason they have not taken off is that they appear unable to capture preparations except in pristine conditions. If there was a unit that could “read” margins through blood and/or saliva, these machines would start selling in a logarithmic trajectory.

Impression taking is a bedrock procedure for the vast majority of dentists. Adhere to these fairly simple principles and your success rate is bound to soar.

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References

Manufacturers
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Antibiotic and antifungal medications are associated with an increased risk of bleeding among patients taking warfarin. A 2012 study by Baillargeon et al evaluated more than 38,000 patients aged 65 years and older who used warfarin continuously. Five antibiotic drug classes were examined: macrolides, quinolones, sulfonamides, penicillins, and cephalosporins. According to the authors, exposure to any antibiotic agent was associated with a twofold increased risk of bleeding that required hospitalization. In addition, the risk of bleeding that would require hospitalization increased fourfold following exposure to azole antifungals (fluconazole, ketoconazole, miconazole). The results of this study are applicable in the management of dental patients receiving antibiotics or antifungals.

For data collection, the authors used data from several sources—including Medicare enrollment files, Medicare Provider Analysis and Review (MEDPAR) files, Outpatient Standard Analytic files, Medicare Carrier files, and Prescription Drug Event records—for a 5% national sample of Medicare beneficiaries. Medicare Part A, which covers hospital expenses, begins automatically at age 65, whereas coverage for outpatient care (Part B) and prescription drugs (Part D) must be purchased.

The study evaluated a cohort of 38,762 Medicare beneficiaries who used warfarin continuously. Presence and duration of warfarin use was examined by evaluating prescription data from the Medicare Part D dataset. Continuous warfarin users were followed from January 1, 2008, until the end of the study period (December 31, 2008) or until the patient was hospitalized for a bleeding event, whichever occurred first. Reasons for warfarin use included atrial fibrillation, stroke, presence of prosthetic heart valve, and venous thromboembolism.

Cases were defined as patients who experienced a bleeding event requiring hospitalization at any time in 2008, based on International Classification of Diseases, ninth revision codes (ICD-9). Four types of bleeding were identified: gastrointestinal, non-gastrointestinal, intracranial, and general warfarin toxicity. The event date was defined as the date of hospital admission. Controls were matched with cases in terms of event date, indication for warfarin use, age, gender, and race/ethnicity.

Antibiotic exposure was determined by assessing the number of days in a given prescription period that followed the initial prescription date in the Medicare Part D dataset. Patients were considered to be exposed if their most recent prescription period for any antibiotic agent overlapped (by at least one day) the 15-day period before the event date. Among patients with antibiotic exposure, the authors categorized the time between the initiation of antibiotic agents and the event date into one of three categories: 0-15 days, 16-60 days, and more than 60 days. The antibiotics were categorized as “all antibiotic medication,” according to the following classes: cephalosporins, penicillins, sulfonamides (cotrimoxazole, a combination of trimethoprim and sulfamethoxazole), macrolides, and quinolones, while antifungals were categorized asazole antifungals.

The authors also examined patients’ use of potentially confounding medications known to interact with warfarin. A prescription for any potentially confounding drug that included at least 1 day in the 15 days before the event date was defined as presence of a confounding drug. The following classes of drugs were examined: antidepressants, antiplatelet drugs, corticosteroids, and selected inhibitors of warfarin hepatic metabolism.

Standard regression analysis was used to calculate odds ratios and 95% confidence interval (CI) for the risk of bleeding associated with prior exposure to antibiotic medications.

Results

The authors identified 38,762 patients as continuous warfarin users. During 2008, 1,136 (2.9%) of those patients were hospitalized with a primary diagnosis of bleeding. Of those, 798 met the definition for a case. The authors reported that continuous warfarin users...
exposed to any antibiotic agent were twice as likely (odds ratio = 2.01) to experience a bleeding event that required hospitalization compared to those who were not exposed to an antibiotic. Assessment of bleeding events revealed that antibiotic users were 2.5 times more likely to experience non-gastrointestinal bleeding and approximately twice as likely to experience gastrointestinal bleeding.  

The authors searched for an association between the start of a prescription and major bleeding and found that those whose prescription began within 60 days of the event date were more likely to have been hospitalized for bleeding compared with control patients who never took antibiotics. Exposed patients whose antibiotic prescriptions began more than 60 days before the event date did not have a statistically significant increased risk for bleeding that required hospitalization in comparison with the control patients. Patients treated with azole antifungals were over four times more likely to experience bleeding, while patients treated with macrolides were almost twice as likely to experience bleeding. Patients treated with quinolones were 1.7 times more likely to experience bleeding, while those taking cotrimoxazole were 2.7 times more likely, those taking cephalosporins were 2.5 times more likely, and those taking penicillins were approximately twice as likely to experience bleeding compared to the control group.  

Of the confounder medications, the serotonin selective reuptake inhibitors and corticosteroids were associated with statistically significant increased risk of bleeding.  

Discussion  
Among older continuous warfarin users, exposure to any antibiotic agent was associated with a twofold increased risk of bleeding that required hospitalization. All five specific antibiotic drug classes were associated with an increased risk of bleeding. Patients who were prescribed azole antifungals and cotrimoxazole had the highest risks of hospitalization for bleeding, which the authors noted was consistent with previous reports. The increased risk associated with antifungals and cotrimoxazole was attributed to their inhibitory effects on CYP2C9, one of the liver enzymes that metabolize warfarin. The results of the study by Baillargeon et al are consistent with some previous reports describing anti-infective drug interactions with warfarin.  

Related studies  
Glasheen et al conducted a retrospective analysis of patients at a university-affiliated Veterans Affairs medical center using warfarin before starting antibiotic therapy with azithromycin, levofloxacin, or trimethoprim/sulfamethoxazole (TMP/SMX). A control drug (terazosin) known to not interact with warfarin was used as the comparator. The incidence of international normalized ratio (INR) elevation and the degree of change and bleeding events after initiation of either medication type was recorded.  

The control drug experienced a mean change in INR of -0.15 (N = 20), compared to increases of 0.51 for azithromycin (N = 32), 0.85 for levofloxacin (N = 27), and 1.76 for TMP/SMX (N = 16). These mean INR changes were significantly different from the control group. INR was elevated beyond therapeutic levels for 5% of the control group, compared with 31% in the azithromycin group, 33% in the levofloxacin group, and 69% in the TMP/SMX group. More clinically significant elevations of INR (defined as elevations beyond an INR of 4) were observed in 0% of the control group, 16% of the azithromycin group, 19% of the levofloxacin group, and 44% of the TMP/SMX; the latter was the only group with documented bleeding episodes. The authors concluded that oral antibiotics (azithromycin, levofloxacin, and TMP/SMX) increased the incidence and degree of anticoagulation among acutely ill outpatients on warfarin medication.  

A 2008 study by Schellemen et al reported that patients taking warfarin for whom azole antifungals and cotrimoxazole were subsequently prescribed demonstrated the highest risks of hospitalization for gastrointestinal bleeding. The authors evaluated United States Medicaid patients receiving warfarin (N = 580,188) to determine whether the potential for interaction between warfarin and orally administered anti-infectives increased the risk of hospitalization for gastrointestinal (GI) bleeding. The authors determined an association between GI bleeding and prior use of ciprofloxacin, levofloxacin, gatifloxacin, cotrimoxazole, or fluconazole. By comparison, there was no association for patients who used cephalaxin (which would not be expected to interact with warfarin) and no association for patients who were not exposed to these drugs. All of the anti-infectives examined were associated with elevated risks of bleeding compared to no exposure. Using cephalaxin as the reference, cotrimoxazole and fluconazole demonstrated the highest risk of GI tract bleeding.  

In 2010, Fischer et al published a population-based, nested case control study using health care databases in Ontario, Canada, between April 1, 1997, and March 21, 2007. The study identified residents 66 years or older who were treated continuously with warfarin. Cases were hospitalized with upper GI bleeding; for each case, the authors selected up to 10 age- and gender-matched
control patient cohort. They calculated adjusted odds ratios for exposure to cotrimoxazole, amoxicillin, ampicillin, ciprofloxacin, nitrofurantoin, and norfloxacin within 14 days before bleeding began.3 The authors identified 134,637 patients who had received warfarin, of whom 2,151 cases were hospitalized for upper GI bleeding. It was found that these cases were almost four times more likely to have recently received cotrimoxazole than patients in the control group. Treatment with ciprofloxacin was also associated with twice the increased risk; however, no significant association was observed with amoxicillin, ampicillin, nitrofurantoin, or norfloxacin.3 In a 2006 study, Zhang et al found that of 17,895 patients who used warfarin, 2,634 (14.7%) were diagnosed with a hemorrhagic event within one week after filling a prescription for warfarin.6 One factor associated with the increased risk of bleeding was the use of warfarin in addition to either cephalosporins or metronidazole.

Dental patient considerations
In the study by Baillargeon et al, many of the antibiotics and antifungals that increase the risk of bleeding in older patients on warfarin (including fluconazole, ketoconazole, miconazole, cephalaxin, cefaclor, azithromycin, clarithromycin, amoxicillin, penicillin VK, ciprofloxacin, levofloxacin, moxifloxacin, and the anti-microbial metronidazole) are used in dentistry.5,7 It has been suggested that antibiotic or antifungal medications interact with warfarin to increase the risk of major bleeding by disrupting intestinal flora that synthesizes vitamin K and inhibiting cytochrome P450 isozymes that metabolize warfarin.2,3,5,8

Baillargeon et al suggested frequent monitoring of INR values for patients who are taking warfarin and antibiotic agents concurrently. Inhibition of vitamin K synthesis by alteration of gut flora or inhibition of cytochrome P450 enzymes can increase INR and bleeding within one to two weeks.2 It may be prudent to monitor anticoagulation status more closely in patients treated with a vitamin K antagonist (that is, warfarin) both during concurrent use of an implicated antibiotic or antifungal and for at least several days after cessation of the antibiotic or antifungal. It also may be prudent to advise these patients to pay particularly close attention to any signs or symptoms of bleeding.

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References
In recent years, dental schools have de-emphasized the teaching of laboratory skills. Certain restorative techniques have been de-emphasized and some curricula have eliminated the laboratory work required to construct restorations. Pouring models and trimming dies, basic waxing and casting, and finishing and polishing methods are a few examples of laboratory procedures that were taught in dental schools in the past and used in dental practice today. Unfortunately, these techniques are no longer being taught in all schools; as a result, fewer graduates will have skills that were commonplace only a short time ago.

Incorporating even a minimal amount of laboratory work in a dental practice could provide the dentist and staff with new challenges, improve the dentist’s preparation skills, increase efficiency, and reduce laboratory expenses. This column presents an example of such laboratory work—specifically, pouring an articulated die model and trimming the die for a single crown.

Pouring impressions
After making an accurate impression, the model should be poured within the time period recommended by the manufacturer. Although impression materials have improved dramatically since the days of plaster and rubber bases, allowing an impression to sit for too long increases the risk of distortion. When a model is not poured in the office, the impression often is boxed up, sent to another location (possibly by air, with a resultant change in atmospheric pressure), and thus, the model is not poured for three to five days after the start of the process. The following simple steps may eliminate errors in the fit of a crown while saving both the dentist and patient time and money.

Model pouring
First, a work space where all necessary equipment and materials are close at hand must be created in the office (Fig. 1). A laboratory microscope is a big advantage, particularly during die preparation. Using a sharp knife, remove the impression material beyond the metal flanges of the impression tray. This allows full seating of the plastic disposable articulator (W.O.W., Premier Dental Products, Co.) into the impression (Fig. 2).
Next, using a marking pen, draw lines on either side of where the preparation is and also on either side of the tooth, to ensure that the articulator is placed accurately into the impression and that the dowel pins will seat in the impression without interference (Fig. 3).

Using the drawn lines as guides, place the dowel pins into the plastic frame—one or two in the preparation and one on either side (Fig. 4). Using an electronic digital scale, measure the water and the die stone (to 0.01 g) (Fig. 5). The die stone (Fujirock, GC America, Inc.) should be mixed in a vacuum mixer according to the manufacturer’s recommendations and placed carefully into the impression (Fig. 6 and 7).

Next, place additional die stone onto the plastic top with the dowel pins and place it into the impression, lining up the drawn lines (Fig. 8). After setting of the stone is complete, prepare a second mix, place a layer on the other part of the articulator, connect it to the first section, close it, and allow it to set (Fig. 9).

**Die preparation**

After the setting of the die stone, the die is sectioned, trimmed, painted, and lubricated. The die can be sectioned by using a die saw in the traditional manner; if contact is tight, a laboratory disk in a straight handpiece can be utilized (Fig. 10). The die is then trimmed using a laboratory carbide in a straight handpiece (Fig. 11). At this point, the die spacer should be painted on the die, taking care to stay away from the margins (Fig. 12).

Prior to waxing, a lubricant is painted on the die and allowed to dry (Fig. 13); if the wax sticks, a second coat may be necessary. At that point, the die model is complete and ready for waxing (Fig. 14).

**Discussion**

Dentists who do even a small amount of laboratory work in their offices notice advantages for the patients served and the practice’s bottom line. By pouring an impression and trimming a die in-house, any mistakes
during preparation will be noticed long before the technician sees the case. This will save time for the patient as well as show the dentist his/her error, which means the error may not happen a second time. The dentist will clearly see any undercuts, indistinct margins, inadequate occlusal space, or other abnormalities soon after the preparation visit. Sometimes these errors are corrected by the technician without informing the dentist; as a result, the dentist gets a restoration back that doesn’t fit properly—requiring another appointment for a new preparation and impression—while failing to learn from the process.
Another noticeable aspect within offices that pour impressions and trim dies is how such activities affect the dental assistant. As more lab work is done in the office, the dental assistant will become interested in the “new” procedures and become more knowledgeable about preparations and excellence in restorative dentistry.

Some dentists who do the model work for cases in-house have asked their technicians for a reduction in fees since they are doing some of the work. Fulfilling this request depends on the relationship between the dentist and the lab person, but it can be done. In these challenging economic times, many dentists have more time on their hands due to a lack of patients. That time could be well spent doing a little more lab work.

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Manufacturers
GC America, Inc., Alsip, IL
800.323.7063, www.gcamerica.com
Premier Dental Products Co., Plymouth Meeting, PA
610.239.6000, www.premusa.com
Dental assistant or patient? Can she be both?

Toni M. Roucka, DDS, MA

The following scenario is not an uncommon occurrence in dental offices. Dentists frequently provide dental treatment to their own families, friends, and staff. It is probably quite rare that a bad outcome such as the one described below would occur; however, it causes one to reflect on how dentists might alter their patient appointment and patient management protocols when treating patients who are “familiar” to them. It is important to be cognizant of some of the moral and professional pitfalls that may arise when providing dental care to such patients. Let’s examine the case.

Mrs. Harker has been a dental assistant at Dr. Leonard’s practice for three years. Dr. Leonard is an excellent employer. He offers generous benefits to his staff, including free dental care for them and their immediate families. He feels it is his duty to do so. Why should they have to go elsewhere for their dental treatment? With a total of five full-time employees, he feels this is a very easy benefit to offer.

Dr. Leonard has a general dental practice that is quite successful. Though he performs all types of dental treatment, he enjoys oral surgery the most. He rarely refers any procedures out and feels confident in all aspects of general dentistry.

One day, Mrs. Harker approached Dr. Leonard with a concern about one of her teeth. Tooth No. 30 was starting to bother her during chewing and was keeping her up at night. Squeezing her in between patients, Dr. Leonard examined the tooth and deemed it unrestorable due to a vertical root fracture. As such, he devised a treatment plan that entailed placing a 3-unit bridge to replace tooth No. 30 once the healing after extraction was complete. Because Mrs. Harker had large restorations on both teeth No. 29 and 31, and would eventually require crowns on these teeth, she opted for a bridge over a dental implant. The extraction was scheduled for the end of the next day, after the last “regular” patient was dismissed.

Mrs. Harker was happy to be getting it over with.

The day of Mrs. Harker’s extraction was very hectic in the office. The staff barely had time for lunch. After the last appointment was completed, Dr. Leonard asked Mrs. Harker if she was still up for the extraction that day. She said she was and they proceeded. One of the other dental assistants, Ms. White, stayed late to assist Dr. Leonard.

What Mrs. Harker failed to tell Dr. Leonard was that she was a newly diagnosed diabetic, only three weeks into treatment. Her medications were being adjusted and she was having some difficulty regulating her blood sugar. She was also still somewhat in denial over the whole diagnosis, so the information wasn’t intentionally omitted; she simply forgot to mention it to him. Besides, she didn’t like to mix personal issues with business and was proud of the fact that she had never used a sick day in three years of working for Dr. Leonard. She considered herself “healthy as a horse.” The diabetes diagnosis was not going to change her lifestyle if she could help it.

Mrs. Harker tolerated the extraction procedure very well. Once it was complete, Dr. Leonard left for the day, with Mrs. Harker and Ms. White chatting in the operatory about their plans for the weekend. Everything appeared fine until Mrs. Harker went to stand up from the dental chair. As she rose, she unknowingly began to experience an episode of hypoglycemia and immediately passed out, hitting her head on the wall of the dental operatory and then on the floor. Not knowing what was happening, Ms. White immediately called 911. Paramedics arrived, administered first aid, including IV fluids, and as a precaution, transported Mrs. Harker to the hospital for some head and neck radiographs. Her blood sugar was quite low. When all was said and done, Mrs. Harker was fine except for a chipped tooth (No. 8), two black eyes, and a bruised ego.

Upon hearing what happened, Dr. Leonard was understandably upset. Looking back on the situation, he began to question whether he should continue the practice of treating his staff and their families and if so, how could or how should he modify this practice?

The facts

- Dr. Leonard has chosen to offer the benefit of free dental care to his staff and their families. Mrs. Harker is his dental assistant and in need of some dental care.
- Dr. Leonard is an accomplished general dentist and comfortable with providing the care that Mrs. Harker needs.

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• Dr. Leonard “squeezed Mrs. Harker in” between “regular” patients for an exam and performed the extraction after normal business hours.
• Mrs. Harker failed to tell Dr. Leonard about her recent diabetes diagnosis.
• Mrs. Harker had a hypoglycemic episode after the extraction resulting in a fall, sending her to the hospital for precautionary radiographs. She now has two black eyes and a chipped tooth (No. 8) as a result of the fall.

The ethical issues
When a dentist chooses to treat a patient that has another relationship to them outside the dentist-patient relationship, they are essentially engaging in a “dual relationship” with that patient. Some examples of dual relationships include when the patient is also a student, friend, family member, employee, or business associate of the care provider. In other professions, dual relationships of various kinds are strictly prohibited. In psychology, for instance, having a sexual relationship with a patient amounts to a criminal act in many states. Dual relationships in dentistry are not directly addressed in the American Dental Association’s Principles of Ethics and Code of Professional Conduct (ADA Code) other than in Section 2.G. Personal Relationships with Patients, where it states, “Dentists should avoid interpersonal relationships that could impair their professional judgment or risk the possibility of exploiting the confidence placed in them by a patient.” Although this was not a case of a “personal relationship” on a social level, it certainly was a case of a dual relationship in that Mrs. Harker was an employee of Dr. Leonard’s who was also being treated as a patient.

There are several ethical issues associated with engaging in dual relationships in dentistry. According to the ADA Code, dentists are to always put the patient’s best interest above their own. Unfortunately, this becomes more difficult to do when a dentist is involved in a dual relationship with a patient. Roles may become blurred and/or conflict. Both parties are subject to acting in ways that they might not ordinarily, which could jeopardize the professional relationship.

In this case, for instance, Dr. Leonard did not provide a proper exam appointment for Mrs. Harker to assess her pain. “Squeezing her in” between “regular” patients might not seem problematic at first, but did he have enough time to take a proper medical history or make a proper diagnosis? Even if he did make a proper diagnosis, we could argue that his interests came first in this circumstance; the patient receiving “free care” was given less scheduled time than paying patients so as not to affect the dentist’s bottom line for the day. Likewise, scheduling Mrs. Harker for her extraction at the end of a long day outside of normal business hours was clearly not in her best interest. She may have felt obligated to take the appointment that was offered to her so as not to inconvenience the dentist, even if she really did not feel like undergoing the procedure that day. On the flipside, some may feel that Dr. Leonard was actually going over and above the call of duty by making special accommodations to treat Mrs. Harker in an expeditious manner. Either way, the fact is that Mrs. Harker was treated differently in this case because she was Dr. Leonard’s dental assistant.

Dual relationships are a two-way street. Patients and dentists are both subject to ethical implications when engaging in them. For example, the charging and payment of fees may become awkward in a dual relationship. The dentist may feel guilty for charging their “friend” and the patient may feel they either deserve a discount or owe their friend “a favor” for the care provided. An employee/patient may have knowledge of office finances that may influence treatment choices. These choices may not always be in the patient’s best interest.

In general, dentists drive the doctor-patient relationship as they possess the professional expertise and knowledge. The professional relationship is one based on trust: Patients trust that the dentist is putting their best interest above his own and will maintain confidentiality, not cause harm, and not abuse sensitive information provided to them. Becoming “too familiar” with a patient gives dentists even more power over that patient as they are in possession of sensitive information that they otherwise would not have. This may put the patient in a more vulnerable position than normal and does not serve their best interest.

The options and course of action
The ADA Code offers no formal guidance on the question of whether the provision of dental care to employees and their families is ethically permissible other than what is mentioned in Section 2.G. (quoted above). The AMA Code does not specifically offer guidance in this area either, but it does offer guidance on treating immediate family members and on the offering of professional courtesy. Section 8.19 Self-Treatment or Treatment of Immediate Family
Members of the AMA Code, strictly prohibits treatment of immediate family for all of the stated reasons that make dual relationships problematic. The AMA Code also emphasizes the fact that objectivity may be compromised when treating family members and that professional judgment may be unduly influenced. The same may be said for treating a close friend or a staff member. Often, employees develop long-term relationships with their employers and this could be a potential problem.

Professional courtesy refers to the provision of care to co-professionals or their families, free of charge or at a reduced rate. This is ethically permissible in the AMA Code and it allows physicians to “use their own judgment” in deciding whether to waive or reduce their fees when treating fellow physicians or their families. Professional courtesy was initially practiced as a way to discourage physicians from treating their own families. It may be a bit of a stretch to call the case above one of “professional courtesy,” but lacking guidance from the ADA and AMA codes in regard to providing professional services to staff, I believe it is relevant.

If professional courtesy is to be granted to an individual, providers must be careful not to violate any insurance contracts or the law. According to AMA Code Section 6.12 Forgiveness or Waiver of Insurance Co-Payments, ADA Code Section 5.B.1. Waiver of Co-Payment and other listed sources, it is unlawful to bill insurance companies and waive the patient portion. This is considered overbilling and is illegal. There is no law, however, that prohibits professional courtesy. Schulte states, “As long as professional courtesy is not precluded by contract or provided in return for referrals, which could violate the Federal Anti-Kick Back Law, it is not illegal.”

In this case, Dr. Leonard is faced with several decisions. The fact is he left his office before his “patient” was dismissed from the dental chair. Looking back, he realizes that he has never done this before. If Mrs. Harker were a “regular” patient, he would have stayed until she was dismissed in stable condition. True, she was not honest with him about her diabetes, but the fact is, she fell in his operatory and ended up requiring a hospital visit and further dental work on tooth No. 8. He was the dentist who provided the care. Is he now obligated to pay for her hospital ER visit? He knows he will be fixing her tooth No. 8 as part of her dental benefits.

These are all questions that have no concrete answers. Dr. Leonard will have to decide how far to extend his “dental benefit.” Paying for Mrs. Leonard’s hospital visit would be expensive but a nice gesture on his part. Is he ethically or legally required to do so? Probably not, but since she is a long-term loyal employee, it may be the right thing to do barring any insurance company constraints as described above. If she chooses to bill her medical insurance for the costs of her hospital treatment and there is an insurance co-payment for the medical care, should Dr. Leonard offer to reimburse her for that? That would be a decision he would have to make. I would argue that under the circumstances, and in the spirit of goodwill, it is probably the right thing to do.

I would also like to add that dealing with such insurance questions gets complicated and is beyond the scope of this paper. I would encourage anyone who is unsure how to proceed in a particular situation to refer to their insurance company contract and/or applicable state and federal laws for further guidance.

In conclusion, the provision of dental care is a complex process. The value of the dentist-patient relationship to the successful outcome of dental treatment cannot be overstated. A professional relationship of mutual trust and understanding will foster better patient compliance, better communication between dentist and patient, and ultimately, better treatment outcomes overall. If dentists choose to treat their own staff members, families, or friends, they must be cognizant of the possible pitfalls associated with dual relationships and be prepared, if necessary, to end the professional relationship in order to serve the best interests of the patient.

Author information
Dr. Roucka received her DDS degree from the University of Illinois, College of Dentistry and an MA in Bioethics from the Medical College of Wisconsin. She is a Navy Veteran and a board member at large for the American Society for Dental Ethics. She is currently an assistant professor and Program Director, General Dentistry, Marquette University School of Dentistry, Milwaukee, Wisconsin.

References
The Time You Spend Reading Our Magazines Is Worth It

And, here’s why: Our publications recently received three journalism awards…

International College of Dentists, Golden Pen, Honorable Mention, General Dentistry, March/April 2011, “Evaluation of the microbial flora found in woodwind and brass instruments and their potential to transmit diseases,” written by R. Thomas Glass, DDS, PhD; Gerwald A. Kohler, PhD; Robert S. Conrad, PhD; and James W. Bullard, MS.


So, keep reading, and keep the good ideas and feedback coming.
Thank you, AGD members, for your support.

Roger Winland, DDS, MS, MAGD
AGD Editor
generaldentistry@agd.org
PROSTHODONTICS
The Academy of General Dentistry and the American College of Prosthodontists bring you this special section on prosthodontics
In the best interest of our patients

I am honored by the invitation to provide the guest editorial for the Academy of General Dentistry’s (AGD) journal, General Dentistry. A special thank you for the will and vision that both Drs. Fares Elias, 2011 Past President of the AGD, and Jonathan Wiens, 2011 Past President of the American College of Prosthodontists (ACP), created to discuss the potential for collaboration between our two organizations. We are fortunate that they are colleagues in the same Michigan town, practiced as neighbors (just 14 miles apart!), and started a healthy dialogue on behalf of our members.

In this day and age, the exponential growth in technology and the plethora of scientific, peer-reviewed publications continue to bring challenges for our private practitioners in their day-to-day care of patients. It requires exceptional time management and resources to stay at the top of our abilities, both in thought processes and skills; in partnership, our organizations can work together to excel for the benefit of our members and ultimately our patients.

Our approximate membership totals for each organization include ~37,000 for the AGD and ~3,400 for the ACP, both of which represent members who have committed themselves to reaching professional and educational goals beyond those achieved in dental school. As such, though difficult to receive in the midst of challenge, the following statement is often repeated in multiple iterations to dental students: This is only the beginning; you will be obligated to your own continued professional development and lifelong learning.

As the AGD provides the recognition to members who have pursued and achieved professional distinction through extensive professional education, the ACP is the only organization that represents prosthodontists as specialists recognized by the American Dental Association through the Commission on Dental Accreditation (CODA) processes. Both of our organizations serve the interest of our members. Together, our practitioners can work to achieve what is in the best interest of the patient.

My professional background includes a limited private practice but primarily, I am an academic-prosthodontist. I work as a specialist in my interactions with dental students to make them the best general dentists possible within the constraints of an ever-evolving education process. I strive to empower them with the knowledge, skills, and values to direct patient care for the best possible outcomes. Although they may not be able to provide the vast expanse of care for every level of difficulty, it is the focus on self-evaluation and self-assessment that empowers the young general dentist with the ability to decide when and if partnership with a specialist is needed. I received a great education in dental school to graduate as a general dentist with a solid foundation, which in turn has helped me when I pursued an advanced education in prosthodontics. I contend that when the decision is made to partner with a specialist, in this instance, a prosthodontist, it makes all of us better when serving the needs of our patients.

I hope we will continue the dialogue for greater advocacy on behalf of our patients and educational partnerships. Toward this end, I encourage your support for having prosthodontist-academicians contribute in dental school education alongside general dentist-academicians. The strength of dental schools is dependent on having outstanding resources, one of which is a high-quality faculty. With the growth in clinically-relevant research and the influence this research has on our decision-making processes, it is incumbent on the faculty to remain at the top of their knowledge and abilities to ensure our graduating general dentists are ready for the practice of today, as well as the practice of tomorrow. Together, our organizations, as well as our members—both general dentists and prosthodontists—can work as a team in the most complex of oral health care needs to serve in the best interest of our patients.

Thank you for the opportunity to address your members and I look forward to the possibilities ahead.

Lily T. Garcia, DDS, MS, FACP
President, American College of Prosthodontists
Denture adhesive use in complete dentures: Clinical recommendations and review of the literature

Ibrahim Duqum, BDS, MS • Kendall Ann Powers, BS • Lyndon Cooper, DDS, PhD, FACP • David Felton, DDS, MS, FACP

This literature review sought to determine the advantages and disadvantages of denture adhesive use among complete denture patients. Manuscripts were obtained by searching the National Library of Medicine’s PubMed database, Cochrane Collaboration Library, ADA Center for Evidence-Based Dentistry website, and EMBASE database. A total of 85 abstracts were reviewed, and 38 articles that met the inclusion criteria for this review were selected. The inclusion criteria included clinical trials and case series in which 10 or more patients were treated, as well as Cochrane Collaboration reviews and in vitro studies where clinical relevance could be determined. The selected manuscripts were reviewed using a standardized manuscript review matrix.

Although denture adhesives improve the retention and function of complete dentures, standardized guidelines are needed for the proper use, application, and removal of denture adhesives. Additionally, long-term studies are warranted on the biologic effects of denture adhesives. There is a need to establish a regular recall program for complete denture patients.

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With complete dentures, insufficient denture retention is a powerful determinant of patient satisfaction. Several factors and complex interactions affect the retention and stability of complete dentures in the oral cavity, including atmospheric pressure, intimate adaptation of both hard and soft tissues beneath the denture base to the intaglio surface of the prosthesis, accurate peripheral extensions of the denture base (determined by physiological movements), and the presence of a thin film of saliva (with acceptable viscosity) between the prosthesis and the tissues. Denture retention can be jeopardized if any of these factors are compromised.

Residual ridge resorption (RRR) is a common, lifelong condition that plagues complete denture patients after exodontia and subsequent denture placement. RRR occurs rapidly within 3-12 months after tooth removal, and continues throughout the patient’s life. Alveolar ridge resorption compromises denture retention and stability, rendering a denture loose and non-serviceable to the patient. Patients with complete dentures require unique considerations due to their compromised oral anatomy, reduced adaptive capacity, and systemic conditions or medications that further affect denture retention and stability, all of which reduce the patient’s ability to successfully wear their prostheses.

In addition to hard and soft tissue alterations over time, these patients can be affected by changes in saliva quality or quantity (due to medications or age), diminished bite force, and reduced neuromuscular control.

While these biologic and physiologic changes compromise denture function, new techniques have been created to enhance both the retention and fit of aging prostheses. These techniques include denture rebasing or relining, denture adhesives, and endosseous dental implants. This article will review the advantages and potential problems associated with the use of commercially available denture adhesives to enhance the retention, stability, and functionality of complete dentures. Definitions for specific terms are listed in Table 1.

Methods
In 2009, the American College of Prosthodontists (ACP) formed a task force to develop contemporary, evidence-based guidelines for the care and maintenance of complete dentures. This task force consisted of individuals representing the ACP, the Academy of General Dentistry, the American Dental Association (ADA) Council on Scientific Affairs, the American Dental Hygienists’ Association, the National Association of Dental Laboratories, and GlaxoSmithKline Consumer Healthcare. As part of this task force, a comprehensive review about denture adhesives was performed by the University of North Carolina faculty and ACP members. Another manual search was performed in May 2012 to include all relevant recent literature published after 2009.
This review evaluated literature obtained by searches in the National Library of Medicine’s PubMed database, Cochrane Collaboration Library, ADA Center for Evidence-Based Dentistry website, and EMBASE database. Key words included, either singularly or in various combinations, the terms “dentures,” “retention,” “stability,” “adhesives,” “toxicity,” and “adaptation.” The inclusion criteria included clinical trials and case series in which 10 or more patients were treated, Cochrane Collaboration reviews, and in vitro studies for which clinical relevance could be determined. Based on this criteria, a total of 85 article abstracts were obtained and reviewed. Selected full-text manuscripts were reviewed using a standardized manuscript review matrix (Fig. 1) and summary information was provided. After a careful review of the articles, additional reference materials were selected from the reference lists of each article and similarly reviewed. Of the original 85 articles, only 38 manuscripts met the inclusion criteria for this review: eight prospective controlled trials, eight cross-sectional cohort studies, seven in vitro studies, six multiple arm cross-over studies, five case series, three randomized controlled trials, and one retrospective study.

**Results**

**Composition of denture adhesives**

Denture adhesives are available in various formulations including powders, liquids, creams, or pads/wafers. While the exact composition of commercially available denture adhesives may vary, they all contain the same generic materials that serve a specific function. Table 2 lists the common components of denture adhesives and their respective functions.

**Ideal characteristics of denture adhesives**

The authors believe that an ideal denture adhesive should be formulated so that it is not toxic to the systemic or oral health of the patient (regardless of short- or long-term use); it is incapable of promoting bacterial or fungal growth; it improves the dentures’ retention, stability, and functionality (that is, the ability to chew foods); it is easy for the patient or primary caregiver to apply and remove; it has an acceptable aroma (or no aroma), taste, and consistency; it does not alter or degrade the intaglio surface of the denture base; it does not modify the occlusion of

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**Table 1. Definitions of terms used in this review.**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Denture retention</td>
<td>The resistance to movement of a denture away from its tissue foundation, especially in the vertical direction; a quality of a denture that holds it to the tissue foundation and/or abutment teeth</td>
</tr>
<tr>
<td>Denture stability</td>
<td>The resistance of a denture to movement on its tissue foundation, especially to lateral (horizontal) forces as opposed to vertical displacement; a quality of a denture that permits it to maintain a state of equilibrium in relation to its tissue foundation and/or abutment teeth</td>
</tr>
<tr>
<td>Denture adhesive</td>
<td>A material used to adhere a denture to the oral mucosa</td>
</tr>
<tr>
<td>Denture service</td>
<td>The procedures involved in the diagnosis and subsequent fabrication and maintenance of artificial substitutes for missing natural teeth and associated structures</td>
</tr>
<tr>
<td>Toxicity</td>
<td>The adverse reactions (dose-response-time relationships) of tissues to selected foreign substances resulting in unacceptable in vivo interactions; toxicity can be at the local or systemic level depending on the amount, rate of release, and specific type of substance available to the tissues</td>
</tr>
</tbody>
</table>

**Table 2. Denture adhesive composition.**

<table>
<thead>
<tr>
<th>Material</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl vinyl ether-maleic anhydride copolymer</td>
<td>High molecular weight copolymers with adhesive and cohesive properties</td>
</tr>
<tr>
<td>Karaya gum</td>
<td>Thickener</td>
</tr>
<tr>
<td>Tragacanth</td>
<td>Water-soluble mixture of polysaccharides that absorbs water to become a gel</td>
</tr>
<tr>
<td>Acacia</td>
<td>Preservative</td>
</tr>
<tr>
<td>Pectin</td>
<td>Gelling agent</td>
</tr>
<tr>
<td>Gelatin</td>
<td>Gelling agent</td>
</tr>
<tr>
<td>Carboxymethylcellulose</td>
<td>Viscosity modifier/thickener</td>
</tr>
<tr>
<td>Mineral oil</td>
<td>Suspending and levigating agent</td>
</tr>
<tr>
<td>Antimicrobial agents (for example, ethanol, sodium borate, sodium tetraborate, hexachlorophene)</td>
<td>Antimicrobial</td>
</tr>
<tr>
<td>Non-toxic additives</td>
<td>Wetting agents and plasticizers</td>
</tr>
<tr>
<td>Flavoring agents (for example, peppermint oil, wintergreen oil)</td>
<td>Improves taste</td>
</tr>
</tbody>
</table>
Fig. 1. The manuscript review matrix used in this review.

<table>
<thead>
<tr>
<th>1. Journal citation (in JOPR format):</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Author’s last name, initials: __________________________</td>
</tr>
<tr>
<td>b. Title of study: __________________________</td>
</tr>
<tr>
<td>c. Name of Journal: ______________________</td>
</tr>
<tr>
<td>d. Year: __________ Issue: __________ Pages: __________</td>
</tr>
</tbody>
</table>

| 2. Purpose (What is the null hypothesis?): ______________________ |

<table>
<thead>
<tr>
<th>3. What were the treatment groups that were compared (CD/CD, CD/natural teeth, CD/RPD, RPD/RPD, RPD/natural teeth)?</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Group A: _____ Group B: _____ Group C: _____ Group D: _____</td>
</tr>
<tr>
<td>b. Were the treatment groups age/sex matched? □ Yes □ No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Study participants (N):</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Number of participants at start of trial: __________</td>
</tr>
<tr>
<td>b. Number of participants at conclusion of trial: __________</td>
</tr>
<tr>
<td>c. Reasons for patient drop out: __________________________</td>
</tr>
<tr>
<td>i. Were dropped patients included in results? □ Yes □ No</td>
</tr>
<tr>
<td>ii. How did the authors rationalize inclusion of dropped patients in the data analysis? __________________________</td>
</tr>
<tr>
<td>d. What was the sample size in each treatment group?</td>
</tr>
<tr>
<td>Group A,N = ___ Group B,N = ___ Group C,N = ___ Group D,N = ___</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. Was there a control group identified? □ Yes □ No</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. If yes, what was the size of group? N = ___</td>
</tr>
<tr>
<td>b. Was the control group age/sex matched to the experimental groups? □ Yes □ No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. What was the method of patient allocation to the various treatment and control groups?</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Random allocation (method used)? __________________________</td>
</tr>
<tr>
<td>□ Sequentially assigned? __________________________</td>
</tr>
<tr>
<td>□ Other? __________________________</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. Type of study (check appropriate response):</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Cochrane Review □ Other systematic review or meta analysis</td>
</tr>
<tr>
<td>□ RCT □ Controlled clinical trial</td>
</tr>
<tr>
<td>□ Case series □ Cross sectional cohort study</td>
</tr>
<tr>
<td>□ Other __________________________</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8. Were there defined inclusion/exclusion criteria for patient selection?</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Yes □ No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9. Was Institutional Review Board approval for the study obtained prior to initiation of trial?</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Yes □ No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>10. Was informed consent obtained from study participants?</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Yes □ No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>11. What types of interventions were utilized in test/control groups?</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEST</td>
</tr>
<tr>
<td>Brushing only</td>
</tr>
<tr>
<td>Brushing with paste</td>
</tr>
<tr>
<td>Ultrasonic cleaning</td>
</tr>
<tr>
<td>Chemical disinfection</td>
</tr>
<tr>
<td>(list types of chemicals used)</td>
</tr>
<tr>
<td>Microwave</td>
</tr>
<tr>
<td>Combination of these (specify)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>12. Assessment methods used:</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Patient satisfaction survey (OHIP or other—specify): _______</td>
</tr>
<tr>
<td>□ Bacteriological tests (specify): __________________________</td>
</tr>
<tr>
<td>□ Level of inflammation (method used): ______________________</td>
</tr>
<tr>
<td>□ Other (specify): __________________________</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>13. Outcomes measured (what were the results?):</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Level of patient satisfaction: __________________________</td>
</tr>
<tr>
<td>□ No. of bacterial CFU formed: __________________________</td>
</tr>
<tr>
<td>□ Tissue inflammation: __________________________</td>
</tr>
<tr>
<td>□ Other: __________________________</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>14. What type(s) of statistical tests were used (specify types):</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>15. Results:</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Was one intervention superior (statistically significant) to the others or to the controls? __________________________</td>
</tr>
<tr>
<td>b. Rank of the interventions by statistical significance only: (i.e., method a &gt; method b = method c) __________________________</td>
</tr>
</tbody>
</table>

| 16. Who funded the study? (Identify funding source, or “no source identified”): __________________________ |

<table>
<thead>
<tr>
<th>17. Were there potential sources of bias? □ Yes □ No</th>
</tr>
</thead>
<tbody>
<tr>
<td>If yes, what were they?</td>
</tr>
<tr>
<td>□ Patient randomization or allocation to treatment groups</td>
</tr>
<tr>
<td>□ Examiner bias</td>
</tr>
<tr>
<td>□ Funding source</td>
</tr>
<tr>
<td>□ Other (please specify): __________________________</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>18. Summary statement (please answer the following questions):</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Was the study design adequate? □ Yes □ No</td>
</tr>
<tr>
<td>If not, please indicate possible limitations in design: __________________________</td>
</tr>
<tr>
<td>b. Were the results accurately reflected in the conclusions?</td>
</tr>
<tr>
<td>□ Yes □ No</td>
</tr>
<tr>
<td>c. Were appropriate statistical tests utilized? □ Yes □ No</td>
</tr>
<tr>
<td>d. Were the results applicable to contemporary prosthodontics practice? □ Yes □ No</td>
</tr>
<tr>
<td>e. Should the manuscript be included as source material for the ACP/GSK denture care guidelines project? □ Yes □ No</td>
</tr>
<tr>
<td>f. Were there other articles referenced in the current manuscript that were overlooked in our initial literature search that should be included in our review? □ Yes □ No</td>
</tr>
<tr>
<td>If yes, please provide the reference here (using JOPR format): __________________________</td>
</tr>
</tbody>
</table>

www.agd.org General Dentistry Special Prosthodontics Section 469
**Complete Dentures**  
Denture adhesive use in complete dentures

<table>
<thead>
<tr>
<th>Author</th>
<th>Trial type</th>
<th>Testing methods</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berg (1991)</td>
<td>In vivo</td>
<td>Patient evaluation and preference of four adhesives tested regarding retention and ability to chew and clean the prostheses and gums.</td>
<td>Denture adhesives positively improved denture retention and chewing ability; one adhesive (Fittydent paste) was clearly preferred by patients over all others tested.</td>
</tr>
<tr>
<td>Cheng &amp; Zhao (2010)</td>
<td>In vivo</td>
<td>Force transducer measured maximum force needed to displace dentures or cause pain in patients with new and old dentures (with and without an adhesive).</td>
<td>Maximum biting force was greater with new dentures than old dentures, but adhesives improved the biting force more in old dentures than new dentures.</td>
</tr>
<tr>
<td>Chew et al (1985)</td>
<td>In vivo, case series</td>
<td>Kinesiograph measured chewing movements in patients with ill-fitting and well-fitting upper dentures before and after application of three adhesives.</td>
<td>Adhesives improved the retention and stability of both ill-fitting and well-fitting dentures, but was greater in ill-fitting dentures.</td>
</tr>
<tr>
<td>de Baat et al (2007)</td>
<td>In vivo</td>
<td>Maximum incisal force to dislodge old and new maxillary dentures measured in denture patients with and without adhesive.</td>
<td>The adhesive improved the maximum incisal force (retention) of old and new dentures but the effect was greater in old dentures.</td>
</tr>
<tr>
<td>Figueiral et al (2011)</td>
<td>Pragmatic clinical trial (PCT)</td>
<td>Vertical tensile tests and intraoral resistance transducers were used to measure maxillary denture retention with five different adhesives.</td>
<td>All but one adhesive demonstrated a significantly greater retention of maxillary dentures.</td>
</tr>
<tr>
<td>Lang et al (2007)</td>
<td>In vivo, randomized controlled trial (RCT)</td>
<td>Mandibular denture movement with and without one adhesive and after removing adhesive.</td>
<td>Adhesive reduced mandibular denture movement to provide increased retention and stability to the patient.</td>
</tr>
<tr>
<td>Gendreau et al (2009)</td>
<td>In vivo, crossover</td>
<td>Bite force, masticatory efficacy, and food occlusion were tested in denture patients with and without three different adhesives; patients rated confidence, comfort, satisfaction, and retention.</td>
<td>Adhesives significantly improved patient satisfaction, bite force, masticatory efficacy, retention, and stability of dentures.</td>
</tr>
<tr>
<td>Ghani &amp; Picton (1994)</td>
<td>In vivo</td>
<td>UCL Retentiometer measured retentive forces at various intervals over 6 hours in denture wearers using three different types of adhesives: liquid, paste, powder.</td>
<td>Powder adhesives were most effective immediately after application but least effective six hours later. Liquid and paste adhesives peaked three hours post-insertion.</td>
</tr>
<tr>
<td>Grasso et al (1994)</td>
<td>In vivo, case series</td>
<td>Maxillary denture movements measured during standardized chewing, swallowing, and speaking activities at intervals with and without one adhesive.</td>
<td>Adhesive significantly improved retention and stability during all activities tested; patients produced significantly higher bite forces with use of the adhesive.</td>
</tr>
<tr>
<td>Hasegawa et al (2003)</td>
<td>In vivo</td>
<td>Three-dimensional motion capture system recorded old and new maxillary denture movements while patients chewed three different foods with and without an adhesive.</td>
<td>Adhesive reduced three-dimensional and rotational denture movements and chewing times in old and new dentures.</td>
</tr>
<tr>
<td>Kapur (1967)</td>
<td>In vivo, RCT</td>
<td>Denture patients using three different adhesives were assessed by masticatory performance, taste perception, and taste threshold tests.</td>
<td>Adhesives improved denture retention but not masticatory performance; taste thresholds were unaltered; retention declined after the consumption of food or drink.</td>
</tr>
</tbody>
</table>

Table 3. Summary of methods and findings of studies that evaluated denture adhesives and their effects on denture retention, stability, and bite force.12-30,37

---

the dentures; it maintains adhesive capabilities for 8–12 hours; and it is cost-effective for the patient.

**Prevalence of adhesive usage**

Little published data exists regarding the prevalence of denture adhesive use. An Australian study evaluated 146 patients wearing dentures and found 52% of the patients did not use denture adhesive, as they believed they satisfactorily managed their dentures without it. Among the remaining denture wearers, 20.5% did not know denture adhesive existed, 32.9% used denture adhesive in the past, and only 6.9% use denture adhesive on a regular basis.10 More recently, Divaris et al reviewed the charts of 2,526 completely edentulous patients over a 10-year period and found that only 15% of the completely edentulous patients with existing complete dentures acknowledged using denture adhesive. There was a direct correlation between complete denture dissatisfaction and denture adhesive use, which the authors attributed to poor fit and function of the dentures.11
### Table 3. Summary of methods and findings of studies that evaluated denture adhesives and their effects

<table>
<thead>
<tr>
<th>Author</th>
<th>Trial type</th>
<th>Testing methods</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kelsey et al (1997)</td>
<td>In vivo, RCT</td>
<td>Patient evaluation of five denture adhesives, in terms of denture retention quality, duration, mastication, and OHR-QOL.</td>
<td>Most patients reported minimal to significant improvement in retention with adhesive use; one adhesive was rated significantly higher than the others.</td>
</tr>
<tr>
<td>Kulak et al (2005)</td>
<td>In vivo, RCT</td>
<td>Patient evaluation of two denture adhesive pastes.</td>
<td>Both adhesives tested improved retention, but there was not a significant difference between the two types.</td>
</tr>
<tr>
<td>Ozcan et al (2005)</td>
<td>In vivo</td>
<td>Bite force until denture dislodgement measured with gnathometer in denture patients (with and without one adhesive) at various intervals.</td>
<td>Consistent improvement in bite force until denture dislodgement for up to six hours after adhesive application.</td>
</tr>
<tr>
<td>Pradies et al (2009)</td>
<td>In vivo, crossover</td>
<td>Gnathometer and dynamometer measured resistance to denture dislodgements in maxillary and mandibular dentures, both without adhesive and with the use of two adhesives.</td>
<td>Adhesives improved the retention and stability of well-fitted dentures; no significant difference between the two types of adhesives.</td>
</tr>
<tr>
<td>Rendell et al (2000)</td>
<td>In vivo</td>
<td>Multichannel magnetometer tracking system measured mean chewing rates in denture patients with and without two denture adhesive creams at various intervals.</td>
<td>Mean chewing rate increased up to four hours after application to a rate that approximated that of the control group comprised of dentate patients.</td>
</tr>
<tr>
<td>Sato et al (2008)</td>
<td>In vivo, crossover</td>
<td>Unilateral bite force measured until denture dislodgement on balancing side occurred to evaluate retention; ease of prosthesis removal judged by remaining colored denture adhesive left on oral mucosa by adhesive gel and cream.</td>
<td>Retention improved in both cream and gel adhesives; gel was significantly easier to remove from the oral mucosa than cream.</td>
</tr>
<tr>
<td>Tarbet et al (1980)</td>
<td>In vivo, RCT</td>
<td>Patients evaluated various aspects of denture performance following application of adhesive.</td>
<td>Adhesive improved chewing ability, comfort, and confidence while reducing denture wobble and amount of food collecting beneath the prosthesis.</td>
</tr>
<tr>
<td>Uysal et al (1998)</td>
<td>In vivo, RCT</td>
<td>Patients evaluated four cushion adhesives in terms of denture retention, ability to chew, ability to clean dentures and gums, and overall preference.</td>
<td>Two of the four cushion adhesives tested significantly improved denture retention and stability.</td>
</tr>
<tr>
<td>Zhao et al (2004)</td>
<td>In vitro</td>
<td>Acrylic resin samples were measured on a universal testing machine to determine bonding load and ease of removal for two denture adhesives.</td>
<td>One adhesive had significantly greater bonding strength, but was more difficult to handle and clean; the other adhesive was weaker, but easier to manipulate.</td>
</tr>
</tbody>
</table>

**Advantages of using denture adhesive**

Twenty studies were identified and reviewed; nineteen of them were clinical trials that focused on the use of denture adhesives relative to denture retention, stability, movement, bite force, ability to chew test foods, and patient satisfaction (see Table 3). Most of the studies were short in duration (that is, same day evaluation) and examined only maxillary dentures. Some trials randomly allocated patients to various experimental groups (depending on the number of adhesives investigated). Other trials lacked a control group, but were crossover in design (that is, comparing the same dentures with and without adhesives). In this last group of studies, denture adhesives improved the retention and stability of the prostheses investigated. A number of studies indicated that the improvement in retention and stability was more pronounced in old or ill-fitting dentures when compared to new prostheses. However, a 1994 study by Grasso...
et al reported no difference in adhesive-related improvement between prostheses that fit well and those that fit poorly. In a 2011 study, Figueiral et al used vertical tensile tests and intraoral resistance transducers and reported that denture adhesives improved retention of maxillary complete dentures for the most part; however, the authors did not indicate the fit of the prostheses studied.

The literature has reported that denture adhesives significantly improve denture-related bite force. Using a multichannel magnetometer tracking system to evaluate jaw movements, Rendell et al evaluated the impact of denture adhesives on the chewing rates in complete denture patients. The mean chewing rates increased immediately after applying the adhesive and continued to increase after two and four hours. Ghani & Picton suggested the retentive force for some types of adhesives do not peak until 2-3 hours after denture insertion.

Kulak et al used subjective measures to evaluate whether adhesives improved chewing ability, comfort, retention, and patient confidence, and found positive correlations in terms of improvements following adhesive use. While many studies indicate that adhesives are effective for up to eight hours, a 1967 study by Kapur reported that despite showing initial improvements in retention, mandibular dentures demonstrated significant loss of retention following the chewing of test foods and imbibing of taste solutions. Kapur believed the significant loss of retention occurred because the denture adhesive material functions by swelling and gelling upon insertion to fill the space between the soft tissues and the denture base.

**Improvemnts in oral health-related quality of life**

It has been determined that the quality of life (QoL) is negatively affected by complete edentulism and the use of complete dentures. In a 2010 study, Nicolas et al conducted a 6-month study involving 14 complete denture patients who reported low QoL scores after denture insertion. During this longitudinal study, patient QoL was assessed at three different times: denture insertion, three months post-insertion, and six months post-insertion. At three months, patients were given denture adhesives to use until the six-month assessment. At each assessment time, patients completed a Geriatric Oral Health Assurance Index questionnaire to determine their oral health-related quality of life (OHR-QoL). The authors found no improvement in masticatory performance, but the adhesives did improve both the patients’ OHR-QOL and their ability to use their dentures. These findings are consistent with other studies that could not link denture stabilization with masticatory performance.

**Adhesives as a direct delivery device for medications**

A longitudinal study by Lo Muzio et al evaluated complete denture patients with chronic aphthous ulcerations and erosive lichen planus lesions. Patients were treated with corticosteroids (that is, clobetasol propionate) alone, in conjunction with an ointment, or incorporated into a denture adhesive. Incorporating the topical corticosteroid into the denture adhesive treated the oral lesions effectively. A 1980 study by Tarbet & Grossman evaluated 111 patients over a six-month period, to determine if denture adhesive caused any changes to soft tissue beneath maxillary dentures. The authors did not find increased mucosal irritation in the denture-bearing tissues; rather, the sites of mucosal irritation present at the beginning of the study were eliminated by the end.

A study by Scher et al investigated the combination of an anti-fungal agent, amphotericin, into a denture adhesive for patients suffering from Candida sp. related denture stomatitis. The study did not reveal a statistically significant reduction in fungal levels; however, there was a reduction in the documented cases of stomatitis. The authors suggested that even though these materials lubricated the tissues, the adhesive had a more profound, beneficial effect on denture stabilization than the amphotericin had in terms of reducing inflammation. Denture stomatitis remains a primary concern for the denture-wearing population. Additional studies are warranted to determine if and how carrier devices (either the denture base or an antimicrobial/antifungal adhesive) can reduce the incidence of denture stomatitis.

**Potential cytotoxic effects and microbial contamination of denture adhesives**

Eight articles analyzed the microbial contamination and potential cytotoxic effects of denture adhesives; these studies are summarized in Table 4. Among these articles are three in vitro studies that evaluated the cytotoxic potential of, and irritation induced by, commercially available adhesives (for example, pads, creams, and powders). A 2005 study by Al et al examined six denture adhesives and found that only one caused severe cytotoxic effects, according to 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazoliumbromide.
The authors suggested that these results were due to the extended use of denture adhesives since most patients wear their prostheses throughout the day. The results raised concerns that denture adhesives might cause mucosal inflammation in denture wearers.39 Using the hen’s egg test chorioallantonic membrane (HET-CAM) method, Dahl performed an in vitro test to evaluate the degree of mucosal irritation caused by 27 denture adhesives.40 The author found the majority of adhesives damaged the vasculature of the chorioallantoic membrane, which indicated that denture adhesives have the potential to irritate mucous membranes.40

Another in vitro study by Gates et al investigated four denture adhesives and found that not only did each one contain fungal and bacterial contaminants, but also that each one could initiate fungal or bacterial growth when plated on the appropriate media.41 The authors proposed microwaving the adhesives in their original containers for 10 minutes to reduce the contaminants; however, this protocol had no effect in 5 of the 24 adhesives tested. The results led the authors to caution against prescribing denture adhesives to immunocompromised individuals.41 A third in vitro study, by Ekstrand et al, utilized the agar overlay technique to assess the microbial contamination in 19 commercially available adhesives and found that all of the adhesives caused severe cryptologic effects.42 In addition, the majority of the test samples—specifically those composed of natural raw materials—demonstrated microbial contamination.42

Interestingly enough, in vivo studies on the cytotoxic effects of denture adhesives have different outcomes than the in vitro studies cited above. In their in vitro study, Al et al suggested that using adhesives for extended periods of time might contribute to the development of mucosal inflammation in denture wearers.39 By contrast, Kim et al conducted a cross-sectional study of 12 maxillary complete denture wearers to quantify the total viable counts of Candida sp.43 Samples were collected from dentures and saliva two weeks prior to adhesive use and two weeks after adhesive use had begun. Neither the group that used adhesive nor the control group (whose patients received no adhesive) demonstrated a statistically significant difference between the Candida sp. counts in saliva and those found in maxillary dentures. The authors suggested patient home care and compliance might have contributed to similar results between the groups.43

In a similar assessment, Oliveira et al compared the number of Candida sp. and colony forming units (CFUs) in 24 patients wearing dentures.44 Saliva samples were collected from a test group of 12 patients using an adhesive denture and a control group of 12 patients not wearing an adhesive denture at insertion, 7 days post-insertion, and 14 days post-insertion. The test group was compared to the control group, and the authors failed to find a statistically significant difference between the groups at two weeks.44

Neither of these in vivo studies analyzed extended use of denture adhesives. In 2012, Ozkan et al examined the microbial effects of prolonged denture adhesive use in the first in vivo study to last more than two weeks in duration.45 The authors quantified the levels of C. albicans and α-hemolytic Streptococcus in 30 complete denture wearers, with 15 patients using a denture adhesive. Smears layers were collected from the saliva, palate, and denture base at insertion (baseline), one month post-insertion, and two months post-insertion. The authors hypothesized that the level of micro-organisms would increase and would continue to increase the longer the adhesive was used. While there was a slight increase in the number of micro-organisms at baseline compared to subsequent measurements, the microbial levels for adhesive and non-adhesive users did not indicate a statistically significant difference.45 These results suggest that prolonged use of denture adhesives do not increase micro-organisms.

Recently, extended and improper use of denture adhesives containing zinc has been linked to negative side effects. Zinc is an antimicrobial agent used in denture adhesives and other cutaneous medications; it plays an integral role in cellular metabolism, which is necessary for immune function, wound healing, DNA and protein synthesis, cell division, and the catalytic activity of nearly 100 enzymes.46 The recommended daily allowances for zinc are 8 mg for women, 11 mg for men, with a tolerable upper limit of 12 mg per day.46 Acute zinc overdose can cause headaches, cramps, diarrhea, loss of appetite, nausea, and vomiting; in addition, two studies have indicated a connection between zinc toxicity and denture adhesive use or abuse, with progressive neurological symptoms (myeloneuropathy) after excessive and prolonged use of denture adhesives containing zinc.47,48 Patient misuse of zinc-containing adhesives caused hyperzincemia and hypocupremia that ultimately led to neurological symptoms. In neither study did the authors elucidate whether the patients were using the zinc-containing denture adhesives.
Correctly, or whether the dentures possessed acceptable retention, stability, fit, or occlusion. Both studies indicated that neurological detriments resulted solely from excessive zinc consumption found in denture adhesives.47-48

**Application and removal of adhesives from the intaglio surface of dentures**

To date, no studies have evaluated effective application of denture adhesive on the intaglio surface of the denture. However, three studies have analyzed effective removal of the adhesive. Sato et al compared the ability of edentulous patients to remove a cream adhesive and an experimental gel adhesive from the maxillary soft tissues and the intaglio surface of the maxillary denture.12 The adhesive was colored with 0.4% indigo carmine to facilitate visual identification in removal. The study used a standardized five-stage method to assess the patients’ ability to remove the adhesive from the maxillary soft tissues. Each stage utilized an undetermined mouth rinse, followed by the application of cotton gauze or a hot water rinse (70°C) for two minutes; each patient repeated the technique five times. Although repeating the process five times did not remove the cream adhesive, the experimental gel adhesive was removed successfully using a single-stage cleaning method.12

Uysal et al evaluated four adhesives according to several categories (retention, function, cleansibility, and so forth).15 The authors applied all the adhesives to a group of 32 patients with newly relined dentures and instructed the patients to use their dentures with the adhesive for 24 hours and clean the dentures using

<table>
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<tr>
<th>Author(s)</th>
<th>Trial type</th>
<th>Testing methods</th>
<th>Findings</th>
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</thead>
<tbody>
<tr>
<td>Al et al (2005)</td>
<td>In vitro</td>
<td>Cytotoxicity and irritation of six denture adhesives were analyzed using the HET-CAM and three cell culture methods.</td>
<td>With one exception, none of the adhesives tested caused noteworthy irritation or cytotoxicity.</td>
</tr>
<tr>
<td>Ekstrand et al (1993)</td>
<td>In vitro</td>
<td>Microbial contamination and formaldehyde content of 19 denture adhesives were examined by various cell culture methods.</td>
<td>All adhesives caused severe cytotoxicity; some had notable formaldehyde content; most had microbial growth and those with pronounced contamination were adhesives based on natural raw materials.</td>
</tr>
<tr>
<td>Gates et al (1994)</td>
<td>In vitro</td>
<td>Microbial contamination of four powder denture adhesives was determined from samples and the original product containers after 10 minutes of microwave irradiation.</td>
<td>Bacterial and fungal growth were found in all of the adhesive samples and original containers as microwave irradiation did not consistently sterilize the contents of the original containers.</td>
</tr>
<tr>
<td>Hedera et al (2009)</td>
<td>In vivo, cohort study</td>
<td>Four patients using denture creams who had progressive myeloneuropathy, hypocupremia, and hyperzincemia were studied to determine the origin of high zinc levels.</td>
<td>All patients had ill-fitting dentures and used large amounts of denture cream, which was determined to be the source of the zinc levels; copper and zinc levels normalized after use of denture cream stopped.</td>
</tr>
<tr>
<td>Kim et al (2003)</td>
<td>In vivo</td>
<td>Samples from the saliva and maxillary dentures of patients were tested for absolute and proportional counts of Candida and total viable counts (TVC).</td>
<td>Denture adhesives did not significantly alter the oral microflora during the trial as there was no statistically significant difference between the test and control groups in the amount of TVC or Candida.</td>
</tr>
<tr>
<td>Nations et al (2008)</td>
<td>In vivo, cohort study</td>
<td>Zinc content of three denture adhesives was analyzed; patients using these adhesives were given copper supplements to determine post-treatment copper and zinc levels.</td>
<td>All patients had improved serum zinc levels and mild neurologic improvement after discontinuing adhesive use.</td>
</tr>
<tr>
<td>Oliveira et al (2010)</td>
<td>In vivo</td>
<td>Absolute CFU counts of Candida species and other yeasts were obtained from saliva samples of patients using an adhesive tape.</td>
<td>No significant difference between the test and control groups in terms of the amount of Candida or other yeasts.</td>
</tr>
<tr>
<td>Ozkan et al (2012)</td>
<td>In vivo, PCT</td>
<td>Microbial content of saliva, dentures, and palate was analyzed in patients using one denture adhesive for extended periods of time.</td>
<td>Prolonged denture adhesive use up to two months did not cause any adverse effects nor increase the microbial diversity in the oral flora; α-haemolytic Streptococci and C. albicans increased at the one- and two-month intervals, but increase was not significant compared to the baseline measurement.</td>
</tr>
</tbody>
</table>
the patient’s method of choice (which was not disclosed in the study). Patient perceptions were tallied and analyzed and the authors reported that 20-30% of patients found it difficult or extremely difficult to remove the adhesive from the denture base and oral tissues; however, the authors did not assess the degree of cleaning performed by the patients.15

Berg compared the perceptions of 32 patients concerning 10 factors related to one denture adhesive formulated by a pharmacy (containing tragacanth powder) and three commercially available adhesives.17 The four adhesives were applied and used for one day; at that point, patient interviews were conducted. Unfortunately, the authors did not verify whether or not the patient could successfully remove the denture adhesive from the denture base and the tissues underlying the prostheses, focusing instead on patient perceptions.17 Only the study by Sato et al evaluated a patient’s ability to remove adhesive effectively from the denture base and oral tissues.12 There are no longitudinal studies on the potential consequences of adhesive accumulating on soft or hard oral tissues, illustrating the need for additional research in this realm of denture adhesive use.

**Correct application of denture adhesives**
Several denture adhesive manufacturers have encouraged and recommended specific methods and instructions for properly applying denture adhesive to the denture base. The denture should be cleaned and the intaglio (tissue side) surface of the denture dried. Next, denture adhesive should be applied in small increments, each one approximately the size of a pea or a pencil eraser (Fig. 2). Three pea-sized increments of denture cream should be placed on the edentulous ridge of the mandibular denture. Next, three to four increments of denture cream should be placed on the anterior ridge, posterior border, and the palatal of the maxillary denture midline (Fig. 3). When powder adhesives are used, one should wet the denture base with water, apply a thin film of the adhesive to the entire intaglio surface, and shake off any excess; when pad adhesives are used, the correct size pad should be positioned onto the denture and any excess material that extends beyond the borders trimmed. Each denture should be seated separately, held firmly in place for 5-10 seconds, and any excess material expressed into the tongue or cheek space during insertion should be removed. To spread the adhesive, the patient should bite firmly for 20-30 seconds; again, any additional excess that expresses into the tongue or cheek spaces should be removed. Dentists should avoid using too much denture adhesive or applying it incorrectly (Fig. 4).

**Discussion**
Complete edentulism remains a prevalent health issue.49,50 Although contemporary treatment modalities (such as implant-supported and retained prostheses) improve the treatment outcome for edentulous patients significantly, conventional complete dentures remain the primary method for restoring edentulous arches.51 Complete dentures are retained in the oral cavity by a series of complex interactions involving atmospheric pressure, intimate adaptation of the underlying tissues to the intaglio surface of the prosthesis, a thin film of saliva of acceptable viscosity present between the tissues and prosthesis, and accurate peripheral extensions of the denture borders based on physiological movements. However, following exodontia, both hard and soft denture-bearing tissues are remodeled constantly via the process of RRR. Although they
Denture adhesive use in complete dentures

are fabricated to meet the demands of edentulous patients, the retention, stability and functionality of complete dentures are affected by RRR. Multiple methods can be utilized to overcome RRR, including dental implant therapy, overdenture attachments anchored to natural teeth, denture adhesives, and denture relines and rebases.

Denture adhesive material functions by swelling and gelling upon insertion to fill the space between the soft tissues and denture base. Removing zinc from denture adhesive formulations has reduced neurological problems related to denture adhesive toxicity. Unfortunately, no longitudinal studies of more than six months duration have been performed to evaluate patient comfort, tissue changes, or denture serviceability. The short-term functionality of denture adhesives is regarded as beneficial; however, at present there is little information available concerning extended use of these materials, particularly in terms of whether adhesives prevent patients from seeking routine dental care because the adhesives provide a false sense of security. It is vitally important that dentists inform patients of the advantages and disadvantages of denture adhesives, instruct and demonstrate how to apply and remove adhesives correctly, and educate patients concerning the significance of routine recall appointments for a removable prosthesis. It is indisputable that standard guidelines for denture adhesive application and removal are needed.

Conclusion
Based on a detailed review of the relevant literature, one can conclude that when properly used, denture adhesives improve complete denture retention and stability as well as overall function, thus improving the edentulous patient’s QoL. There is a paucity of evidence concerning the effect of long-term (that is, for more than six months) use of dental adhesive. Denture adhesives should be used according to the manufacturer recommendations, following specific guidelines for application and removal to prevent potential misuse. When prescribing and using denture adhesives containing zinc, one should be aware of their potential for adverse systemic effects. Based on this literature review, dentists should develop and implement long-term maintenance and recall programs for edentulous patients.

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References


Exercise No. 315

Complete Dentures

Subject Code 671

The 15 questions for this exercise are based on the article, *Denture adhesive use in complete dentures: Clinical recommendations and review of the literature* on pages 467-477. This exercise was developed by William U. Wax, DDS, FAGD, in association with the General Dentistry Self-Instruction committee.

Reading the article and successfully completing this exercise will enable you to understand:

- the problems associated with denture adhesives;
- the advantages of using denture adhesives; and
- how to use denture adhesives correctly.

1. All of the following are considered factors in denture retention except one. Which is the exception?
   - A. Atmospheric pressure
   - B. Quality of saliva
   - C. TMD
   - D. Denture adaptation

2. Residual ridge resorption is a lifelong challenge for the denture patient. Methods have been devised to help cope with this problem.
   - A. Both statements are true.
   - B. The first statement is true; the second is false.
   - C. The first statement is false; the second is true.
   - D. Both statements are false.

3. Denture adhesives improve all of the following except one. Which is the exception?
   - A. Retention
   - B. Appearance
   - C. Stability
   - D. Function

4. All of the following may affect denture retention except one. Which is the exception?
   - A. Reduced adaptive capacity
   - B. Compromised oral anatomy
   - C. Medication side effects
   - D. Increased bite force

5. Which of the following has been linked to negative side effects in denture adhesives?
   - A. Zinc
   - B. Calcium
   - C. Iron
   - D. Potassium

6. All of the following are listed components of denture adhesives except one. Which is the exception?
   - A. Mineral oil
   - B. Karaya gum
   - C. Flaxseed oil
   - D. Carboxymethyl cellulose

7. Corticosteroids can be incorporated in denture adhesives to treat oral lesions. The stabilization of the denture by the adhesive is more beneficial than the addition of any antifungals.
   - A. Both statements are true.
   - B. The first statement is true; the second is false.
   - C. The first statement is false; the second is true.
   - D. Both statements are false.

8. The irritating effects of denture adhesives may result in
   - A. improved intersurface contact.
   - B. increased fungal growth.
   - C. bacterial accumulation in the adhesive.
   - D. damage to the blood vessels.

9. All of the following are symptoms of zinc overdosage except one. Which is the exception?
   - A. Jaundice
   - B. Cramps
   - C. Headache
   - D. Nausea

10. Long-term retention of denture adhesives may cause all of the following except one. Which is the exception?
    - A. Severe irritation of the oral tissues
    - B. Adhesive solidification
    - C. Increased denture adhesion
    - D. Damage to the denture
11. Denture adhesives should be applied generously. When applying denture adhesive, the denture should always be dry.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.

12. With reference to longitudinal studies, the longest study of adhesive use on denture serviceability was ___________ months.
   A. two
   B. four
   C. six
   D. eight

13. In the Australian study, what percentage of patients refrained from using adhesive in their dentures?
   A. 20.5%
   B. 32.9%
   C. 48.0%
   D. 52.0%

14. In the Divaris et al study, what percentage of patients used a denture adhesive?
   A. 2%
   B. 5%
   C. 10%
   D. 15%

15. Because denture adhesives may become contaminated with fungus and/or bacteria, one set of authors suggested restricting usage in _______________ patients.
   A. xerostomic
   B. pregnant
   C. prosthetic joint
   D. immunocompromised
Accelerated treatment protocols: Full arch treatment with interim and definitive prostheses

Carl Drago, DDS, MS

With the advent of titanium, root form implants, and osseointegration, dental treatment has undergone a metamorphosis in recent years. These new techniques enable dentists to provide anchorage for various kinds of prostheses that improve masticatory function, esthetics, and comfort for patients. Implant treatment protocols have been improved relative to implant macro- and micro-geometries, surgical and prosthetic components, and treatment times. Over the past 20 years, immediate occlusal function (also known as loading) has been established as a predictable treatment modality, provided certain specific criteria are met. In many cases, edentulous patients, crippled by the loss of their teeth, can undergo outpatient surgical and prosthetic procedures and return to a masticatory function that is near normal—sometimes after only one day of surgical and prosthetic treatment. This treatment option is also available for patients with advanced, generalized periodontal disease.

Computer-assisted design/computer-assisted manufacturing (CAD/CAM) has transformed how dental prostheses are made, offering improved accuracy, longevity, and biocompatibility; along with reduced labor costs and fewer complications than casting technologies.

This article reviews the principles associated with immediate occlusal loading and illustrates one specific accelerated prosthetic treatment protocol used to treat edentulous and partially edentulous patients with interim and definitive prostheses.

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Originally, osseointegration was designed for edentulous patients, specifically those patients with edentulous mandibles who had difficulty managing mandibular complete dentures.1 Lindquist et al recorded high implant cumulative survival rates (CSRs) with two-stage surgical protocols where implants were placed and soft tissues were closed.1 During initial healing, implants were not exposed in the oral cavity. Initially, four to six months of unloaded healing was necessary for osseointegration prior to a second surgical procedure. This second procedure was scheduled to uncover the implants, place trans-mucosal abutments and begin prosthetic procedures. Unfortunately, patients generally had to continue wearing ill-fitting dentures during this entire time. Ironically, patients generally scheduled this type of treatment because of trouble managing their mandibular dentures, yet the fixed implant prostheses were not placed until 9-12 months after implant placement.

The literature has demonstrated high survival rates for implants placed (with high primary stability) into the parasymphysis regions of edentulous mandibles, splinted together with some type of rigid interim prostheses, and placed into immediate functional occlusion.2-6 This modality also may be considered for partially edentulous patients with severe periodontal disease.7 In a 2002 study, Cooper et al placed mandibular implants with high primary stability immediately after extraction of periodontally compromised teeth.7 These implants were rigidly splinted together with acrylic resin prostheses, and placed into fully functional occlusion. At evaluations 6 to 18 months after placement, the implants demonstrated a CSR of 100%.7

Buser et al and Cochrane et al considered implants to be successful if they satisfied the following criteria:

- Absence of pain or any negative subjective sensation
- Absence of clinically detectable implant mobility
- Absence of any recurrent peri-implant mucositis and/or peri-implantitis accompanied by swelling, redness, or pain of the peri-implant mucosa
- Absence of continuous peri-implant radiolucency
- Absence of mesial and/or distal vertical bone loss of more than 30% of the endosseous part of the implants
- No need to repair or replace the implant-supported prosthesis
- Subjective evaluation of the treatment outcomes

The average number of implants required for implant prostheses has been discussed in the literature.
In a retrospective chart review, Strietzel et al reported that nine was the median number of implants required for maxillary fixed implant prostheses (SD = 1.6; range = 6-12), compared to eight implants for mandibular fixed prostheses (SD = 1.4; range = 6-10). These findings were similar to those published by Del Fabbro et al in 2006. In 2007, Capelli et al studied immediate occlusal loading in maxillary and mandibular jaws: the implant CSR for the maxilla was 97.6% for up to 40 months post-loading, no implant failures were reported for the mandible; the prosthesis CSR was 100%. These results indicated that immediately loaded tilted implants achieved the same outcome as upright implants in both jaws, suggesting that immediate rehabilitation of edentulous maxillae and mandibles with hybrid prostheses (supported by six or four implants, respectively) may represent a viable treatment alternative compared to more demanding surgical procedures, such as grafting.

A 2010 clinical study by Agliardi et al followed 173 edentulous patients for up to 59 months. Four implants (two tilted, two vertical), were placed according to a specific protocol (All-on-4, Nobel Biocare). Provisional, all-acrylic resin prostheses and implants were inserted on the same day, with definitive prostheses inserted four to six months later. A total of 154 immediately loaded prostheses (61 maxillary, 93 mandibular) functioned for at least one year and were included in the analysis. Four vertical maxillary and one tilted mandibular implant failed within six months of occlusal loading; no further implant failures were noted. At one year, the CSR was 98.4% for maxillary implants compared with 99.7% for mandibular implants.

The authors concluded that the All-on-4 protocol can be considered a viable treatment option for immediate rehabilitation of both the mandible and maxilla. These studies reported consistent clinical results associated with immediate, interim, acrylic resin prostheses. The treatment approach required fabricating two prostheses: interim acrylic resin prostheses (made and inserted within one to two days of implant placement) and definitive prostheses (fabricated with metal frameworks approximately three to six months after implant placement and occlusal loading). Other protocols provide patients with definitive cast metal frameworks/hybrid prostheses within 3-5 days of implant placement. These protocols involve slightly more coordination among the surgical, prosthetic, and laboratory teams, but have proven to be a viable alternative to previous protocols that included interim and definitive prostheses.

**CAD/CAM frameworks**

Recent years have seen continued developments related to the fabrication of implant frameworks and abutments. Complex castings involving multiple units are difficult to fabricate with passive, accurate fits. There are multiple reasons why conventional castings do not result in accurate fitting frameworks, including the expansion/contraction of materials (such as impression materials, dental stones, wax, and casting investments). Mitha et al studied titanium implant frameworks cast with the lost wax technique and found vertical gaps in both wax patterns and castings. Significant differences were found in distortion between wax patterns and castings, which, given the authors’ criteria for the standard of fit to keep within 150 µ of misfit for passivity, were larger than the wax frameworks by between 416 and 477 µ. The authors concluded that conventionally cast titanium frameworks probably could not be made to the degree of accuracy required to fit passively on abutments because of the multiple variables inherent in casting processes.

By contrast, a 2008 study by Tăn et al reported that waxing and casting using the lost wax technique resulted in smaller vertical marginal gaps between restorations and abutments (23.91 ± 9.80 µ) than the CAD/CAM process (79.43 ± 25.46 µ). However, it should be noted that these results referred to individual, single-unit restorations rather than multi-unit implant frameworks.

In a 2010 laboratory study, Drago et al determined that CAD/CAM implant frameworks supported by five mandibular implants fit significantly better than cast frameworks made on the same patient models. That same year, Eliasson et al measured milled titanium implant frameworks for two different implant systems, concluding that all the frameworks presented signs of misfit, no framework actually demonstrated a “passive” fit, and clinical frameworks had greater misfits than frameworks fabricated in laboratory studies. The authors reported that all the frameworks in their study demonstrated levels of precision of fit within clinically acceptable limits.

In 2012, Ortorp & Jemt followed 126 edentulous patients for whom 67 prostheses with CAD/CAM titanium frameworks (test) had been provided (in 23 maxillae and 44 mandibles), while 62 prostheses fabricated with gold-alloy castings (control) were placed in 31 maxillae and 31 mandibles. Clinical and radiographic 10-year data were collected and statistically compared. At 10 years, the prostheses
demonstrated a 95.6% CSR for the CAD/CAM group compared to 98.3% for the gold-alloy castings group; implants demonstrated a 95.0% CSR for the CAD/CAM group compared with 97.9% for the control group \((P > 0.05)\). No implants were lost after five years of follow-up; however, one prosthesis in each group was lost due to implant loss, one CAD/CAM prosthesis failed due to framework fracture, and two metal fractures were registered in each group. The authors also identified that maxillary prostheses required more maintenance appointments than mandibular prostheses \((P < 0.001)\).

### Case report
A 45-year-old woman sought treatment with the chief complaint of “loose teeth” in need of repair (Fig. 1). The patient had not seen a dentist in over 15 years and did not want to wear dentures. A complete physical and radiographic examination revealed localized, acute, severe periodontitis (type IV); partially edentulous maxillae and mandible; and Class II malocclusion with poor anterior guidance.

When the teeth were determined to be non-restorable, two treatment options were offered to the patient: One involved an immediate loading protocol with extraction of the teeth, placement of implants and insertion of full arch prostheses on the day of implant placement. The definitive treatment included prostheses with CAD/CAM frameworks approximately 4-6 months later. The second option included extraction of the teeth and insertion of immediate complete dentures. If the patient could not adapt to the dentures, implants would then be considered for definitive treatment.

After discussing the benefits and limitations of each, the patient decided to proceed with the first treatment option (see Table 1).

### Accelerated treatment protocol: Initial diagnostic phase
To facilitate treatment, all necessary prosthodontic procedures—preliminary impressions for diagnostic casts, jaw relation records (including facebow and centric jaw relation records), shade selection, and initial determination of the new vertical dimension of occlusion—were performed.

The patient’s dentition was restored using an accelerated prosthetic treatment protocol that utilized definitive screw-retained hybrid prostheses made with CAD/CAM technology.

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**Table 1. Treatment plan options presented to the patient at the consultation appointment.**

<table>
<thead>
<tr>
<th>Treatment plan No. 1</th>
<th>Treatment plan No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction, alveolectomy, implant placement, immediate occlusal presented loading with full arch, fixed interim prostheses at new vertical dimension of occlusion</td>
<td>Extractions, alveolectomy, insertion of immediate complete dentures</td>
</tr>
<tr>
<td>Follow-up and osseointegration of dental implants</td>
<td>Tissue conditioning of immediate complete dentures</td>
</tr>
<tr>
<td>Evaluation of osseointegration, vertical dimension, centric occlusion, phonetics, and esthetics</td>
<td>Evaluation of retention, stability, function, esthetics and phonetics. Determination of definitive treatment plan: conventional or implant supported/retained prostheses</td>
</tr>
<tr>
<td>Fabrication of definitive prostheses with CAD/CAM frameworks</td>
<td>Determination of fixed or removable implant supported/retained prostheses. Implant placement with or without immediate occlusal loading</td>
</tr>
<tr>
<td>Follow-up care</td>
<td>Fabrication of definitive conventional or implant supported/retained prostheses</td>
</tr>
</tbody>
</table>

### Fig. 1. A clinical preoperative photograph of the patient’s teeth in centric occlusion.
and positions of the teeth—were performed in one day, based on discussions with the patient relative to her wishes. (The actual procedures will not be described here in detail; numerous sources are available for learning step-by-step instructions.) The casts were mounted in an average value articulator (Stratos 100, Ivoclar Vivadent). The tentative location of the new mandibular incisal edge position was marked on the mandibular incisor, while the location of the posterior occlusal plane was marked at two-thirds of the vertical height of the retromolar pad.

The casts were mounted in an average value articulator (Stratos 100, Ivoclar Vivadent). The tentative location of the new mandibular incisal edge position was marked on the diagnostic cast; the posterior location of the occlusal plane was located at approximately two-thirds of the vertical height of the retromolar pad (Fig. 2). The incisal guide pin was raised approximately 8 mm from the original vertical dimension of occlusion (VDO); this developed the restorative space required to place the teeth in their correct positions. The patient did not want to see the maxillary incisal edges while at rest; however, she did wish to see 50% to 66% of the maxillary incisors when she smiled. The teeth were removed from the maxillary cast, along with additional stone that corresponded to a restorative volume of approximately 12-15 mm. The author measures restorative volume as the space from the crest of the alveolar ridge to the location of the maxillary central incisor incisal edge (Fig. 3). Maxillary and mandibular

<table>
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<th>Treatment plan No. 1: Immediate occlusal loading</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Treatment plan No. 2: Complete dentures</th>
<th>Benefits</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient never has to wear complete dentures</td>
<td>Somewhat long, initial surgical/prosthetic appointment</td>
<td>Less invasive surgery</td>
<td>Removable dentures with palatal coverage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed, non-removable prosthesis</td>
<td>Immediate loading is not guaranteed; implants need high insertion torque (&gt; 50 Ncm) for immediate occlusal loading to take place</td>
<td>Less technique-sensitive</td>
<td>Adaptations needed for patient to be successful</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No palatal coverage</td>
<td>Expense</td>
<td>Decreased expense</td>
<td>Bone resorption continues beneath the dentures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimal long-term bone loss</td>
<td>Technique sensitive</td>
<td>Optimal esthetics</td>
<td>Decreased masticatory function</td>
<td></td>
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<tr>
<td>Improved masticatory function</td>
<td>Patient adaptation is required (as with all prosthetic procedures)</td>
<td></td>
<td>Increased office visits for maintenance and adjustments</td>
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<tr>
<td>Long-term history of documented success</td>
<td></td>
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<tr>
<td>Optimal esthetics</td>
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denture teeth (Mondial, Heraeus Kulzer) were set in Class I occlusion with a horizontal occlusal plane. Group function was developed for right and left working movements and the prostheses were processed and polished (Fig. 4).

Accelerated treatment protocol: Second treatment phase (surgery and conversion of the interim prostheses)

The patient was sitting upright with her head unsupported. Prior to anesthesia and sedation, dots were placed on the patient’s nose and chin with an indelible marker (Sanitary Color Transfer Applicators, Great Plains Dental). The marks were transferred to a wooden cotton applicator; the middle mark represented the planned location of the maxillary central incisal edges in the interim prosthesis; the lower dot was transferred consistent with the tentative increase in the vertical dimension of occlusion planned for the new prostheses (Fig. 5). At that point, the patient was sedated and prepared for maxillary surgery. The maxillary teeth were removed, a full thickness mucoperiosteal flap was elevated, and an alveolectomy was performed that provided 12-15 mm of restorative volume between the alveolar crest and the planned locations of the maxillary central incisal edges (Fig. 6). The maxillary canines and lateral incisor segments had been removed from the interim prosthesis, which allowed the surgeon complete visual access relative to restorative volume and anterior/posterior implant positioning. Visual access could also have been accomplished with a clear surgical duplicate of the interim prosthesis.

Implants were placed (NobelActive, Nobel Biocare) with insertion torques in excess of 70 Ncm as measured on a manual torque.
The two distal, tilted implants were placed parallel to the anterior walls of the maxillary sinuses; the anterior implants were placed relatively vertical in the lateral incisor areas. Straight internal connection conical abutments were placed on the anterior implants (with abutment screws torqued to 35 Ncm) such that the screw access openings were lingual to the anterior teeth. Next, multi-unit abutments (at 30° angles) were placed on the distal implants so that the screw access openings were located within the occlusal surfaces of the posterior teeth (abutment screws torqued to 15 Ncm) (Fig. 7). The flap was closed with a combination of bone and soft tissue sutures that repositioned the peri-implant soft tissues on and to the alveolar ridge. The patient was discharged to the doctor for the prosthodontic procedures.

Abutment impression copings (Impression Coping Open Tray Multi-unit, Nobel Biocare) were placed onto the abutments. Next, 30-gauge orthodontic wire was sectioned, placed within the concavities of the impression copings and luted with Triad® Gel (Dentsply International) (Fig. 8). The locations of the impression copings were identified and corresponding holes were made in a stock impression tray (Crystal Disposable Impression Trays, Henry Schein Inc.) such that the copings did not touch the tray or splinted impression copings. Polyvinyl siloxane impression material (Imprint 3 Quick Step Light Body and Imprint 3 Penta Quick Step Heavy Body, 3M ESPE) was used to make the definitive impression. A master cast was fabricated using vacuum-mixed dental stone per the manufacturer’s instructions (Coe Cal, GC America Inc.). Two sections of teeth (canines and lateral incisors) were removed from the maxillary prosthesis prior to the surgical phase of treatment; this facilitated complete visualization of the temporary cylinders relative to the denture base. Metal temporary abutment cylinders (Temporary Coping Multi-unit Titanium, Nobel Biocare) were placed on the two anterior implants. The maxillary prosthesis was adjusted to fit around the cylinders; the dental midline was made to be consistent with the facial midline. In order to consistently seat the prosthesis in its correct position, quick setting polyvinyl siloxane impression material (Imprint 3 Quick Step Light Body, 3M ESPE), was injected onto the intaglio surface of the maxillary prosthesis; the prosthesis was seated paying careful attention to the dental midline, occlusal plane, and anterior/posterior positioning (Fig. 9). After the stabilizing impression was removed, a rubber dam was cut and placed onto the anterior temporary cylinders; at that point, the prosthesis was re-seated, with careful attention paid to the facial midline, orientation of the occlusal plane, and lip support. While the author held the prosthesis in position, a dental assistant injected autopolymerizing resin (Secure Hard Pick-Up Material, 3M ESPE) around the cylinders to completely attach them to the denture base. The resin set and the prosthesis were removed (Fig. 10).

Locations of the posterior abutments were identified in the stabilizing impression. In the laboratory, holes were drilled through the denture base and the Mondial posterior denture teeth. Using laboratory

---

Fig. 8. Clinical image of abutment impression copings in place; light cure composite resin was used to initially hold orthodontic wire segments in place on each impression coping. These impression copings were designed with concavities that hold the orthodontic wire segments in place during this procedure.

Fig. 9. The intaglio surface of the maxillary stabilizing impression.
screws, the denture base was seated on the two anterior cylinders and the base was adjusted so that no part of the denture base touched the master cast (Fig. 11). Metal, multi-unit temporary cylinders were placed onto the posterior abutment analogs and the anterior metal temporary cylinders were re-positioned onto the master cast with laboratory screws. The maxillary interim prosthesis was placed (with the mandibular interim prosthesis) into Class I occlusion, so that the tooth segments were re-oriented into their proper positions. Secure Hard Pick-Up Material was used to attach the posterior cylinders and anterior tooth segments to the denture base. The prosthesis was contoured, finished, and polished for use as the maxillary interim prosthesis (Fig. 12).

By this time, the surgeon had anesthetized the patient’s mandible, removed the teeth, and started the alveolectomy. The surgeon placed the completed, maxillary interim prosthesis onto the anterior abutments with retaining screws and attached the mandibular prosthesis to the maxillary prosthesis by using posterior vertical ball clasps (Ball Clasps .032, Henry Schein Inc.) (Fig. 13). The ball clasps were attached to the posterior portions of the mandibular denture base after processing. To retain the ball clasps into the maxillary prosthesis, two corresponding concavities were placed into the posterior portions of the maxillary denture base. This facilitated treatment by eliminating the need for an interocclusal record to orient the mandibular prosthesis to the maxillary prosthesis. The surgeon was free to concentrate on obtaining the correct jaw position relative to the prostheses and judge the amount of restorative volume created by the mandibular alveolectomy. The doctor used 12-15 mm as the baseline for the total restorative volume. Restorative volume must take into account abutment and cylinder heights, as well as the thickness of the denture base for strength and rigidity. The surgeon completed the alveolectomy, placed four mandibular implants (with insertion torques of at least 70 Ncm) and sutured the flap. The two distal implants were tilted; the two anterior implants were relatively vertical. This arrangement provided a clinically acceptable anterior/posterior spread. The canine and lateral incisor segments were removed from the mandibular prosthesis before mandibular clinical procedures were performed. Removing the denture teeth from the denture base made it possible to visualize implant placement relative to tooth locations within the interim prosthesis.
The mandibular procedures duplicated the maxillary procedures as described above with one exception: The anterior cylinders and the mandibular denture base were connected with the mandibular prosthesis attached to the maxillary prosthesis via posterior ball clasps. As a result, the doctor only had to concentrate on maintaining the correct jaw position (Fig. 14); to make sure the VDO was consistent, this position was checked against the cotton tip applicator and the marks on the nose and chin. The mandibular prosthesis was removed and the conversion to the interim prosthesis was completed in the laboratory (including removal of the ball clasps from the denture base). The mandibular prosthesis went into place with prosthetic screws torqued to 15 Ncm and the access opening restorations were completed with light cure resin. The patient left the office approximately seven hours after arriving. She now had two fixed, implant-retained interim prostheses in Class I occlusion, at an appropriate VDO with improved esthetics (Fig. 15). One of the primary benefits of immediate occlusal loading is that patients never have to go through an edentulous stage wearing complete dentures.

Accelerated treatment protocol: Third treatment phase (definitive prostheses)
Osseointegration occurred uneventfully. Approximately four months after extraction, implant placement, and immediate occlusal loading, the patient was ready to receive the definitive prostheses. (During this time, the patient had a hemangioma removed from her upper right lip.) The patient was questioned about the esthetics, tooth display, lip support, phonetics, and hygiene allowed by the interim prosthesis. The patient was very pleased with the results of the interim prostheses and basically wanted no changes for the definitive prostheses.

The traditional prosthodontic protocol typically includes some combination of the following: preliminary impressions for construction of custom impression trays, definitive impressions, verification index, initial jaw relation records, wax try-in, metal framework try-in, wax try-in with teeth on the frameworks, and insertion. These procedures typically require up to eight separate visits; however, the accelerated treatment protocol used in this case combined all of the above visits into three appointments (see Table 3).

Table 3. Treatments performed at each appointment for fabrication of the definitive prostheses with CAD/CAM frameworks, using the accelerated treatment protocol.

<table>
<thead>
<tr>
<th>Appointment No. 1</th>
<th>Evaluation of esthetics, jaw relation records (facebow and centric jaw relation records).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abutment level impression using the interim prostheses as the verification indexes.</td>
</tr>
<tr>
<td></td>
<td>Articulator mounting of the master casts (with the interim prostheses).</td>
</tr>
<tr>
<td></td>
<td>Mounted diagnostic casts of the interim prostheses (cross-mounted against the interim prostheses and master casts).</td>
</tr>
<tr>
<td></td>
<td>Wax dentures were set in the laboratory, with plastic temporary cylinders.</td>
</tr>
<tr>
<td></td>
<td>Optimal tooth positions and jaw relations were transferred to the master casts via cross mounting the casts of the interim prostheses.</td>
</tr>
<tr>
<td></td>
<td>The wax dentures and master casts were then sent to a milling center for fabrication of the CAD/CAM frameworks.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Appointment No. 2</th>
<th>Framework and wax try-in, evaluation of the esthetic results and jaw relation records, remount mandibular cast (if needed), and second wax denture setup for esthetic modifications per patient request (if needed).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Insertion of interim prostheses.</td>
</tr>
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</table>

| Appointment No. 3 | Insertion of definitive prostheses.                                                                                                                                                                                                                                      |
Appointment No. 1
The patient was extremely pleased with the results of treatment and did not want any changes made to the definitive prosthesis. Prior to removing the interim prosthesis, facebow and jaw relation records were made at the existing VDO; the dental midline was consistent with the facial midline and was so recorded. The interim prostheses were removed. The peri-implant soft tissues were healthy, and abutments and implants were stable (Fig. 16). The interim prostheses passed the one-screw test for passivity; the interim prostheses was contained within the impression as the verification index. Long impression coping screws were used to seat the interim prostheses/verification indexes onto the abutments. A Crystal Disposable Impression Tray was adjusted to fit around the screws for use with the open tray technique when making the impressions. To make the definitive impressions, Imprint 3 Quick Step Light Body was used in, under, and around the prostheses, while Imprint 3 Penta Quick Step Heavy Body was used in the tray (Fig. 17). The impressions were poured to fabricate master casts. After the dental stone had set, the master casts (with the interim prostheses in place) were mounted in the Stratos 100, using the facebow and centric jaw relation records (Fig. 18). A diagnostic cast of the maxillary interim prostheses was mounted with the centric jaw relation record against the mandibular interim prosthesis/master cast, while a diagnostic cast of the mandibular interim prosthesis was mounted with the centric
jaw relation record against the maxillary interim prosthesis/master cast. This step allowed the dental laboratory technician to set denture teeth for the CAD/CAM prostheses without forcing the patient to wait. The interim prostheses were returned to the patient, who was discharged. These procedures took approximately two hours of chairtime.

Temporary Coping Multi-unit plastic cylinders were placed onto the abutment analogs in the master casts (Fig. 19), and Mondial teeth (of the appropriate size and shade) were set against the casts of the respective interim prostheses (Fig. 20). Since the patient wished to maintain the esthetics of the interim prostheses, a clinical try-in was not needed, as the denture setup was to be used only to design the frameworks. The wax dentures were finished and sent to an implant milling center to design and mill the CAD/CAM frameworks (Bella Tek CAM StructSURE Precision Milled Bars, Biomet 3i). The wax dentures and master casts were scanned and frameworks were designed and milled (Fig. 21).

The frameworks were returned to the doctor; at that point, the denture teeth were removed from the scanned, wax dentures and set on the frames (using the cross-mounted diagnostic casts described in Table 3) prior to the next clinical appointment. The occlusion was developed as bilateral Class I, with group function in right and left working movement. Anterior guidance was developed as anterior disclusion with the central and lateral incisors.

Appointment No. 2
At the second appointment, the interim prostheses were removed and abutments and implants were stable. The frameworks (with denture teeth) were tried in and both frameworks passed the one-screw test. The jaw relationships were confirmed. The patient had a thorough chance to evaluate the esthetics of the definitive prostheses (Fig. 22); she was pleased with the esthetic results and wanted no changes. The wax prostheses were removed and the interim prostheses were reinserted. The patient was discharged and scheduled to return for insertion of the definitive prostheses. The appointment lasted approximately one hour.

Appointment No. 3
At this appointment, the interim prostheses were removed, and the abutment screws were re-torqued (15 Ncm for the angled posterior abutments; 35 Ncm for the straight anterior abutments). Initially, the definitive prostheses were placed with laboratory try-in screws; even occlusal contacts were established throughout the prostheses. Group function was developed for right and left working movements, while anterior guidance was established with the incisors. The prostheses were removed and denture bases were finished and polished. They went back into place with new prosthetic screws, torqued to 15 Ncm. Access openings were blocked out with cotton and restored with light cured composite resin. The patient was very pleased with the esthetic
results and was discharged with written and verbal post-operative instructions (Fig. 23). This appointment took approximately one hour.

Summary
Numerous short- and long-term clinical studies, using multiple implant systems, have documented successful cases involving immediate occlusal loading with full arch, fixed prostheses. The keys for successful clinical treatment include thorough radiographic and physical examinations, accurate diagnoses and care, complete treatment planning. Ideally, treatment planning should involve surgical, prosthodontic, and laboratory personnel. All clinicians need to be involved to obtain optimal, consistent restorative volumes during the surgical phases of treatment. The author recommends making 12-15 mm of vertical space available for implant restorative components and prostheses to ensure that the tooth positions and strength of the prostheses will not be compromised. High implant placement insertion torque values (at least 50 Ncm) are needed for implant primary stability prior to fabricating fixed, interim prostheses and immediate occlusal loading. Fabrication of interim prostheses follows the basic prosthodontic principles associated with conventional and immediate dentures in determining the location of teeth, orientation of the occlusal plane, esthetics, phonetics, vertical dimension of occlusion, and lip support. Once osseointegration has been achieved, definitive prostheses can be constructed. The best material to use for this process involves CAD/CAM technology to mill titanium alloy frameworks and combines multiple short prosthodontic visits into fewer, longer visits that, in the author’s experience, have proven to be more efficient in clinical practice (and better received by patients) than conventional appointment scheduling with multiple, shorter appointments. That is not to say that the more conventional methods of performing these treatments are incorrect; rather the treatment described in this article is simply quicker and more patient-friendly.

Dental implant treatment will continue to evolve in terms of materials, procedures, protocols, and so forth. The accelerated treatment protocol illustrated in this article is one group practice’s adaptation to the continued evolution of dental implant therapy.

Disclaimer
The author has no financial, economic, commercial, and/or professional interests related to topics or products presented in this manuscript.

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Exercise No. 316

Implant Restorations

Subject Code 616
The 15 questions for this exercise are based on the article Accelerated treatment protocols: Full arch treatment with interim and definitive prostheses on pages 480-491. This exercise was developed by Steven E. Holbrook, DMD, MAGD, in association with the General Dentistry Self-Instruction committee.

Reading the article and successfully completing this exercise will enable you to:
- recognize the advantages of immediate occlusal loading of implants;
- identify the principles associated with immediate occlusal loading of implants; and
- understand the accelerated prosthodontics protocol for the restoration of edentulous and partially edentulous patients.

4. Adequate space for restoration in this case was obtained by
   A. increasing the vertical dimension of occlusion (VDO) and alveolectomy of the maxilla and mandible.
   B. increasing the VDO and alveolectomy of the maxilla only.
   C. alveolectomy of the maxilla and mandible without increasing the VDO.
   D. increasing the VDO and alveolectomy of the mandible only.

5. In this case, the fit of the final frameworks was checked using
   A. a verification jig.
   B. the one screw test.
   C. radiographic verification.
   D. abutment scanning.

6. The accelerated protocol used in this case refers to
   A. the elimination of the interim prosthesis to shorten treatment time.
   B. the placement of an interim prosthesis to allow immediate occlusal loading.
   C. the use of a CAD/CAM generated stent to speed implant placement.
   D. longer prosthodontic visits that were well received by patients.

7. The study by Ortorp & Jemt found a 10-year prosthesis cumulative survival rate (CSR) for the CAD/CAM group of 95.6% compared to a CSR of ___% for the casting group.
   A. 88.7
   B. 92.3
   C. 96.5
   D. 98.3

8. The VDO was verified at the time of surgery by the use of a
   A. phonetic examination.
   B. CAD/CAM generated appliance.
   C. cotton tip applicator.
   D. prefabricated stent.
9. According to Cooper et al, mandibular implants placed with high primary stability, immediately after extraction of periodontally compromised teeth, rigidly splinted together with acrylic resin prostheses, and placed into fully functional occlusion exhibited a post-implant placement CSR of ____% at 6 to 18 months.
   A. 100  
   B. 98  
   C. 88  
   D. 50

10. Strietzel reported that the median number of implants in their retrospective chart review for maxillary fixed implant prostheses was ____.
   A. 4  
   B. 6  
   C. 9  
   D. 12

11. One of the benefits of immediate occlusal loading is that the patient never has to wear a complete denture. Another benefit of immediate occlusal loading is that no patient adaptation is required.
   A. Both statements are true.  
   B. The first statement is true; the second is false.  
   C. The first statement is false; the second is true.  
   D. Both statements are false.

12. A clinically acceptable anterior-posterior spread was achieved in the mandible by
   A. placing two anterior implants, two implants in the canine areas, and two implants in the molar areas following nerve repositioning.  
   B. the placement of six parallel implants anterior to the mental foramen.  
   C. placing two distal tilted implants and two anterior implants relatively vertical.  
   D. placing two short implants in the retromolar areas in addition to four implants anterior to the mental foramen.

13. A laboratory study by Drago et al determined that the fit of CAD/CAM implant frameworks were significantly better than the fit of cast frameworks made from the same models. Eliasson et al measured the precision of fit of milled titanium frameworks and concluded that no framework actually had a passive fit.
   A. Both statements are true.  
   B. The first statement is true; the second is false.  
   C. The first statement is false; the second is true.  
   D. Both statements are false.

14. The treatment time to remove the teeth and to place the implants and the interim prostheses for the accelerated protocol used in this case was approximately ____ hours.
   A. two  
   B. four  
   C. six  
   D. seven

15. The benefits of immediately loaded prostheses placed with the accelerated prosthodontics protocol compared to conventional dentures include all of the following except one. Which is the exception?
   A. Minimal long-term bone loss  
   B. No palatal coverage  
   C. Improved masticatory function  
   D. Removable by patient

Answer form is on page 552.
Answers for this exercise must be received by October 31, 2013.

To enroll in Self-Instruction, click here.
Impact of tooth loss on oral and systemic health

S. Offenbacher, MS, DDS, PhD • S.P. Barros, MS, DDS, PhD • S. Altarawneh, DDS • J.D. Beck, MS, PhD
Z.G. Loewy, MS, PhD

Periodontitis is a primarily bacterial infection that is common in dentate individuals, while denture stomatitis is a predominantly fungal infection that is common among denture wearers. Both infections may increase a patient’s risk for chronic systemic infection dissemination, and may in turn increase the risk of chronic, inflammatory-based systemic diseases. Systemic diseases for which chronic oral infections are believed to confer attributable risk include atherosclerotic and coronary disease, stroke, chronic obstructive pulmonary disease, diabetes, and hypertension. It appears that invasive oral pathogens trigger a systemic inflammatory response via mediators released by the cardiovascular system and liver, putting the patient at increased risk for these diseases. Data comparing gene expression between denture wearers with and without denture stomatitis (and associated Candida albicans infections) has demonstrated unique up- and down-regulation patterns for a number of genes. It appears that down-regulated genes (whose functions are thereby diminished) are associated with reduced epithelial barrier integrity. By contrast, there appears to be an association between up-regulated genes (which have enhanced function) and inflammatory responses that facilitate the ability of C. albicans to bind with and penetrate the oral mucosa.

Molecular biological approaches suggest that future therapeutic development could target reducing either the local inflammatory processor, the binding and attachment of C. albicans to the oral mucosa, or both. Ongoing investigations are attempting to incorporate interventions into matrices, to provide a local and sustained presence to therapeutic interventions.

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Periodontal disease is characterized as a localized chronic inflammation of the gingival and periodontal tissues that leads to the gradual and progressive destruction of connective tissue and loss of bone structure that supports the teeth; it is considered to be bacterial in origin.1 Up to 50% of the U.S. population has been affected by mild-to-moderate forms of periodontitis.2 Its prevalence can be even higher in developing countries, where individuals have reduced access to routine dental care and may practice less effective dental hygiene.

Over the past 20 years, extensive research has demonstrated associations between periodontal disease and an increased risk of such illnesses as coronary heart disease, atherosclerosis, acute vascular diseases (such as stroke and myocardial infarction), diabetes, chronic obstructive pulmonary disease, and adverse pregnancy outcomes.3,4,5,6 While definitive causal associations with periodontitis have not been proven clearly to date, a chronic systemic inflammatory process has proven to be a common underlying principle for these associations.7,8

This article examines the potential for similar associations in terms of edentulism and denture wearers. While the specific microbiology of dental and denture plaque differ—the former is primarily bacterial while the latter is more influenced by yeast microbes—both can lead to sustained inflammatory tissue responses. Denture stomatitis is the common oral microbial-related inflammatory condition among denture wearers, while periodontitis is most common among dentate individuals. This article focuses on how these conditions can link to systemic disease, and the implications for denture wearers.

Periodontitis as a model of an oral-systemic infection pathway

Periodontal disease provides a model of infectious and inflammatory processes that can affect oral and systemic health. Periodontal disease involves localized bacterial infection and inflammation, as a number of commonly observed mediators of the innate immune response—including interleukins (for example, IL-1 and IL-6), tumor necrosis factor alpha (TNF-α), and prostaglandins (for example, PGE2)—are released. The inflammatory response results in a loss of tissue integrity, which appears clinically as increased probing depth and a loss of both bone-tooth periodontal attachment and alveolar bone structure. The
loss of epithelial integrity allows bacterial pathogens within the oral biofilm to enter the systemic circulation, promoting a further systemic inflammatory response.

In what can be seen as an expanding sequential cascade response, the orally derived inflammatory challenge (together with the invasion of oral pathogenic bacteria) triggers systemic inflammatory responses. One response is the release of soluble intracellular adhesion molecules (sICAMs) by vascular endothelial cells. These sICAMS produce an inflammatory activation of the entire vascular tree, which is a major part of the circulatory system in the human body.

A second response is the hepatic acute phase, in which the liver releases inflammatory mediators, including IL-6 and C-reactive protein (CRP). This hepatic response is designed to clear invasive organisms (or their derived products, such as endotoxins) from the circulatory system. These various hepatic inflammatory mediators have been proven to further damage the vasculature tree, especially the major elastic vessels; IL-6, CRP, and systemic pathogenic bacteria all promote atherogenesis and arterial deposition of oxidized low density lipoprotein (LDL) cholesterol and enhance vascular plaque formation. The systemic inflammatory mediators target multiple organ systems, exacerbate chronic inflammatory diseases, and can increase risk for cardiovascular disease (CVD), insulin resistance and diabetes, renal disease, and complications associated with pregnancy.

Ridker reported that an elevation in CRP (measured as high-sensitivity CRP) increased the risk of cardiovascular events (including myocardial infarction and stroke) more than fourfold. It was also reported that the elevation of other inflammatory mediators (such as IL-6 and sICAM-1) are significant risk factors for coronary disease. For comparison, elevated cholesterol levels (measured as total cholesterol, LDL-cholesterol, or the ratio of total to LDL cholesterol) show an increased risk for CVD by 200-300%, but elevated cholesterol levels have lesser predictive value for risk than CRP. These findings indicate that the risks for cardiovascular events and the onset of Type 2 diabetes involve not only abnormal lipid or carbohydrate metabolic pathways, but also include inflammatory conditions. At present, there is insufficient evidence to support the claim that periodontal disease is a cause of CVD, diabetes, and so forth; however, it is clearly a risk factor or an effect modifier.

The presence of periodontitis alters the cumulative lifetime trajectory path, increasing the risk of these diseases and affecting the severity of the disease in the presence of other risk factors such as obesity and smoking. The risk of chronic inflammation leading to the development of CVD is not trivial; more than 50% of all heart attacks occur in persons having normal lipid profiles. In addition to recommending the monitoring of blood lipids, the American Heart Association recently recommended measuring plasma CRP as an important and independent predictor for risk of heart attack.

Periodontal disease not only increases the risk for CVD and other diseases, it also is associated with the thickening of arterial walls (atherosclerosis). Carotid artery intima-media wall thickness (IMT) has been associated with coronary heart disease and stroke. A large study involving more than 6,000 persons with no prior history of coronary heart disease used standardized measures of attachment loss to define severe periodontitis (≥ 30%; n = 1,248), moderate periodontal disease (defined as 10 < 30%; n = 4,769), and mild to no periodontitis (< 10%). This study used ultrasound to measure intramedial wall thickness (IMT) of the carotid arteries. This study found that subjects with severe periodontitis had 1.3 times the odds risk ratio (OR) significantly greater thickening of arterial walls (carotid IMT ≥ 1 mm) among adults with severe periodontal disease compared to those with less severe periodontal disease (OR = 1.31; 95% CI: 1.03 - 1.66), after adjustment for other atherosclerosis risk factors such as age, race/study center, gender, body mass index, LDL-cholesterol, diabetes, hypertension, education, smoking, and waist-to-hip ratio. In addition to increased risk of arterial wall thickening among subjects who have not been diagnosed with CVD, periodontal disease also significantly increases the risk of recurrent stroke. Sen et al examined stroke patients by performing periodontal examinations during hospitalization and assessing their medical status over a 20-month follow-up period. Stroke patients with a low percentage of diseased periodontal sites had a much lower likelihood of stroke recurrence than those with a high percentage of sites affected by periodontitis. Periodontal disease had a hazard ratio of 3.69 (95% CI: 1.01 – 13.46) for stroke recurrence, even after adjusting for confounding factors such as diabetes, hypertension, cholesterol, and smoking.

**Associations between edentulism and denture wearing for risk of systemic disease**

Periodontitis is a disease which requires the presence of dentition, as it is not observed among edentulous individuals, regardless of denture use. Among adults age 65 or older,
periodontal disease is a greater risk factor for tooth loss than caries; however, the relative contribution of periodontal disease versus the relative contribution of caries in the terminal dentition leading to incident complete edentulism is not known. 

Although periodontal disease is a major cause of edentulism, reliable estimates of how great a role periodontitis plays in edentulism are elusive, as many factors (such as access to care) can affect tooth loss and rates of edentulism. Clearly, most edentate individuals have a history of chronic exposure to oral infections. The use of dentures does not abrogate the potential for oral infection, as dentures have been shown to be a major reservoir of microbes and therefore a chronic source of infection and potential inflammatory responses. Epidemiological data suggest that denture stomatitis occurs in approximately 50% of denture wearers. A six-year survey included a cohort of over 17,000 U.S. adults (both dentate and edentulous) who underwent a comprehensive oral examination.

In this population sample, the most frequently observed oral lesion was denture stomatitis (Type I—III), with an overall prevalence of 6.0% (see Figure 1). Like biofilm on natural teeth, denture biofilm is complex due to its organized structure and the types and numbers of organisms present. A 2010 study by Glass et al identified more than 900 individual species of aerobic and anaerobic bacteria, yeasts, and amoebae within denture biofilm. Others have reported similar findings concerning the complex microbial content of denture plaque. It has also been long recognized that unlike dental biofilm, the biofilm that forms on denture materials harbors a much larger population of yeasts. There is a strong pathogenic association between Candida yeasts (specifically C. albicans) and the presence of denture stomatitis. It is likely that denture-associated microbes have effects similar to those associated with the dental plaque microflora, and the potential to contribute to (or increase the risk of) systemic organic disease, since poor denture hygiene produces a pathogenic denture plaque that could lead to local and systemic inflammatory responses. The literature has demonstrated an association between edentulism and chronic obstructive pulmonary disease (COPD). A recent study assessed the severity of COPD among 11,378 dentate and 2,087 edentate individuals by using standardized guidelines developed by the Global Initiative for Chronic Obstructive Lung Disease in 2006 ("GOLD Stages"), which rank COPD into four stages of increasing severity (Stage I–IV) based on spiometry. The authors reported a positive association between edentulism and a significant increase in risk for severe COPD. By logistic regression analysis the OR for stage 2 (moderate) COPD was increased 2.1-fold (95% CI: 1.79–2.38) and the OR for stage 3-4 (severe) COPD was increased 3.4-fold (95% CI: 2.61–4.69) among edentate versus dentate individuals. When the analysis included adjustments for known COPD risk factors (that is, race, gender, age, diabetes, hypertension, CVD, smoking and tobacco use, alcohol use, and low sociodemographic status), the risk association was slightly lower (although still significant). The risk of severe COPD is lowest among those with periodontally healthy teeth, while dentate individuals with periodontal disease are at higher risk, and edentulous individuals are at even greater risk. After adjusting for age, it would appear that edentulism is associated with risk of COPD for reasons that extend beyond a history of periodontal disease.

Other studies have demonstrated associations between an increased risk of diabetes mellitus and edentulism (or factors associated with edentulism, such as C. albicans.)
In an uncontrolled observational study, Aly et al reported isolating *C. albicans* from two-thirds of 439 patients with diabetes mellitus.\(^3\) A 2000 study by Guggenheimer et al compared 405 insulin-dependent diabetes mellitus patients and 268 non-diabetic controls, reporting that 15.1% of diabetic patients (com-
pared to 3.0% of control patients) had clinical candidiasis, including median rhomboid glossitis, denture stomatitis, and angular cheilitis.

Among those with diabetes, there was a significant association between *C. Albicans pseudohyphae* and smoking (OR = 2.4), denture use (OR = 2.3), and elevated glycosylated hemoglobin (OR = 1.9).\(^3\) Dorocka-
Bobkowska et al found a high incidence of *Candida* colonization among denture wearers with non-
insulin dependent diabetes, suggest-
ing that patients with diabetes have an increased risk of oral pathogenic yeast infection, or perhaps a predis-
position to these infections.\(^3\)

Soon to be published data from the *Atherosclerosis Risk in Com-
munities* study, conducted in part by the authors of this article, has shown positive and signi-
cificant association between *C. Albicans* colonization 
and overall health. Among those with diabetes, there was a significant association between *C. Albicans pseudohyphae* and smoking (OR = 2.4), denture use (OR = 2.3), and elevated glycosylated hemoglobin (OR = 1.9).\(^3\) Dorocka-
Bobkowska et al found a high incidence of *Candida* colonization among denture wearers with non-
insulin dependent diabetes, suggest-
ing that patients with diabetes have an increased risk of oral pathogenic yeast infection, or perhaps a predis-
position to these infections.\(^3\)

The authors of this article evalu-
ated the inflammatory response in 

denture stomatitis by comparing the patterns of mucosal gene expression 
in oral mucosa with the presence of 
inflammatory mediators in saliva, as a measure of candidate biomarkers.

Subjects were edentulous, but other-
wise healthy adults 45 years of age or older. All used at least a full maxil-
ary denture, but did not have to use 
denture adhesive daily for retention or comfort. Exclusion criteria 

included significant organic disease, chronic disease with oral manifesta-
tions other than denture stomatitis, 

conditions requiring antibiotic use 
prior to dental examinations, use of 

antibiotics or antifungals within the 

month prior to and/or having initi-

ted new medication(s) within three 

months prior to screening, and use 

of tobacco products within the past 

six months. Seventeen subjects had 

no signs of denture stomatitis, while 

15 had *Candida*-associated denture 

stomatitis (confirmed by culture) 

of Newton Stage 2 or 3 severity. 

Denture fit and retention (assessed 

using the Kapur index) did not 

differ between subjects, regardless of 

whether or not they had stomatitis.\(^3\)

Oral palatal punch biopsies were obtained from each subject. For healthy subjects, samples were taken from one ridge site; for subjects with denture stomatitis, one biopsy was taken from an area of mucosa which appeared healthy, and the other from an inflamed ridge area. The analysis of gene expression was car-
ried out using whole transcriptome Affymetrix chips (Affymetrix, Inc.). Using a microchip array approach, the Affymetrix analysis allows for simultaneous rapid screening of over 30,000 genes. Essentially, the tech-
nique can quantitatively identify specific genes which are expressed (at elevated or decreased levels) in a non-biased manner by searching across the entire genome to identify which mRNA species are being expressed differentially to reflect the activation or suppression of specific genes. Comparing results of tissue biopsy samples from individuals with healthy mucosa against those from patients with denture stomat-
itis can provide insights regarding the changes in gene expression and the cellular and biological processes occurring in the disease state.

An assay of the gene array expres-
sion profiles identified 3,034 genes 

expressed differentially when healthy 

denture wearers were compared to 

those with *C. albicans*-associated 

denture stomatitis. It is significant 

that among those with denture 

stomatitis, there was no difference 

in the pattern of gene expression, 

regardless of whether the biopsies 

were taken from inflamed or 

healthy-looking mucosa. In addi-
tion, there was no significant asso-
ciation for age, gender, or race in 
terms of the patterns of differential 
gene expression in healthy denture 

wearers and subjects with denture
These results indicate that the changes between dental wearers with healthy mucosa and those subjects with denture stomatitis appear to be a disease-related response. Changes in gene expression associated with denture stomatitis include both up- and down-regulation. Charts 1 and 2 provide examples of genes undergoing changes in response to denture stomatitis. For instance, in patients with denture stomatitis, 71 genes displayed significant down-regulation of expression, including several genes which encode proteins associated with the structure and integrity of the epithelial barrier (Chart 1). The reduced expression of the genes and reduction in synthesis of the proteins they encode could alter epithelial barrier structure and increase its permeability. The increased amount of hyphae inserted by \textit{C. albicans} into underlying epithelial layers (and its submucosal penetration and colonization) increases in subjects with denture stomatitis. A correlation appears to exist between the expression of genes and the structure of the epithelial barrier with respect to permeability. The pattern of down-regulation observed in the patients with increased insertion of hyphae by \textit{C. albicans} into the epithelial barriers may provide some understanding toward a mechanism that could be a factor in denture stomatitis.

Denture stomatitis is also associated with increased up-regulation (more than 2-fold), reflecting the increased expression of 235 genes. Among patients with denture stomatitis, genes with the greatest levels of up-regulation included those associated with expression of inflammatory mediators (IL-1β and IL-8), chemokines (for example, chemokine ligand-1), and alarmin molecules (for example, SERPIN-B1). As shown in Chart 2, two genes having the highest level of up-regulation are lactotransferrin (which is involved in the epithelial uptake of \textit{C. albicans}) and mucin-21, which serves as a putative receptor for mucosal attachment of \textit{C. albicans}. Genetic up-regulation in cases of denture stomatitis reflects an increase in the inflammatory response and the enhanced ability for \textit{C. albicans} to bind to and penetrate the oral epithelial mucosa.
Denture stomatitis is associated with an increased (4- to 9-fold) up-regulation of endocytosis markers, receptor molecules for *C. albicans* mucosal binding, and inflammatory mediators; in addition, this condition produces an increased (4- to 12-fold) down-regulation of both adhesion and epithelial disruption markers. Typical activation pathways in stomatitis include neutrophil, lymphocytic, and mononuclear activation; and toll-like receptor-2 (TLR-2)-mediated innate immune responses, which release inflammatory mediators. These patterns are consistent with a host-response that serves predominantly as a defense against fungal infection rather than bacterial infection; however, the denture-associated microbiome clearly presents a mixed infectious challenge.

In addition to the genetic analysis, saliva samples were analyzed (using standard analytical approaches) to determine differences between healthy individuals and stomatitis patients, in terms of the levels and expression of inflammatory mediators and other proteins. This analysis demonstrated a direct activation of the inflammatory process, as reflected by the levels of inflammatory mediators (such as interleukins and TNF-α) increasing 2- to 5-fold. Differential salivary proteins expressed in *C. albicans*-associated denture stomatitis include salivary gland products as well as immunoglobulins and neutrophils; epithelial and tissue/plasma proteins. Interestingly, the patterns of the inflammatory response observed in denture stomatitis in the tissues are consistent with a fungal infection rather than a bacterial one. In addition, there was a correlation between the levels of inflammatory mediators observed in this study and the level of *C. albicans* on denture surfaces, implying that the denture is the source of the infection.

**Summary**

Denture stomatitis is a common condition that affects a large percent of denture wearers, and is associated with candidal infection and mucosal inflammation. The source of the infection is the denture itself, which provides a matrix that allows for the development of a biofilm plaque containing high levels of these yeasts and other infectious organisms which contribute to inflammation, increased levels of mediators of inflammation, and oral ridge resorption observed in denture stomatitis. Patients who wear dentures are at increased risk for several systemic diseases, including COPD, heart disease, atherosclerosis, hypertension, congestive heart failure, and diabetes. The increased risk for systemic disease among denture wearers is present even after adjusting for other relevant risk factors such as smoking, body mass, serum lipid levels (for example, cholesterol), education, age, race, and gender.

The role of unclean dentures as a chronic source of microbial infection contributing to systemic disease has long been overlooked. Unclean dentures may represent a previously unrecognized risk factor for systemic diseases and may explain why people who have lost their teeth and wear dentures have much poorer overall health and increased morbidity and mortality compared to those with healthy teeth and gums. Dentures are an important source of sepsis and must be treated daily with effective antifungal/antimicrobial agents. Additional study is needed to determine the potential benefits of improved denture hygiene and disinfection in terms of preventing adverse systemic diseases.

Current therapeutic intervention in denture stomatitis often relies on use of antifungal agents to eliminate the fungal infection on denture surfaces and the oral mucosa. However, as observed in the genetic and salivary analyses described above, inflammation is also a critical component in the activation response observed in denture stomatitis. Incorporating an appropriate anti-inflammatory therapeutic agent into a matrix could allow dentists to treat denture stomatitis.

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**References**


Exercise No. 317

Removable Prosthodontics

Subject Code 670
The 15 questions for this exercise are based on the article Impact of tooth loss on oral and systemic health on pages 494-500. This exercise was developed by Daniel S. Geare, DMD, in association with the General Dentistry Self-Instruction committee.

Reading the article and successfully completing the exercise will enable you to understand:
• the risks and nature of periodontal disease;
• the nature of denture stomatitis; and
• the health risks of denture stomatitis.

1. Periodontitis affects up to ______ of adults in the United States.
   A. 50%
   B. 55%
   C. 67%
   D. 72%

2. Periodontitis is characterized as
   A. generalized chronic inflammation.
   B. gradual destruction of connective tissue.
   C. predictable loss of bone.
   D. having multiple infectious causes.

3. Periodontitis is presently associated with all of the following conditions except one. Which is the exception?
   A. Diabetes
   B. Oropharyngeal cancer
   C. Acute coronary syndrome
   D. COPD

4. Periodontal bacterial infection results in a sequential cascading response. Aspects of this response include the soluble intracellular adhesion molecule response as well as the hepatic acute phase response.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.

5. The C-reactive protein (CRP) response from the liver is designed to
   A. clear invasive organisms.
   B. reduce the inflammatory response.
   C. activate liver enzymes.
   D. reduce blood pressure.

6. CRP has also been shown to affect all of the following except one. Which is the exception?
   A. Atherogenesis
   B. Insulin resistance
   C. Development of coronary disease
   D. Blood clotting

7. Approximately ________ of denture wearers experience denture stomatitis.
   A. 25%
   B. 33%
   C. 50%
   D. 75%

8. The predominant infectious agents on denture biofilms are
   A. bacterial.
   B. viral.
   C. fungal.
   D. protozoan.

9. There is an increased risk of COPD in edentate individuals. This is because the organisms of periodontal disease have been associated with the development of COPD.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.

10. According to the ARIC study, edentulism is associated with increased risk of all of the following except one. Which is the exception?
    A. Coronary artery disease
    B. Elevated lipid levels
    C. Elevated body fat
    D. Elevated blood sugar levels
11. In cases of denture stomatitis, gene expression of oral mucosa can
   A. increase epithelial permeability.
   B. increase susceptibility of Candida infections.
   C. track the similarity patterns of age, gender, and race.
   D. make the patient more susceptible to oral cancer.

12. Identified genes associated with epithelial uptake of Candida albicans include all of the following except one. Which is the exception?
   A. Lactotransferrin
   B. Interleukin 1β
   C. Liver arginase
   D. Chemokine

13. “Up-regulation” of genes is associated with
   A. increased permeability of epithelium.
   B. increased inflammatory response.
   C. controlling bacterial byproducts.
   D. controlling tissue uptake.

14. Unclean dentures can contribute to all of the following except one. Which is the exception?
   A. COPD
   B. Chronic infection
   C. Peripheral neuropathy
   D. Atherosclerosis

15. Historically, treating denture stomatitis involved eliminating the fungal infections on the denture surface. It is important to now include anti-inflammatory agents as part of the treatment modality.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.
Removable partial denture assisted by implant-retained fixed prosthesis opposing implant-retained overdenture

Hyun-seok Nam, DDS, MS • Kwang-yeob Song, DDS, MS, PhD • Ju-mi Park, DDS, MS, PhD • Won-suk Oh, DDS, MS

Restoring an edentulous mouth is a challenge when the patient has both high esthetic expectations and financial limitations. This case report describes the prosthodontic management of an elderly edentulous patient with a maxillary anterior implant-supported fixed partial denture in conjunction with a distal extension-base removable partial denture opposing a mandibular implant-retained overdenture. The patient’s clinical outcome after 30 months is presented.

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Endosseous dental implants are used frequently to provide edentulous patients with support, stability, and retention for dental prostheses. The patient’s comfort and function are enhanced by securing a prosthesis to the implants. However, many edentulous patients cannot afford a fixed prosthesis that may require a large number of implants, additional surgical procedures, and controlled systemic conditions. Restoring an edentulous mouth with implant-retained overdentures (IODs) is a practical approach for reducing the cost of treatment while satisfying the patient’s need for esthetics and function. Using IODs also eliminates the need for additional surgical procedures, such as augmentation of the enlarged sinus, lateral displacement of the inferior alveolar nerve, and distraction osteogenesis. The dentures are secured by implants placed in the anterior portions of the maxilla and the mandible and acrylic resin restores the lost tissues.

The main problems with IODs are continuous resorption of the bone underneath the denture base and the patient’s lack of self-esteem, since removing the denture often leaves patients with no teeth present in the mouth. Currently available implants have moderately rough surfaces, which appear to accelerate tissue healing, withstand stresses, and enhance the remodeling capacity of the bone. With the development of this enhanced surface, the clinical application of the implant treatment has been widely expanded to support, stabilize, and retain a removable partial denture (RPD) where the anterior portion of the edentulous mouth is restored with an implant-supported fixed partial denture (FPD). An RPD is subsequently designed to restore a posterior portion of the edentulous arch. The patient’s comfort and esthetics are maintained as the anterior teeth remain in the mouth even after the denture is removed.

This case report describes a patient whose edentulous maxilla was restored with an anterior implant-supported FPD and a distal extension-base RPD against an opposing mandibular IOD. The implants were found to be stable with no prosthetic complications after 30 months of follow-up evaluation, and met the patient’s demands for esthetics and function.

Case report
A 68-year-old woman complained of difficulty with her conventional maxillary and mandibular removable dental prostheses and sought a fixed dental prosthesis in the anterior portion of the maxilla. Her past medical history was not specific. An intraoral examination revealed complete edentulism of the maxilla and the mandible (Fig. 1) with moderately compromised vertical dimension.

Fig. 1. The edentulous mouth at estimated vertical dimension.
residual ridges of both arches. The patient preferred to avoid the extensive surgical intervention and high cost of treatment. Several treatment options were proposed, including no treatment, complete dentures (CDs), implant-supported FPDs, IODs, implant-supported FPDs in conjunction with RPDs, and combinations of the above. The patient chose an anterior implant-supported FPD and a distal extension-base RPD for the maxilla and an IOD for the mandible.

Using stock trays, diagnostic casts were made from irreversible hydrocolloid materials (Aroma Fine DF III, GC America Inc.). Impressions of the edentulous arches were made and mounted on an articulator (PROTAR evo 7, KaVo Dental) for diagnostic waxing. Using surgical guides, eight regular-neck endosseous dental implants (SLA Implant, Straumann) were placed: four two-stage implants in the maxilla at the right canine and left first molar (4.1 mm x 10 mm) and right second premolar and left first premolar (4.1 mm x 12 mm) sites, and four one-stage implants in the mandible at the right and left lateral incisor (4.1 mm x 12 mm) and right and left first premolar (4.1 mm x 10 mm) sites (Fig. 2). Two weeks following the implant placement, the existing dentures were relined with a resilient material (Visco-Gel, Dentsply DeTrey), which was replaced every other week for six months.

After the second-stage surgery, an open-tray technique was used to make impressions of the maxillary and mandibular arches. The impression copings were placed on the implants and connected to each other with an acrylic resin (Pattern Resin LS, GC America Inc.). Using border-molded custom trays, the impressions were made with a vinyl polysiloxane (VPS) impression material (Exafine Regular Type, GC America Inc.) and poured in a Type IV dental stone (Fujirock, GC America Inc.) to create the master casts. The casts were mounted on an articulator to arrange artificial denture teeth (Endura Anterio, Shofu Dental Corp.) in the occlusion rims. The wax-trial dentures were evaluated intraorally and indexed with a silicone putty impression material to duplicate the position of the teeth and aid in subsequent prosthodontic procedures.

The maxillary implants were placed under function by means of an anterior provisional implant-supported FPD made of tooth-colored autopolymerizing acrylic resin (Tokuso CureFast; Tokuyama Dental) that used temporary abutments (RN synOcta, Straumann) (Fig. 3). The posterior occlusion was established with a maxillary interim RPD against a mandibular interim CD to evaluate esthetics and function.

Four separate individual custom abutments were waxed (using non-segmented cast abutments with a silicone index), milled, and cast in a Type III gold. A full-contour waxing was performed over the custom abutments (to create an anterior, resin-veneered, implant-supported fixed partial denture metal framework) and surveyed to create guiding planes, rest seats, and undercut areas and to design a distal extension-base RPD. A mandibular implant-retention bar was designed to connect the mandibular implants as a one-unit and to present Hader bar segment (Hader-EDS Bar System, Attachments International) in the middle and extra-coronal resilient attachments (ERA Attachment, Sterngold Dental) at each end. To ensure the health of the gingival tissue and allow for an esthetic arrangement of artificial denture teeth, a waxing...
was performed using non-segmented castable abutments with the silicone index. The wax bar was milled and the attachment elements were secured in line by placing the IOD with a dental surveyor (Ney Dental Surveyor, Dentsply Prosthetics).

The waxed implant-supported FPD framework was invested and cast using a nickel-chrome alloy (T-3 C&B Alloy, CMP Industries), while the bar was cast using a Type III gold alloy. The finished metal frameworks were fitted intraorally using a screw test and a silicone material (Fit Test, GC America Inc.) to ensure a passivity of the frameworks.27 The fit of the implant-supported FPD framework was evaluated over the custom abutments placed on the implants (Fig. 4 and 5).

The fitted implant-supported FPD metal framework was veneered using an acrylic resin (Vertex SC, Vertex Dental) and artificial denture teeth (Endura Antero, Shofu Dental Corp.) from the right first premolar to the left first premolar across the arch. The custom abutments were screwed and torqued to 35 Ncm to the implants, and the processed and finished implant-supported FPD was luted with a resin cement (Premier Implant Cement, Premier Dental) on the abutments. The screw access holes were filled with a composite resin (Filtek Z250, 3M ESPE).

Using border-molded custom trays, final impressions for a maxillary RPD and a mandibular IOD were made with a VPS impression material (Exafine Regular Type, GC America Inc.). The implant-retention bar was taken in the impression for constructing the IOD. A distal extension-base maxillary RPD was designed to restore the posterior occlusion of the maxilla with the maxillary major connector of a modified palatal strap, occlusal rests over the implants, and wrought wire clasp retainers. The cast and finished metal framework (made from a chrome-cobalt alloy) was fitted intraorally and adjusted to avoid a binding against the abutment tooth under occlusal function (Fig. 6).28

The maxillary and mandibular master casts were mounted on an articulator and artificial denture teeth were arranged in the occlusion rims. Following an intraoral evaluation, the wax dentures were processed with a heat-polymerized acrylic resin (SR-Ivocap, Armstrong Laboratory, Inc.), finished, and polished.

The RPD and IOD were fitted intraorally using a silicone material and a tungsten carbide bar, with the mandibular implant-retention bar screwed and torqued to 35 Ncm to the implants. The occlusion was first adjusted with the prostheses mounted on an articulator, then refined intraorally using a computerized occlusal analysis system (T-scan III, Tekscan Inc.) to harmonize with the patient’s oral function (Fig. 7). The patient was provided with post-insertion instructions and returned for regular follow-up appointments. Using an acrylic resin, the plastic matrices of the attachment elements were connected intraorally to the IOD at the three-week recall appointment. Thirty months after placement of the prostheses, the patient showed no signs or symptoms of biologic and mechanical complications, although the plastic matrices of the attachment elements are replaced at every six-month recall appointment (Fig. 8).

Discussion

The edentulous mandible commonly receives two or four implants for an IOD in its anterior portion where the prosthesis is either retained by means of individual attachments or an implant connecting bar.2,3,10,13,15 The design of the prostheses does not appear to be critical to the success of mandibular IODs with modern implant surfaces; however, the prosthetic...
complications appear to be lower when bar-retained IODs are used rather than ball-retained IODs.\textsuperscript{3,4,29}

In the present case, the implants were placed bilaterally in the lateral incisor and premolar sites that were to be connected with a metal bar, where the bar conformed with the patient’s arch shape and aligned the axis of rotation of the prosthesis with the patient’s transverse horizontal axis.\textsuperscript{2,10,13,15} In general, the bar design appears to enhance the patient’s comfort by guiding the path of denture placement, increasing the stability and support of a denture, and promoting a uniform stress distribution to the supporting structure of the tissue.\textsuperscript{3,4,29} The denture retention does not appear to diminish significantly over time.\textsuperscript{3,4}

Restoring an edentulous maxilla using dental implants can be challenging because of the configuration of the residual ridge, quality of the bone, and the patient’s expectation for esthetics.\textsuperscript{11,18} In general, four implants are placed in the anterior portion of the maxilla to support an IOD when a patient’s systemic and anatomic conditions make constructing an implant-supported FPD unsuitable.\textsuperscript{12,19} However, the patient’s oral health can be compromised by failing to comply with denture removal at night. The mucosa may become inflamed; possible parafunctional activities may induce biologic and prosthetic complications such as peri-implantitis, bone loss, and loosening of the attachment elements.\textsuperscript{14,19}

An anterior implant-supported FPD may provide better esthetics and enhance the patient’s psychological comfort without compromising speech in a relatively well-preserved maxilla.\textsuperscript{12,24} According to Nedir \textit{et al}, implants with fixed prostheses demonstrated significantly lower complication rates than removable prostheses, where complication rates with fixed restorations were not recurrent incidents and did not increase over time.\textsuperscript{29}

The abutment fit to dental implants should be passive to avoid biologic and mechanical complications.\textsuperscript{5,6,30} To eliminate potential strain at the abutment-implant interface due to an improper fit, the individual custom abutments of a high-noble alloy were connected to the implants with screws before the FPD was cemented over the abutments.\textsuperscript{8} This cement- and screw-retained prosthesis is retrievable; the screw access holes prepared in the denture were in line with those in the abutments.\textsuperscript{9} This method may be a viable option for satisfying a patient’s demands for affordable esthetics and function. However, care should be taken to avoid using a base metal alloy on patients experiencing hypersensitivity, particularly in the U.S., where the prevalence of nickel allergy is relatively high.\textsuperscript{31}

The maxillary posterior segments were restored with a conventional distal extension-base RPD to oppose the mandibular IOD, support the position of the condyle, provide bilateral loading in centric, and harmonize with the patient’s oral functions.\textsuperscript{7,23,24} Support for the RPD was obtained from the implants, the residual ridges, and the palate by means of the occlusal rests, the denture bases, and the maxillary major connector of a modified palatal strap. The rests were designed to direct the forces along the implants and control the RPD’s rotation, keeping the axis of rotation over the rest seats.\textsuperscript{28} The wrought wire clasp retainers were soldered to the retentive mesh area to maintain flexibility without recrystallizing the wire. In addition, minimum undercuts (0.01 in) were utilized to avoid lateral forces on the implants under function.\textsuperscript{32}

The occlusion was equilibrated to centralize the masticatory forces with a lingualized occlusion scheme and eliminate interferences in eccentric positions.\textsuperscript{33} The anterior guidance was minimal to reduce a lever action on the implants. The patient was instructed not to use the anterior teeth in mastication and encouraged to return for regular recall appointments. A 30-month follow-up evaluation indicated that the implants were stable; however, the validity of this treatment mode has yet to be determined scientifically in terms of ensuring long-term success and promoting the patient’s oral health.

\textbf{Summary}

Restoring an edentulous maxilla with a combination of an anterior implant-supported fixed partial denture and a distal-extension RPD against a mandibular IOD may benefit some patients by eliminating the psychological discomfort associated with the lack of the maxillary anterior teeth once a denture is removed. This article examined the clinical outcome of an elderly edentulous patient who received a maxillary implant-supported fixed partial denture and a distal-extension RPD against a mandibular IOD to maximize comfort and esthetics. Additional studies are necessary to determine the validity of this prosthodontic treatment for restoring an edentulous mouth.

\textbf{Disclaimer}

The authors have no financial, economic, commercial, and/or professional interests related to topics presented in this manuscript.

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Sequential provisional implant prosthodontics therapy

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The fabrication and long-term use of first- and second-stage provisional implant prostheses is critical to create a favorable prognosis for function and esthetics of a fixed-implant supported prosthesis. The fixed metal and acrylic resin cemented first-stage prosthesis, as reviewed in Part I of this article, is needed for prevention of adjacent and opposing tooth movement, pressure on the implant site as well as protection to avoid micromovement of the freshly placed implant body. The second-stage prosthesis, reviewed in Part II, should be used following implant uncovering and abutment installation. The patient wears this provisional prosthesis until maturation of the bone and healing of soft tissues. The second-stage provisional prosthesis is also a fail-safe mechanism for possible early implant failures and also can be used with late failures and/or for the necessity to repair the definitive prosthesis. In addition, the screw-retained provisional prosthesis is used if and when an implant requires removal or other implants to be placed in a sequential approach. The creation and use of both first- and second-stage provisional prostheses involve a restorative dentist, dental technician, surgeon, and patient to work as a team. If the dentist alone cannot do diagnosis and treatment planning, surgery, and laboratory techniques, he or she needs help by employing the expertise of a surgeon and a laboratory technician. This team approach is essential for optimum results.

A mong the various prosthodontic procedures employed in the creation of an implant-supported prosthesis, the two least understood yet quite important phases are the fabrication of first- and second-stage provisional prostheses. These provisional prostheses enable the patient and restorative dentist to predictably create a cosmetic and functional result.1 The diagnostic wax-up is a requirement prior to any treatment and the basis for the proposed prosthesis. This wax-up is then duplicated and casts of the wax-up are poured. They are used for case presentation to the patient to explain and illustrate the proposed definitive result. The wax-up is also used to create the cemented fixed first-stage provisional prosthesis, a surgical template, which is the basis for the retrievable screw-retained second-stage provisional prostheses.2–5 The risks and benefits of implant prosthodontics should be explained to the patient prior to any treatment. Alternative treatments with risks and benefits may also be presented. The restorative dentist must explain why implant dentistry is the preferred course and the standard of care for prosthetic problems rather than utilizing conventional prosthodontic treatment.

The patient will wear the fabricated transitional prostheses from first-stage through the insertion of the definitive prosthesis. This allows the patient to become accustomed to the esthetics, contours, and occlusion of the restoration that is created from the first day of treatment. Whether it is created by a dentist alone or a technician and surgeon working together, the first-stage provisional prosthesis and then the second-stage provisional prosthesis should be used as the architectural design of the definitive prosthesis, so as to help the patient visualize and become accustomed to the end result.

The rationale and technique for utilization of provisional prostheses will be presented in two parts.

Part I. Technique for fabrication of first-stage fixed provisional prostheses: Fixed metal and acrylic provisional prostheses

Diagnostic casts are made and mounted with a facebow transfer and verified intraoral maxillo-mandibular records. The team should then perform a diagnostic analysis of the patient and in particular note any parafunctional habits that would tend to complicate the selected treatment. A diagnostic analysis should aid the practitioner in determining the presence of an even and harmonious occlusal plane, both inter-arch and intra-arch. The dentist should then be able to determine where any deflectional occlusal contacts are and correct them. The practitioner should relate to the patient the clinical diagnosis and
treatment plan, and explain using the diagnostic wax-up.³ The patient should be informed the diagnostic wax-up is the restorative template for the design of the provisional prostheses and serves as an aid in predicting a positive patient outcome in the definitive prosthesis.

After completion of the diagnostic wax-up, the restorative dentist should design a fixed-metal and acrylic-resin provisional prosthesis.³ The extent of the proposed metal framework is dependent upon the patient's occlusal contacts, the functional forces of occlusion, as well as such habits as bruxism, clenching, the patient’s typical diet, pipe smoking, and alcoholism. The proposed metal and acrylic-fixed provisional prosthesis is then fabricated by the dental technician prior to any surgical or prosthetic treatment (the surgical template is fabricated at the same time from a duplicate cast). Accurate full arch casts are made and then mounted on an articulator. If there are enough teeth present, the casts can be hand articulated. If this is not the case, an interocclusal record is made in the centric relation position.

This prosthesis is designed and then waxed on an unprepared cast. Usually, no preparations or reshaping of the patient’s existing teeth are needed (Fig. 1-5).⁴ Recontouring is performed only if the abutment teeth are in premature occlusal contact or tilted so as to interfere with the implant placement and path of draw of this prosthesis. The technician and practitioner should examine the mounted casts in order to incorporate occlusal, palatal, and/or...
lingual rests as needed. Posterior buccal cast clasps should be included in the design of the metal framework (Fig. 6). No facial clasps are designed or waxed for a prosthesis that will be used in the esthetic zone.

Retention beads are created from salt or manufactured retention beads (Zahn Dental) and are incorporated in the wax-up on the side facing the selected teeth to become an integral part of the nonprecious casting as an aid in retention after cementation. To determine how much metal to use, the wax-up with the sprues attached is weighed, and that weight number is multiplied by the density of the selected non-precious metal. The result is the amount of metal to be used in grams. This is then weighed out on a scale, while the investment is hardening.

The technician should then wax the design for the metal-fixed provisional prosthesis. After completion, the wax-up is invested in a phosphate-bonded investment and cast with a non-precious alloy. The metal is cast and allowed to cool completely on the laboratory bench. After cooling, the metal casting is removed from the investment and cleaned. Sprues are removed and then the casting is cleaned in an ultrasonic cleaner. The casting is accurately fitted to the cast, and then the metal facing the soft tissues is highly polished. The occlusal contacts are refined and the prosthesis is processed to the desired shade. After the prosthesis is fitted accurately to the cast, facial clasp arms (if used) are covered with heat-cured acrylic resin by sandblasting

Fig. 6. Posterior view of mounted maxillary and mandibular casts to analyze the space available for the planned metal and acrylic provisional prosthesis. Note the design of the prosthesis is drawn on the cast. No rest seats are prepared on abutment teeth. Room for rests is determined on the articulator and can be placed where there is interocclusal room. The pontic area is relieved gingivally so that it does not impinge upon the surgical area.

Fig. 7. Cast and processed maxillary first-stage provisional prosthesis to replace teeth No. 8 and 9. This is ready for cementation on the day of surgery. Note the retention areas on the metal of the palatal clasp arms.

Fig. 8. Completed maxillary provisional prosthesis after fitting the prosthesis to the cast, polishing, and processing acrylic resin artificial teeth to the framework for replacement of teeth No. 8 and 9.

Fig. 9. Intraoral palatal view of provisional prosthesis cemented to place on the day of surgery with Multilink cement.

Fig. 10. Intraoral facial view of cemented provisional prosthesis on day of surgery.
the buccal clasp arm; opaque it, then heat cure the appropriate acrylic resin (Fig. 7). The missing teeth are then created on this framework using heat-cured acrylic resin. It is easier to use facial and incisal silicone or plaster indices, as well as a heat and pressure machine, such as the Ivomat (Ivoclar Vivadent, Inc.) machine, to cure the resin in 20 minutes, rather than investing, boiling out wax, packing, curing, and deflasking the acrylic resin in a flask (Fig. 8).

After surgery (usually on the day of surgery, but maybe the next day) the completed provisional prosthesis is fitted intraorally and the occlusion adjusted where needed (Fig. 9, 10). The clinician should verify the occlusion and ensure that the acrylic resin on the pontic areas does not touch the surgical area. The prosthesis is cemented into place with resin-bonded cement, such as Multilink cement (Ivoclar Vivadent, Inc.). After set, excess cement is removed. The patient wears this prosthesis until the implant or implants are ready for uncovering. This also is used in a bilateral posterior first-stage fixed provisional prosthesis (Fig. 11-16).

**Transitional implants for fixed first-stage provisional prostheses**

Transitional implants allow the clinician to fabricate a fixed provisional prosthesis that may be temporarily cemented to place in a partially edentulous case, without attaching it to the patient’s teeth. The advantage of using transitional implants such as Immediate Provisional Implants (IPIs) (Nobel Biocare), especially in the fixed partially edentulous situations is that it avoids the cementation of a metal framework to the teeth adjacent to the edentulous areas (Fig. 17). If there is sufficient bone, the transitional implants may be used when the posterior sections of

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**Fig. 11.** Maxillary diagnostic cast. The existing posterior fixed prostheses were to be removed on the cast prior to intraoral extractions, grafting, and implant placement.

**Fig. 12.** Maxillary cast with full arch non-precious metal framework fitted to the cast. Note the posterior fixed prostheses scheduled for removal have been cut off the cast.

**Fig. 13.** Gingival view of processed metal and acrylic provisional prosthesis.

**Fig. 14.** Occlusal view of completed first-stage provisional prosthesis.

**Fig. 15.** Maxillary arch on the day of surgery following removal of teeth bilaterally, placement of implants, bone grafts, collagen membranes, and suturing.

**Fig. 16.** Intraoral occlusal view of the cemented provisional prosthesis that was inserted on the day of surgery.

**Fig. 17.** IPI. This implant is 14 mm long and 2.8 mm wide. The gingival end may be cut shorter if needed. It is placed a minimum of 3.0 mm from the submerged endosteal implant bodies.
the dental arch are edentulous, thus avoiding a removable prosthesis. The partially edentulous provisional prosthesis is usually cemented only to the transitional implants, which makes it easier to clean the remaining teeth in the dental arch. This ease of cleaning is important for a patient that has a high caries rate, as no part of the provisional prosthesis attaches to teeth. It will permit the patient to practice good oral hygiene procedures.7

The missing teeth are created on this framework using heat-cured acrylic resin. It is easier to use facial and incisal silicone indices, as well as a heat and pressure machine, such as the Ivomat, to cure the resin in 20 minutes. On the day of surgery, the completed provisional prosthesis is fitted intraorally and the occlusion adjusted where needed. Then the prosthesis is cemented into place with a noneugenol, acrylic/urethane-based temporary cement, such as Improv (noneugenol, acrylic/urethane-based temporary cement) (Alvelogro). The patient wears this prosthesis until the implant(s) are ready for uncovering. The fixed first-stage prosthesis can be used to replace one tooth and up to five or six teeth missing in the four quadrants of the dental arch. When restoring a maxillary lateral incisor, cuspid, and bicuspid with a steep vertical overlap, there should be anterior and posterior abutments as well as posterior occlusal and/or anterior rests, with a cast non-precious framework.

The problem with transitional implants is that because they can fuse to bone, they may not always be removed from the bone. If that happens, then the surgeon cuts the top off the implant body at the level of the bone and covers it with soft tissue. It can also be trephined out and a bone graft placed.

**First-stage provisional prostheses supported by transitional implants**
The first-stage fixed metal and acrylic provisional prosthesis can be used in conjunction with transitional implants for a partially or completely edentulous situation.8-11 It can also be used alone to fabricate a fixed first-stage provisional prosthesis, usually in the partially edentulous situation. For partially edentulous patients, IPIs may be used for a cemented fixed restoration. They are 2.8 mm in diameter and 14 mm long. The gingival length of the implant can be reduced to create different lengths. This is done by the surgeon at the time of the surgical procedure.
surgery. These implants are placed a minimum of 3 mm from the endosteal submerged implant bodies. The surgeon must use a surgical template for their placement, which is done at the same time as placement of the definitive implant bodies (Fig. 18).

A cast made from the diagnostic wax-up is used to fabricate a thick heat-cured acrylic resin shell of the area being treated. Following surgery, metal copings are seated over the occlusal ends of these transitional implants (Fig. 19). The dentist must ensure that there is sufficient occlusal room between the occlusal ends of the metal copings that are seated on the mini implants, and then an impression is taken and a cast is poured. Metal analogues of the IPI implants are used and are seated into the copings. The cast is poured and once set, the full arch maxillary and mandibular casts are mounted on an articulator (Fig. 20). After the casts are articulated, the metal copings are cleaned and placed over the occlusal ends of the implant analogues. They are connected with auto polymerizing acrylic resin. After set, they are tried intraorally. Any discrepancy in fit is corrected intraorally by cutting the acrylic resin connection, seating the copings correctly on the implants, and then reconnecting with autopolymerizing acrylic resin (Fig. 21, 22). Any undercuts below the occlusal portion should be blocked out. The positions of the analogues in the cast should be corrected. The previously processed acrylic resin shell should be fitted over the joined metal copings and connected with acrylic resin of the same shade. The prosthesis should then be removed from the cast after processing in the Ivomat.

The processed prosthesis is then corrected occlusally. The contours are refined and polished (Fig. 23, 24). A try-in is performed intraorally to verify the occlusion and ensure that the acrylic resin does not encroach upon the surgical sites. Cement is placed inside the metal copings of the provisional implants and this interim prosthesis is cemented with Improv cement. Thus, the prosthesis can be retrieved without torquing the provisional implants. This methodology permits the implant team to sequentially change a failing dentition into a transitional implant-supported prosthesis without the patient wearing a completely mucosal-supported removable prosthesis or preparing or cementing a prosthesis to the remaining teeth. This protocol becomes a practice booster in how not to interfere with a patient’s daily life. The method usually avoids a loss of vertical dimension of occlusion, which the patient needs for comfortable speech and mastication.
Part II. Technique for fabrication of second-stage provisional prostheses

Before uncovering the previously placed implant bodies (Part I), impressions should be taken and the casts mounted on a semi-adjustable articulator. The technician should fabricate a shell of heat-cured acrylic resin of the appropriate shade and shape. The guide for this is the cast made from the diagnostic wax-up.

On the day of implant uncovering, abutments are installed either by the surgeon or restorative dentist (Fig. 25-28). An impression is taken, abutment replicas attached, and a cast poured. Appropriate metal provisional cylinders are attached intraorally to abutments, using guide pins or prosthetic screws (Fig. 29). These cylinders are painted with the appropriate shade of opaque (Fig. 30). Once dry, they are luted together with autopolymerizing acrylic resin of the selected shade. The accuracy of the impression is verified with these luted provisional cylinders. When an error is noted on the cast, the replica is removed and screwed to the provisional cylinder. The cast is then altered, using a fast-setting stone. The processed screw-retained second stage provisional prosthesis is installed (Fig. 31). The hexes of the abutment and the inside of the metal provisional cylinder prevent rotational movement of this prosthesis (Fig. 32). As the soft tissues heal, the prosthesis is altered for cosmetics so as to match the adjacent central incisor (Fig. 33).
When fabricating a second stage screw-retained provisional prosthesis for a maxillary first bicuspid implant, after ensuring that the hexes of the abutment and metal provisional cylinder are compatible, the contour of the facial surface is critical for cosmetics and for the optimum contour of the dental arch. The length of the buccal cusp should blend in with the adjacent cuspid anteriorly and second bicuspid posteriorly (Fig. 34-38).

If an abutment requires changing to an angulated abutment for either esthetics or a shorter one, or to a direct connection to the implant (UCLA connection) due to limited interocclusal space, it should be accomplished at this point. It may be difficult to change one or more abutments due to bleeding following implant uncovering. Usually, the bleeding is reduced or stops prior to the patient’s arrival in the restorative dentist’s office. Most times when the patient needs a change of the abutment, they still have the effects of the local anesthetic used by the surgeon, or the restorative dentist, whoever uncovers the implant bodies.

Management of bilateral posterior screw-retained provisional prostheses requires that impressions are taken on the day of implant uncovering (Fig. 39) and casts (Fig. 40, 41) are mounted on a semi-adjustable articulator, and the previously made heat-cured acrylic resin shell is attached to the provisional cylinders. After curing, the provisional prosthesis is carved and polished. A try-in of the provisional prosthesis should be done intraorally. With one screw at either end, right-angled bite-wing radiographs are taken to verify the fit. The entire provisional prosthesis must fit with this one screw test regardless of the extent of the prosthesis. The one screw test means that when the prosthesis is being evaluated, the clinician observes if there is a rocking motion, just as with a conventional prosthesis. Then a prosthetic screw is inserted into the posterior casting and screwed to place.

Radiographs are taken with the film being held parallel to the long axis of the implant. The titanium
alloy provisional cylinders of the provisional prosthesis should all fit accurately without any space between the cylinder and the abutment. In addition, the contact areas are verified with unwaxed extra-fine dental floss. Once the fit is verified, the occlusion and contours are refined. If there is an error in the fit of one or more provisional cylinders, the provisional prosthesis is sectioned, the cylinders attached to the abutments intraorally, and the sections luted together with autopolymerizing acrylic resin of the same shade. After curing and ensuring the fit of the cylinders to the abutments intraorally, the replicas on the cast are altered.

The prosthesis should be reinforced with metal to avoid breakage and distortion. After the provisional prosthesis has been fitted and polished, the technician or dentist cuts a lingual or palatal groove from one end of the restoration to the other. A braided gold plated stainless steel wire (Keystone Industries) is cut and fitted to that groove. The wire is then luted in place with autopolymerizing acrylic resin of the appropriate shade and polished. Rigidity of the prosthesis is needed for incremental loading. The acrylic resin occlusal surfaces with metal centric occlusal stops from the provisional cylinders are needed to maintain vertical dimension of occlusion and the desired centric occlusal contacts.

The prosthesis is polished and inserted into the patient’s mouth. The screw access channels are provisionally sealed with cotton and dental stopping (Hygenic Corp.), or Cavit (3M ESPE) or Fermit (Ivoclar Vivadent AG). The patient is seen one week later, and the fit of the components and occlusion is verified. Vertical dimension of occlusion must be confirmed prior to insertion of the prosthesis. The vertical dimension should not be increased inadvertently since problems that may occur are loss of bone; difficulty in speech and with mastication; and temporomandibular joint complications. This provisional prosthesis is worn until the gingiva has keratinized and stabilization of bone levels is seen on radiographs. Soft tissues should not bleed when the prosthesis is unscrewed, and the area around the abutment should not close over. Keratinized and healed soft tissues should remain in the position held by the provisional prosthesis.
prosthesis. The provisional prosthesis is thus used to create a non-surgical cosmetic gingivoplasty of the soft tissues (Fig. 42-44). The provisional prosthesis supports the development and maturation of the dentogingival complex and acts as a failsafe for the practitioner. Therefore, if there is an early failure, such as loss of implant(s) or bone grafts, it can be corrected prior to definitive prosthesis fabrication. If breakage or loss of an implant occurs, or the implant body cannot be restored because of its position and/or other surgical errors, this problem should be corrected prior to construction of the definitive implant prosthesis.

The use of a second-stage provisional prosthesis is important to avoid implant and graft losses, especially with a sinus bone graft. These areas need gradual loading to allow for graft maturation and to reduce implant body loss; thus, requirements of occlusal loading are in a vertical direction (along the long axis of the implant bodies), and cast metal reinforcements are used to provide rigidity. There should not be occlusal contact in eccentric positions, and the occlusal table should be narrowed and the cuspal angulation shallow. The second-stage provisional prosthesis fabricated over a sinus bone graft should be worn for at least 1 year prior to fabrication of a definitive prosthesis to allow time for maturation of the grafted sinus. This gradual loading has also been termed progressive loading because the occlusal contacts should be in minimal contact at first, and then over a period of two to three months, the amount of centric occlusal contact is increased in a vertical direction, only along the long axis of the implants.

After insertion of the prefabricated definitive prosthesis, the patient should be given possession of the second-stage provisional prosthesis and be informed that it must be saved. If repairs to the definitive prosthesis have to be made at a later date, this secondary provisional prosthesis can be reinserted so that the patient is never without a prosthesis.

Discussion

The use of fixed cemented first-stage provisional prostheses followed by a screw-retained second-stage provisional prosthesis has been described from the single tooth up to and including a full arch implant prosthesis. The success of this treatment depends first upon the patient’s understanding of the treatment protocol and the need for the surgeon, restorative dentist, and dental technician to work as a team. The optimum result can only be achieved if everyone understands what the desired goals are. The surgeon, restorative dentist, and technician cannot work independently from each other. After completion of treatment, it is the restorative dentist who will receive all the complaints and problems if there is no understanding among team members. The creation of a functional and cosmetic prosthesis that satisfies the patient requires complete interdependence between the team members. The use of fixed provisional prostheses enables the team to create the desired esthetics and function. The patient will retain and preserve the second-stage provisional prosthesis after insertion of the definitive prosthesis in case there is a need for repairs or if an implant is lost or added at a later stage. It is the fail-safe mechanism that prevents the patient from ever going without teeth.

Summary

The team approach to implant dentistry is most prominently noted when everyone collaborates in the diagnosis and treatment planning, fabrication of fixed- and second-stage provisional prostheses. This becomes most evident when an entire arch of a maxilla and a mandibular reconstruction is done sequentially, so that the patient is never without teeth and he or she can function from the day of surgery without any interruption in lifestyle. The authors have described the rationale and technical steps required from the treatment planning phase, the use of cemented first-stage provisional prostheses and the fabrication and use of a retrievable second-stage provisional prosthesis.

Disclaimer

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**Manufacturers**

Alvelogro, Snoqualmie, WA 888.268.3286, www.alvelogro.com
Hygienic Corp., Akron, OH 800.321.2135, www.hygieniccorp.com
Ivoclar Vivadent, Inc., Amherst, NY 800.533.6825, www.ivoclarvivadent.us
Nobel Biocare, Yorba Linda, CA 800.993.8100, www.nobelbiocare.com
Zahn Dental, Melville, NY 800.496.9500, www.hennyschein.com
3M ESPE, St. Paul, MN 888.364.3577, solutions.3m.com
Preparing fixed partial denture abutments such that they provide a path of placement free of undercuts

John Mamoun, DMD

The abutments of a fixed partial denture (FPD) should provide a path of placement, so that the denture may be seated onto the abutment without the tooth structure blocking the margin or intaglio surface. This article presents a literature review concerning the path of placement (also referred to as the path of insertion or the path of draw). In addition, the article presents clinical techniques for verifying an undercut-free path of placement for a prepared abutment and describes how to determine if a laboratory technician can fabricate a clinically acceptable FPD for an abutment that features undercuts within the path of placement. The article provides definitions of terms such as “path of placement” and “undercut” and explains concepts such as “parallelism of multi-unit fixed partial denture abutments.”

**The creation of a path of placement that is free of undercuts among the abutment(s) of a fixed partial denture (FPD) facilitates fabrication of an FPD that accurately fits the abutment(s) and seals the abutment margin(s).** This article defines the concept of an FPD undercut and provides a summary and a literature review of the concept of the crown or bridge path of placement. Other sources offer a comprehensive summary of the general criteria for shaping abutments prior to the placing of various FPD prostheses (including all-metal, all-ceramic, and porcelain-fused-to-metal).

An FPD undercut is a line segment on the axial surface of an FPD abutment, where one point of the line segment is located more occlusal than the other, such that the more gingival point appears to be more axially located compared to the more occlusal point; this line segment becomes visually apparent when the dentist attempts to view, with one eye closed, all points that are on a perimeter that is located slightly lateral to the outer perimeter of the margin of the abutment when using a set of visual axes for viewing the perimeter points such that all of those visual axes are of the same angle in three-dimensional space.

An abutment is undercut relative to a specified path of placement of an FPD that is made for that abutment while being seated onto the abutment. Two representative opinions on the definition of an FPD path of placement that appear in the dental literature define it as “the specific direction in which a prosthesis is placed on the abutment teeth or dental implant(s),” and also as “an imaginary line along which the restoration will be placed onto or removed from the restoration.”

The path of placement for an FPD may also be described as a set of parallel axes or directions. While an FPD is being moved onto its abutment(s) to the point where it seats onto the abutment(s), each atom (or element of mass) of the FPD moves in three-dimensional space along its own respective axis. The atoms of the FPD collectively move along multiple axes as the FPD is moved onto and is seated onto the abutment(s). Some of these imaginary axes pass longitudinally through the body of the abutment, while some pass slightly lateral to the outermost perimeter of the abutment’s margin(s). Since the axial aspect of an FPD is positioned lateral to the axial aspect of the abutment(s) when the FPD is seated on the abutment, it follows that the atoms of the axial aspect of the FPD must follow axes that are located slightly lateral to the axial aspect of the abutment(s).

Accordingly, an FPD path of placement is defined as a set of axes that are parallel in three-dimensional space, such that if each atom of an FPD, respectively, travels...
Along one of these axes within this set, then the FPD will seat onto its abutment(s); that is, the margin(s) of the abutment(s), and no tooth structures will obstruct complete seating of the FPD.

An FPD path of placement may be described mathematically using two parameters. One parameter is the location at the gingiva of the perimeter of the path of placement that circumscribes each respective abutment of the FPD. The points along the perimeter are the origin points of those axes of the path of placement that are positioned laterally to the axial aspect of the abutment(s). A second parameter is the angle in three-dimensional space of the axes of the path of placement. The common angle of the path of placement axes helps determine whether tooth structure obstructions will be present along the path of placement.

Typically, a dentist shapes a fixed partial denture abutment such that the perimeter of the path of placement that the abutment provides is located slightly lateral to the perimeter of the margin of the abutment at the gingiva. This is because an FPD seals the margin(s) of abutment(s), and its intaglio surface most closely hugs the axial walls of the abutment(s), when it can follow an obstruction-free path of placement such that the perimeter of this path of placement is located just lateral to the perimeter of the abutment margin(s).

When assessing if a path of placement is free of undercuts, the dentist views the abutment(s) and tries to locate a set of the visual axes, all parallel to one another, that allow the dentist to see all points that are located slightly lateral to the perimeter of the abutment(s) at the most apical aspect of the abutment(s), if the dentist viewed the margins using visual axes from this set. These axes would be parallel to the axes of the path of placement of the FPD made for the abutment(s). In other words, the dentist is visualizing how the intaglio surface of the FPD made for an abutment would move along this path of placement. When all such margin points are visible to the dentist, it means the abutment would be free of undercuts with that path of placement.

If the dentist cannot locate any set of visual axes that make it possible to view all points along the slightly lateral perimeter, then the abutment is undercut. By definition, an abutment “is undercut” when a dentist, after arbitrarily choosing the perimeter of the path of placement of this abutment to be located slightly lateral to the perimeter of the margin of the abutment at the most apical aspect of the abutment, cannot visualize a specific set of parallel axes that originate from points along this slightly lateral perimeter, such that an FPD with a margin perimeter that was the same as the perimeter of this path of placement, would not encounter obstructions located on the axial wall of the abutment(s), to its complete seating onto its abutment(s) if it moved along this set of parallel axes.

Interproximal tooth structure obstructions to seating an FPD along a path of placement

When an abutment is prepared next to an unprepared tooth that tilts toward the abutment, there should appear to be no overlap of the occlusal-interproximal line angle of the tilted tooth on the side of the unprepared tooth facing the abutment tooth, with the margin of the abutment on the side facing the tilted tooth, when the dentist views the abutment using visual axes parallel to the imaginary axes of a potential path of placement, the perimeter of which is “ideal” (that is, located slightly lateral to the perimeter of the abutment margin). If such overlap is visually apparent, the tilted tooth should be modified so that it does not obstruct the seating of an FPD and will achieve a more ideal embrasure space contour in this area.

The role of the dental laboratory in managing abutment undercuts

If a laboratory technician fails to notice and block out an undercut abutment, the wax pattern used to make the FPD may fill this undercut, which may result in an FPD with a protrusion on its intaglio surface, or with a margin that has an axial inclination which may prematurely contact the axial wall of the abutment and prevent complete seating of the prosthesis.

Evaluating the clinical acceptability of undercuts on FPD abutments

An abutment may feature a visually apparent but minor undercut that the dentist views the abutment using visual axes parallel to the imaginary axes of a potential path of placement, the perimeter of which is “ideal” (that is, located slightly lateral to the perimeter of the abutment margin). If such overlap is visually apparent, the tilted tooth should be modified so that it does not obstruct the seating of an FPD and will achieve a more ideal embrasure space contour in this area.

If a laboratory technician fails to notice and block out an undercut abutment, the wax pattern used to make the FPD may fill this undercut, which may result in an FPD with a protrusion on its intaglio surface, or with a margin that has an axial inclination which may prematurely contact the axial wall of the abutment and prevent complete seating of the prosthesis.
not block the view of any points along the abutment margin perimeter. The FPD can seat fully onto the abutment and seal the abutment margins, provided the undercut on the master cast is blocked out prior to fabricating the FPD. Microscopes may be necessary to detect the undercut on the master cast of the abutment and to confirm that the undercut has been blocked out. The intaglio surface of the FPD made for that abutment may not hug the axial wall of the abutment at the points where the blockout material was applied; however, the FPD may still seal the abutment margin completely and offer clinically acceptable retention.

**Paths of placement that feature undercuts contiguous with margins**

When the dentist views the abutment with a visual axis that is parallel with the path of placement, an undercut may block visibility of a point on the margin. The characteristics of such an undercut determine whether a clinically acceptable FPD can be fabricated.

Undercuts that block visibility of a point on the abutment margin also may block visibility of a point on the outer margin or the inner margin perimeter. All abutment margins have an outer margin perimeter. The inner margin perimeter consists of the perimeter or line angle formed at the intersection of the axial wall of the abutment and the most axial aspect of the horizontal component of the margin (Fig. 2). An abutment with either a knife edge or feather edge (a margin with an extremely minimal horizontal component)—or with no margin—will have an outer margin perimeter only. If an abutment has a margin with a horizontal component—such as a chamfer or a shoulder margin, where the axial wall of the abutment extends gingivally to the margin and continues horizontally along the chamfer or shoulder to the outer edge of the abutment—it will also have an inner margin perimeter.

**Undercuts on margins of abutments with no horizontal margin component**

For an abutment margin that has no horizontal component to be free of undercuts when viewed along a candidate path of placement, the complete outer perimeter of the abutment at the level of the margin must be fully visible to the dentist using visual axes that are parallel with the axes of the potential path of placement.

If an abutment margin has no horizontal component, and the abutment appears to have an undercut that blocks visibility of a point on the outer perimeter of the margin, a dental laboratory technician may attempt to block out the undercut and extend the margin of the FPD gingivally to the vertical level of that point. However, the resulting FPD that is fabricated for that abutment may not completely seal the outer perimeter of the margin at that point and may be clinically unacceptable (Fig. 3). Alternatively, the lab technician may create an FPD margin that is superior to that undercut. The FPD may be clinically acceptable if it fits snugly on the abutment, seals the entire abutment along the prosthesis margin, and features a sufficient amount of ferrule coverage and aggregate retention. There may be some exposed tooth structure inferior to the fixed prosthesis margin at the undercut point, but it may be convex enough that it doesn’t constitute a gap or result in a future plaque trap.

**Undercuts on margins of abutments with a horizontal margin component**

Both the outer and the inner perimeters of the margin should be fully visible when the dentist views the abutment. If the abutment has an undercut that blocks visibility of a point on the inner perimeter of the margin (Fig. 4), a laboratory technician may be able to block it out on a cast of the abutment, so that the resulting FPD can still fully seal the outer perimeter of...
the margin. Such an FPD may be clinically acceptable.

If an abutment has a margin that has a horizontal component, and the abutment has an undercut that blocks visibility of a point on the outer perimeter of the margin (Fig. 5), a laboratory technician would not be able to fabricate an FPD that could fully seat onto its abutments by moving along the ideal path of placement. Instead, the laboratory technician would need to add blockout material to the master cast of the abutment, expanding the perimeter of the FPD’s path of placement beyond the range of this undercut (Fig. 6). The resulting FPD would have a margin perimeter wider than the margin perimeter of the abutment, and may not seal the margin of the abutment at the point where the blockout material was applied to a degree that would be clinically acceptable.

Alternatively, the technician may finish the FPD margin so that the margin was superior to that undercut point. However, the horizontal component of the margin inferior to that point would become an exposed ledge of margin surface and could become a clinically significant plaque trap, which may result in a clinically unacceptable FPD.

**Verifying a single-unit FPD path of placement**

To verify that a path of placement for a single unit FPD is free of undercuts, the dentist must view the abutment and try to find a visual axis that allows the dentist to view the entire perimeter of the abutment margin (Fig. 7).

This method of verifying a path of placement free from undercuts only works if the abutment of the FPD is tapered enough to allow a dentist to view its entire margin using a single viewing axis. However, if the abutment has a minimal taper or is a perfect cylinder, the dentist may not be able to locate a single viewing axis with complete visibility of the margin(s). Instead, the dentist must verify the visibility of all points along all margin perimeters using multiple visual axes, all of which must be at the same angle in three-dimensional space. When all margin points are visible on parallel viewing axes, the abutments provide a path of placement free from obstructions.

Dentists shape the abutments of an FPD so that the axial wall of the abutment converges from the gingival to the occlusal direction; however, the axes of the path of placement are parallel to one another, forming a cylinder that circumscribes the tapered abutment (Fig. 8). The side of this cylinder does not necessarily form a right angle with the base, particularly if the abutment is tilted.

To view each respective path of placement axis so that the dentist is viewing the axis parallel to the path of placement that the axes form, the dentist must view each path of placement axis, respectively, using a visual axis that is 180 degrees with respect to that axis. In this viewing perspective, all points of the line segment that make up that axis appear to be superimposed onto each other, so that the axis appears to be a point instead of a line segment (Fig. 3).

The dentist must view all axes from the same angle as the one used to view the first axis, so that the other axes appear to be points in the same perspective.
If the dentist views all imaginary axes of the path of placement using the same angle of viewing, so that each individual axis appears as a point when it is viewed, and such viewing enables the dentist to see all points along the margin perimeters of all abutments, then the abutment(s) will provide a path of placement that is free of undercuts for the FPD that will be made for the abutment(s). This is the general way of verifying that an abutment(s) provides an undercut-free path of placement for a future FPD (Fig. 3).

Verifying the existence of a multi-unit FPD path of placement
To verify that a path of placement free of undercuts exists among multiple abutments of a multi-unit FPD, the dentist first must be able to identify a path of placement for each individual abutment of the multi-unit FPD. That is, for each individual abutment, the dentist must be able to locate a visual axis such that the entire margin of the abutment is visible when the dentist views this abutment along this visual axis. In addition, the dentist must be able to identify a set of such individual visual axes, such that all of those individual visual axes are parallel to one another. That is, the dentist must be able to sense intuitively that all of the visual axes within this set of axes intersect a single imaginary plane in three-dimensional space at the same angle.

Dentists commonly state that a path of placement for a multi-unit FPD exists when a dentist determines that its abutments “are parallel with one another."1,3,6-9 The author believes that there is some ambiguity in conceptualizing how abutments, which are essentially conical shapes that converge in a gingival-occlusal direction, can be “parallel” with one another. More precisely, to establish the existence of a multi-unit FPD path of placement, what must be parallel are the respective visual axes of each abutment so that the entire margin of each abutment is visible when the dentist views each abutment along its respective visual axis.1

Basic clinical technique for verifying a path of placement for a multi-unit FPD
When using direct vision to assess if a path of placement exists among the abutments of the multi-unit FPD, the dentist finds a visual axis that allows the dentist to completely see the margin of the first abutment. The dentist then must keep his or her eye steady so as to continually look along a visual axis that is parallel in three-dimensional space with the axis used to view the first abutment.1,6 While keeping the eye steady, the dentist moves his or her head in a direction that is parallel with the imaginary plane that intersects with the visual axis used to view the first abutment. When the second abutment comes into view, the dentist will hopefully be looking at it using a visual axis that is parallel with the one used to view the first abutment, so that the second visual axis intersects the same imaginary plane as the first visual axis intersects at the same angle of intersection. If the margins of the second abutment are
Preparing FPD abutments such that they provide a free path of placement

are also fully visible, with both visual axes that were used to view the abutments being parallel with each other, then the abutments are aligned with a single path of placement.

Examining a final impression of the abutments is another way to verify a path of placement for a multi-unit FPD. The dentist examines an impression of one preparation (with one eye closed) and turns the impression until discovering a visual axis that makes it possible to see the entire surface of the axial wall of the preparation as it appears in the impression. No point along the axial wall should appear to be more axially located compared to a point directly occlusal to it. While maintaining the angle of the visual axis used to view the first preparation, the dentist moves the impression along an imaginary plane until the next preparation comes into view. If the second preparation appears to be free of undercuts, the dentist continues to move the impression parallel to the same imaginary plane until the other preparations come into view. A path of placement exists among the abutments when no point along the impression of the axial aspect of the abutment(s) appears to be more axially located compared to a point located directly occlusal to it. Impression material that flowed sub-gingivally past the margins of the abutments, which is known as “flash,” appears in the final impression to curl in an axial direction. However such flash is not part of the impression of the axial aspect of the abutment.

Sometimes, a well-made provisional restoration can have an intaglio surface that is precise enough to verify that there are no undercuts in the path of placement provided by the abutments.1,2 If any obstructions remain after removing excess material from the interproximal aspects of the provisional restoration, the abutment should be examined again for undercuts.

During the preparation appointment, an impression of the abutments can be made (using fast-setting plaster or a polyvinylsiloxane material designed for casting chairside models) to create a physical model of the abutments.1,2 The physical model can be assessed for undercuts; in addition, a digital scan of the abutments can be used to create a virtual computer model of the abutments.

**Optimizing the ability to verify a path of placement**

As mentioned previously, the dentist should always have only one eye open when assessing if an abutment(s) provides an undercut-free path of placement for a future FPD.1,2 If both eyes were open (stereoscopic vision) and one eye saw a part of the margin that the other eye did not see, the brain may mentally combine the viewpoint of both eyes and see the entire margin; as a result, the dentist may not notice a preparation with an actual undercut. Viewing the preparation with only one eye allows the dentist to confirm a path of placement for an abutment for which the entire margin is visible.

In addition, the dentist can view the abutment while drying it with high-volume evacuation suction. Otherwise, air bubbles from liquids (or refraction of light through the liquid that wets the abutment) can obstruct or distort views of the abutment margin or axial wall. The dentist should use front-surface mouth mirrors to view abutment margins. Non-front-surface mirrors—that is, where the reflecting surface of the mirror is not external but is covered with a thin transparent layer of glass or plastic—can show a double-image of the object at certain angles. This distortion may prevent clear visibility of abutment margins when margins are viewed at microscope-level magnification.

Large intraoral mouth mirrors may be helpful for capturing images of multiple abutments in a single mirror view.6 The wide mirror functions as a viewing plane and helps to ensure that the visual axes that the dentist uses to view the multiple abutments intersect with a single imaginary plane at the same respective angles.

When assessing multiple posterior maxillary abutments for a path of placement, dry angles placed on the buccal mucosa prevent it from drooping over the mouth mirror and blocking the view of the abutment margins. Dry angles also improve the dentist’s ability to retract the buccal mucosa with passive force, using the edge of a mouth mirror. In the event of resistance to the placement of the mouth mirror, pushing against the resistant cheek muscle may shift the mouth mirror off the imaginary plane used to view the initial abutments.10

Microscope-level magnification (6-8X magnification or more) allows a dentist to detect microscopic undercuts within individual abutments that hinder alignment of multiple abutments with a single bridge path of placement. Microscopes allow a dentist to detect undercuts in crown abutments that might appear foreshortened in the viewing axis. Magnification improves a dentist’s ability to sense tiny deviations in the visual axis of their eye or in the translational movement of their head when the dentist is observing multiple abutments to determine if they are aligned with a single path of placement. Such tiny inadvertent movements of the dentist’s eye or head, microscopic in scale, can alter the eye’s visual axis so that...
the current visual axis is no longer parallel with the visual axis used previously to view other aspects of the abutment margins. Magnification is also useful for sensing deviations when the dentist uses indirect vision (that is, viewing through a mouth mirror) to assess the alignment of multiple abutments with a single path of placement.

When examining a final impression of the abutments for the presence of undercuts, use of microscope-level magnification helps in distinguishing between the perimeter of the abutment margin and impression flash from material that may have flowed past the margin during the impression process. Microscope-level magnification improves a dentist’s ability to tell intuitively if the impression has inadvertently moved on the imaginary reference viewing plane. A dentist with unaided vision may be able to shape abutments so that they provide an unobstructed path of placement, but he or she will need excellent visual acuity to detect any microscopic undercuts in a potential path of placement. A dentist using unaided vision can prepare the axial walls of abutments using tapered torpedo-shaped diamond burs that cut into the axial wall with a pre-set minimum depth cut, creating an axial wall that has sufficient depth of cut and taper to verify that the abutment is free of visually apparent undercuts along the path of placement. However, it may be difficult to evaluate preparations with minimal taper.

The use of head-mounted illumination ensures that all aspects of the abutment’s axial walls and margins will be illuminated simultaneously while the dentist views them with visual axes that are parallel to the axes of the potential path of placement. Unlike head-mounted illumination, coaxial illumination helps to ensure that shadows will only appear on those parts of the axial wall that have undercuts.

Maintaining an FPD’s path of placement

Of course, once an FPD path of placement is created, the alignment of the abutments must be captured with an accurate impression, from which the dental laboratory must make accurate master casts. Dimensional distortions in the impressions or the master casts may result in a discrepancy between the perimeter of the path of placement on the model of the abutment and that found in the actual abutment. This discrepancy may result in an FPD made for a path of placement that does not exist intraorally.

In addition, a provisional restoration cemented with a strong cement such as polycarboxylate or glass ionomer helps to ensure retention and that the abutments will not shift during provisionalization. On the day the FPD is inserted, the provisional FPD may have to be sectioned and an ultrasonic scaler used to remove the cement from the abutments.

Summary

If an abutment provides a path of placement that is free from undercuts, and an FPD made for that abutment moves along that path of placement, the FPD margin will vertically reach the level of, and seal, the abutment margins. In addition, the FPD made for that abutment will closely hug the abutment walls.

It may be difficult to verify that there are no infinitely small undercuts in an abutment path of placement. However, it is not necessary to verify that a path of placement is free of infinitely small undercuts, as long as any undercuts that are present are so small that a laboratory technician can block them out and still fabricate an FPD with clinically acceptable retention and seal.

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References

The impact of obesity on prosthodontic treatment

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Obesity has become a worldwide epidemic and an increasing public health concern that has a negative impact on both overall systemic and oral health. At the same time, the need for prosthodontic treatment has increased and has been projected to be more in demand in the future. It has also been predicted that the need to provide prosthodontic treatment to an increasing number of obese patients may become routine. However, delivering prosthodontic treatment to obese patients may be a challenge due to their anatomy, physiology, and physical characteristics. It is important to recognize the potential comorbidities and assist patients in seeking necessary help. It may be necessary to modify hardware, equipment, techniques, treatment positions, and/or prosthodontic protocols to ensure that these patients receive the proper care and avoid unforeseen complications. An obese patient with a compromised medical history and complex dental status may be managed best by a multidisciplinary team approach.

Obesity is defined as abnormal or excessive fat accumulation that may impair health. It develops from an imbalance between energy intake and expenditure that is affected by genetic, environmental, and psychosocial factors. The World Health Organization (WHO) recommends body mass index (BMI) as a means of measuring and categorizing obesity for adult men and women. BMI is calculated by dividing a patient’s weight (kg) by square of their height (m²). A patient with a BMI ≥25 kg/m² is classified as overweight, whereas a BMI ≥30 kg/m² is defined as obese.

Obesity has become an epidemic in many developed and developing countries, and its prevalence is increasing globally. Since 1980, the prevalence of obesity has more than doubled in North America, United Kingdom, Eastern Europe, Middle East, Pacific Islands, Australia, and China. In 2005, it was determined that 9.8% of the world’s adult population (approximately 396 million people) was obese. That number increased to more than 500 million adults in 2008; it has been projected that 1.12 billion individuals will be obese by 2030.

The United States has the highest obesity index among high-income countries. Between 2003 and 2010, the prevalence of obesity in the U.S. adult population increased from 32% to 37.4%. If this trend continues, 51.1% of U.S. adults will be obese by 2030. Within the U.S. population, obesity is prevalent among the baby boom generation (people born between 1946 and 1965), who became obese at younger ages compared to their predecessors. The impact of this generation’s obesity on the health care system is tremendous. The forthcoming surge of obesity predicted for older adults over the next three decades will lead to potentially higher obesity-related comorbidities and a higher demand for age-related health care treatment.

It has been projected that the demand for prosthodontic treatment will exceed the available number of providers by 2020; this unmet need for prosthodontic treatment will continue to increase as the baby boom generation matures, despite an estimated decline in the age-specific rates of edentulism. With the high prevalence for obesity in the U.S. and its continued epidemic trends, it can be assumed that prosthodontic treatment for obese patients will become more prevalent. As a result, it is important to understand the topic of obesity, its effects on systemic and oral health, and its consequent implications for prosthodontic treatment. Due to the complex nature of prosthodontic treatment, oral health care professionals should understand diagnosis, treatment planning, and management of obese individuals. This article provides an overview of the effect of obesity on systemic and oral health, and discusses how obesity could affect prosthodontic treatment.
Effect of obesity on systemic health

Comorbidities

The impact of obesity on health care is enormous and cannot be overlooked.\(^2,3,14-18\) Based on the potential differences in anatomy and physiology, evidence suggests that obese individuals are of a different cohort compared to the normal-weight population.\(^14\)

Obesity is related to a number of chronic diseases, including type 2 diabetes, cardiovascular diseases, certain type of cancers (endometrial, breast, prostate, colon), and sleep-breathing disorders.\(^14,19-26\)

Obesity also is associated with health-related risk factors such as high cholesterol levels and asthma.\(^22\) As a result, obese patients are predisposed to comorbidities and increased complications in overall systemic and oral health.\(^14\)

To provide the most appropriate care for this cohort of patients, it may be necessary to modify existing treatment protocols.

Arthritis

Obesity has been identified as a strong risk factor for arthritis, the most common cause of physical disability in the United States.\(^10,27\)

Between 2007 and 2009, one in five U.S. adults reported doctor-diagnosed arthritis.\(^28\)

Osteoarthritis (OA), the most common type of arthritis, was the fourth most frequent cause of hospitalization in 2009 and the leading indication for joint replacement surgery.\(^29,30\) Clinical OA includes pain, acheing, or stiffness affecting hand, knee, or hip joints, which may limit physical activities.\(^31\) Obesity is strongly linked to OA of the knee, and has been attributed to an increasing need for knee and hip joint replacement.\(^32,33\)

Gastroesophageal reflux disease

Gastroesophageal reflux disease (GERD) is a common gastrointestinal disorder affecting 15% of the U.S. population weekly and 7% of this population daily.\(^34\)

Reflex occurs when the lower esophageal sphincter (LES) relaxes and cannot prevent fluid or solid matter from returning to the cervical esophagus, pharynx, or the oral cavity. Risk factors for GERD include hiatal hernia, pregnancy, and obesity.\(^35\)

Obesity is associated with increased LES relaxation, postprandial gastroesophageal reflux, and esophageal acid exposure. The frequency of transient LES relaxation is correlated with increases in BMI and waist circumference.\(^36,37\)

There is a positive association between GERD and increased BMI.\(^38\) Individuals with a BMI ≥30 have approximately twice the risk of having GERD compared to those with a normal (<30) BMI.\(^39\)

Obese individuals are more likely to experience hiatal hernias, which contribute to GERD symptoms.\(^40,41\)

Obstructive sleep apnea

Obese individuals are more prone to develop obstructive sleep apnea (OSA) than their normal-weight counterparts.\(^42\) OSA is defined as an interruption of normal sleep patterns. The most common clinical signs of OSA include a large neck circumference, a retrognathic mandible, an excessive amount of fat deposition in the palate, an enlarged tongue and pharynx, a long soft palate, tonsillar hypertrophy, a wider dental arch, nasal septum deviation, narrow velopharyngeal airways, and adipose tissue in the upper body.\(^42-45\)

Common signs and symptoms associated with OSA involve xerostomia, GERD, depression, and drooling.\(^46\) A high number of comorbidities (such as hypertension, depression, and stroke) are related to untreated or undiagnosed OSA.\(^46\)

Wound healing and bone mineral density

Obese patients are prone to a higher incidence of postsurgical wound dehiscence, drainage, and infection.\(^37-47\) Many of these complications may be due to impaired immune response, subtherapeutic pharmacokinetic mechanism, increased susceptibility to infection, and impaired wound healing.\(^48-62\)

Wound healing is a multifactorial process, which involves complex biological interactions.\(^58,63,64\) Hypovascularity and hypoperfusion have been associated with delayed wound healing and a decreased ability to combat infection.\(^56,66\)

Predisposing factors associated with obesity complicate the healing process, suggesting a poor outcome for wound healing in this subset of the population.\(^48,49,56,59,65\)

The direct relationship between obesity and bone mineral density (BMD) is controversial.\(^66-70\) Obesity can have a detrimental effect on bone and has been shown to adversely influence the cortical bone structure and strength.\(^57,59,62,67,70-72\)

Obese individuals have lower BMD and bone mineral content relative to their weight compared to normal-weight individuals.\(^66,68\) Relatively low bone strength index implies reduced capacity to withstand mechanical load and increases the risk for fracture.\(^59,67,72\)

Effect of obesity on oral health

Anatomy

Administering dental treatment to obese individuals may prove challenging due to the physical characteristics associated with these patients, notably the increased...
mandibular length, shorter upper face height, and increased total facial height. These patients tend to have decreased oral openings; additional amounts of oral soft tissue; short, thick necks; and excess tongue volume.

Xerostomia and dental caries
Pharmacological treatment of comorbidities associated with obesity may lead to some oral side effects. For example, xerostomia can result from many antidepressant medications prescribed for OSA-related depression or from the application of some types of nasal continuous positive airway pressure (CPAP).

Both obesity and dental caries are multifactorial diseases and both are related to the individual’s dietary habits. The literature suggests a positive relationship between sugar-sweetened beverage intake and weight gain which may also contribute indirectly to caries development. Some studies have shown an increased prevalence of dental caries in obese young adults and the elderly population. In addition, data from the third National Health and Nutrition Examination Survey demonstrated a correlation between the decayed missing filled teeth (DMFT) score and both BMI and waist-to-hip ratios among an adult population.

Periodontal health
The literature has reported significant associations between obesity and periodontal disease. It has been suggested that obesity is a second risk factor (following smoking) for inflammatory periodontal tissue destruction; in addition, obesity has been associated with increased clinical attachment loss and deeper periodontal pocket depths.

According to the literature, the underlying biological mechanism connecting obesity and periodontal disease is adipocytokine and its destructive effect on periodontal tissue. Zeigler et al reported that the sum of bacterial cells in subgingival biofilm is higher among obese patients. Obesity has been shown to impair the immune system; such an impairment could result in increased alveolar bone loss after oral bacterial infections such as gingivitis and periodontitis. These data suggest that obesity is a significant predictor for periodontal disease.

Edentulism
Obesity is associated with an increased risk of partial and complete edentulism. Dental caries, medication-induced xerostomia, periodontitis, and tooth erosion are risk factors that may lead to premature tooth loss in the obese population. Some contributing causes of edentulism in obese patients may be that these patients tend to seek dental care irregularly, have higher dental anxiety, and have poor health-related quality of life.

In one Swiss population study, the highest waist-circumference quartile cohort had 19.7 teeth, compared to 21.5 teeth for their normal-weight counterparts. Consequently, the obese cohort was shown to require more dentures. In a nationwide survey of elderly people in Great Britain, individuals with less than 21 teeth were three times more likely to be obese.

Chewing ability
Partial edentulism is associated with poor oral health status among the obese, which may contribute to a poor dietary selection. Obese dental patients demonstrate poorer masticatory performance, longer chewing time, increased chewing cycles, and lower bite force. Obese patients tend to chew less when consuming meals and avoid harder foods in favor of softer foods, which may contribute to the obesity of the patient.

Oral wound healing
Obesity also has been associated with surgical and post-surgical complications in dentistry, including difficulty during third molar extractions and increased postsurgical extraction complications. In addition, predisposing factors associated with obesity complicate the healing process, suggesting a poor outcome after surgical extraction in this population.

Effect of obesity on prosthodontic treatment
Technique and hardware
The anatomical and physiological makeup of obese individuals may pose a challenge to delivering dental treatment. For instance, a standardized blood pressure cuff may result in a false positive reading for an obese individual. To provide an accurate reading, the width of the blood pressure cuff should be more than one-third the length of the upper arm circumference. In addition, a standard dental chair or operator unit may not be suitable for obese patients. Armless treatment chairs and armless waiting room chairs have been recommended to accommodate these individuals.

Positioning an obese patient in a dental chair may prove challenging due to their physical attributes, as their neck may not extend fully. Dentists should exercise caution when placing these patients in a supine or recumbent position, which may predispose airway obstruction, hypoxemia, and intensified metabolic requirements leading to fainting or dizziness after long periods of time in a supine position. Modifications may be necessary to ensure that
these patients are comfortable in the dental chair. Providers may also need to maintain good posture when treating obese patients in modified chair positions. Prosthodontic procedures involving full mouth rehabilitation usually are lengthy and require multiple appointments.

The physical characteristics of obese patients may limit visibility of and access to anatomical landmarks when administering local anesthesia and performing certain extraoral examinations (for instance, palpating lymph nodes in the head and neck region). Prosthodontic treatment examinations (for instance, palpating lymph nodes in the head and neck region). Retracting increased soft tissue mass and thick cheeks with a normal size mirror may prove challenging for oral health care providers.

**Prosthodontic treatment**

Obese complete dentate, partially or completely edentulous patients with or without additional medical conditions may be classified as Prosthodontic Diagnostic Index Class III or Class IV categories. These patients typically present challenges due to their physical characteristics and possible comorbidities; as a result, they may be best managed by a prosthodontist when complex care is required. This process includes diagnosis, treatment planning, and potential surgical and restorative procedures, as well as maintenance or recall. The thick cheeks and enlarged tongue found in some obese patients may impede certain prosthodontic procedures, such as crown preparation and impression making, and also may predispose this cohort to a smaller neutral zone for teeth arrangement when fabricating complete dentures. Establishing borders for removable dental prostheses and fabricating a final impression can be difficult because of the smaller opening in the oral cavity, large soft tissue mass, and poor visibility and accessibility in the posterior region.

Caries, periodontitis, medication-induced xerostomia, and tooth erosion are common risk factors among obese patients that could lead to partial or complete edentulism. Successful prosthodontic treatment depends on early diagnosis of xerostomia, knowledge of its causes, and proper management. To reduce the risk of further caries development, frequent water consumption, xylitol use, artificial saliva products, fluoride application, and calcium phosphate mouth rinses have been recommended.

At the initial treatment planning phase, dentists should recommend dietary counseling and assist patients in seeking help (when necessary) for obesity and its comorbidities. It is important for dentists to understand the consequences of obesity on overall dentition and provide proper prosthodontic treatment for these patients to regain function and improve their nutritional intake. Multiple factors (such as a patient’s medical history, dental needs, and potential obesity-related risks) should be considered carefully to avoid unforeseen complications. A well-planned treatment sequence and a multidisciplinary team approach may be required to ensure proper management.

Prosthodontic treatments often involve surgical procedures, such as extraction, periodontal surgery, or implant placement. Surgical protocols may need to be modified to minimize complications during the healing period. Obesity is associated with a complicated healing process and poor postsurgical outcomes. A 2007 study reported that the total amount of time required for extraction increased in patients with higher BMI. The intrasurgical procedure time should be planned beforehand, and the patient should be monitored for postsurgical complications. Longer healing time may be necessary for this cohort due to their anatomical, biological, and physiological differences, and their greater prevalence for comorbidities; in addition, medications and doses should be selected carefully. Recommended pharmacological agents are easily titratable, have a short length of action, and are not distributed to fatty tissues. Modified protocols to avoid the risk of overdose may need to be established when prescribing a weight-based medication dosage for this cohort.

Obese patients with arthritis tend to have a higher prevalence of xerostomia, which can lead to the development of caries, periodontal diseases, and lesions in the oral mucosa. According to Pokrajac-Zirojevic et al, patients with OA or rheumatoid arthritis (RA) are less likely to visit dental professionals than their nonarthritic counterparts. As a result, dental procedures for OA and RA patients are more likely to involve extraction and prosthodontic treatment. According to Laurell et al, patients with RA tend to have less satisfactory function of removable dental prostheses (usually due to unstable impaired occlusion) compared to their normal-weight counterparts. OA patients whose hands are symptomatic of the condition may have difficulty performing daily oral hygiene or even maintaining a prosthesis. A more frequent recall program may ensure the proper function of the dental prostheses and should resolve any unforeseen complications among these patients.

For obese patients with GERD symptoms, acid reflux into the oral cavity can lead to chemical tooth erosion.

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differs from attrition in that one may observe the loss of tooth structure not only on the occlusal/incisal surfaces of the teeth, but also on the buccal and lingual surfaces. Individuals who experience symptoms of vomiting one or more times a week, heartburn, belching, pain on awakening, an acid taste in the mouth, or stomach pain are 31 times more likely to experience dental erosion than those who do not.137 To ensure the lasting durability and high survival rate of a prosthesis, it is essential to select the most suitable dental materials for this population.

For obese patients with OSA, the most common treatment involves using oral appliances for mandibular advancement. However, occlusal changes (such as posterior open bite and altered incisor position) have been observed when using these appliances.44 When fabrication of an occlusal appliance is indicated, the prosthodontist may be the best person to manage and actively monitor these patients for any changes in occlusion.

Multidisciplinary team approach

The health care professional may need to manage obese patients through a multidisciplinary team approach (medical doctors and dental specialties) in order to choose the best manageable prosthodontic treatment. It is important to diagnose comorbidities associated with obesity (such as arthritis, GERD, and OSA) early and refer these patients to intervention programs through medical professionals, such as dietary counseling for weight loss and other lifestyle modifications.138 For example, when severe erosion is observed in GERD patients, dental rehabilitation should be postponed until the acid reflux has been treated medically. Patients with severe erosions require a multidisciplinary approach to dental rehabilitation, which may require endodontic and periodontic therapy in addition to prosthodontic treatment.

Treatment for OSA should be based on the recommendation of the physician. Some suggested treatments for OSA involve appliances, including CPAP appliances to maintain upper airway flow during sleep and/or oral appliance therapy, which usually involves mouth guards or modified retainers.139,140 Surgical treatments such as uvulopalatopharyngoplasty (either alone or combined with a genial advancement) or maxillomandibular advancement are both effective options.141-143 Dental surgical procedures, such as reflecting a flap, may prevent using a CPAP immediately postsurgery.139

Summary

The high prevalence of obesity and the increased demand for prosthodontic treatment in this patient population have several implications for the health care professionals. Treating obese patients in the everyday health care setting may become more routine. As a result, dental professionals should become knowledgeable about the effect of obesity on patients’ systemic and oral health. Dentists should be able to identify related risk factors during the diagnosis phase, and be aware of obesity’s implications when delivering prosthodontic treatment. Treatment protocols should be modified to ensure that these patients receive appropriate dental care. To ensure the proper function of the dental prostheses, both a frequent recall program and a rigid maintenance program (one which monitors optimal oral hygiene for this cohort) should be implemented. A multidisciplinary team approach is needed to ensure a more comprehensive rehabilitation for the obese patient population.

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Prosthodontics: The impact of obesity on prosthodontic treatment


Antimicrobial effect of three new and two established root canal irrigation solutions

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This study sought to assess the efficacy of two established and three relatively new root canal irrigants against five different microorganisms using the agar diffusion method. Sodium hypochlorite (NaOCl)-based irrigants demonstrated the most effective antimicrobial activity. Received: December 2, 2011
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The literature has shown that microorganisms are major contributors to the initiation and perpetuation of pulpal and periapical diseases. Enterococcus faecalis belongs to the genus Enterococci, which are Gram-positive cocci. E. faecalis plays an important role in the failure of root canal treatment. It occurs in persistent periradicular lesions nine times more frequently than in primary infections. Candida albicans is the most prevalent fungal species in the oral cavity. It occurs much more frequently in persistent root canal infections than in primary infections. The genus Actinomyces consists of a heterogeneous group of non-acid-fast, non-motile, non-spore-forming, obligately anaerobic, facultatively anaerobic Gram-positive rods.

Eliminating microorganisms from infected root canal systems is a complicated task that requires various instrumentation techniques, irrigation regimens, and intracanal medications. Mechanical instrumentation alone does not result in a bacteria-free root canal system; indeed, ex vivo and clinical evidence indicates that mechanical instrumentation leaves significant portions of the root canal walls untouched. Therefore, the use of an irrigation solution with antimicrobial activity is recommended.

Sodium hypochlorite (NaOCl) is the most commonly used endodontic irrigant for chemomechanical preparation of the root canal system, offering excellent antimicrobial activity against bacteria, fungi, and biofilms. Chlorhexidine (CHX) is another irrigant that is commonly used in endodontics. CHX is a cationic biguanide that appears to act by adsorbing onto the cell walls of microorganisms, resulting in leakage of intracellular components. Although studies comparing the antibacterial effect of CHX and NaOCl have produced somewhat conflicting results, it seems that when used in identical concentrations, their antibacterial effects ex vivo (in infected dentin) and in vivo (in the root canal system) are similar. Furthermore, CHX is an effective antifungal agent and its efficacy is significantly less than that of NaOCl.

Tetraclean (Oguna Laboratori Farmaceutici), like MTAD (Dentsply Tulsa Dental), is a mixture of an antibiotic (doxycycline), an acid (citric acid), and two detergents (propylene glycol and cetrimide); however, Tetraclean contains a different concentration of doxycycline (50 mg/mL) and different types of detergent (polypropylene glycol and cetrimide) compared to MTAD. A 2009 study reported that NaOCl and Tetraclean displayed very similar bactericidal activity against E. faecalis, while a 2007 article demonstrated that Tetraclean was more effective than MTAD against E. faecalis and polymicrobial biofilms.

Hypoclean (Idropan Dell’Orto Depuratori, SRL) is a new NaOCl-based endodontic irrigant composed of 5.25% sodium hypochlorite and two detergents. There are very few published studies regarding its antibacterial activity; however, Mohammadi et al demonstrated that Hypoclean offers substantivity for up to four weeks.

Given the paucity of studies regarding the antimicrobial activity of Tetraclean and the absence of studies on the antimicrobial activity of Hypoclean and Chlor-XTRA (Vista Dental Products), it was decided to assess the antimicrobial activity of these products against E. faecalis, C. albicans, A. israelii, Lactobacillus casei, and Pseudomonas aeruginosa using three concentrations of NaOCl (5.25%, 2.6%, and 1.3%) and two concentrations of CHX (2.0% and 0.2%). Chlor-Xtra contains a wetting agent, proprietary surface modifiers, and alkylating agents.

Most of the microbial strains chosen for the present study were relevant because they are a part of the endodontic microflora.
Materials and methods
Overnight cultures of microorganisms were grown on brain-heart infusion (BHI) agar plates (Becton Dickinson & Company). Petri dishes containing Muller-Hinton (MH) agar were prepared for all microorganisms except for A. israelii and C. albicans. Brucella agar (Oxoid Microbiology Products) supplemented with 5% defibrinated sheep blood, 1% vitamin K, and 0.5% hemin was used to grow A. israelii, while Sabouraud dextrose agar was used to assess the efficacy of irrigants against C. albicans.

A total of 150 plates were divided into five groups, one for each of the microorganisms tested (n = 30). Thereafter, each group was divided into eight subgroups according to the irrigation solution used. Three paper disks were placed in each plate. Antibacterial susceptibility blank test disks (6 mm in diameter) were soaked with 30 µL of the test solutions (1.3%, 2.6%, and 5.25% NaOCl; 0.2% and 2% CHX; Tetraclean; Hypoclean; and Chlor-XTRA) and stored at 4°C until use. The disks were placed on plates stored for one hour at 4°C, then incubated for 48 hours at 37°C. Using a transparent ruler, zones of inhibition were measured across two diameters (perpendicular to each other) and recorded. The tests were repeated five times for all isolates, and the means were then calculated. Data were analyzed using a Kruskal-Wallis test; in addition, a post hoc test was used for multiple comparisons between different groups.

Results
NaOCl-based irrigants demonstrated the most effective antimicrobial activity, and the 5.25% NaOCl solution was the most effective irrigant against E. faecalis (P = 0.012). Hypoclean was the most effective irrigant against C. albicans, P. aeruginosa, and L. casei (P = 0.009), while Chlor-XTRA was the most effective solution against A. israelii (P = 0.009). The complete results are listed in Tables 1 and 2.

Discussion
The agar diffusion test is a well-established, simple method for studying the antimicrobial activity of root canal irrigants. The antibacterial activity of each root canal irrigant is dependent on its diffusion into agar. However, there are several disadvantages to the agar diffusion test. First, it is impossible to distinguish between the agents’ microbiostatic and microbicidal properties; in addition, the results are easily affected by diffusion of the materials across the medium. Other
factors that could affect the results include good contact between test material and agar, inoculum size, and incubation time. However, if these factors are controlled precisely, compatible and repeatable results can be achieved.13-16

Few studies have been conducted to determine the antimicrobial activity of the recently developed NaOCl-based irrigation solutions (Tetraclean, Hypoclean, and Chlor-XTRA) used in the present study. In 2010, Pappen et al investigated the antibacterial effect of several products against Enterococcus faecalis and discovered that Tetraclean and MTAC-2 (a variant of MTAD in which the detergent is replaced by 0.1% CTR) killed planktonic E. faecalis in less than 30 seconds.17

Two years earlier, Neglia et al evaluated in vitro the efficacy of NaOCl and Tetraclean against E. faecalis, and found that Tetraclean was at least as effective as NaOCl in its antibacterial activity.18 In an ex vivo tooth model, the same authors found that only the teeth irrigated with Tetraclean saw a gradual decrease in bacteria; no bacteria were detectable three days post-irrigation. For the teeth irrigated with NaOCl, the drop in the bacterial burden was rapid but temporary, and 70% of the teeth were re-colonized within 48 hours post-irrigation. The residual antibacterial activity of Tetraclean has been shown to last for up to four weeks.18

In 2011, Mohammad et al demonstrated that Hypoclean offered significantly lower residual antibacterial activity compared to Tetraclean.12 However, there have been no studies regarding the antibacterial activity of Chlor-XTRA.

In the present study, the 1.3% NaOCl solution was the least effective irrigant against A. israelii, while the 0.2% CHX solution demonstrated the weakest antimicrobial activity against four (E. faecalis, C. albicans, L. casei, and P. aeroginosa) of the five tested microorganisms. This finding is not surprising, as most studies recommend a 2% concentration of CHX to irrigate the root canal system.9

There is no consensus regarding the antibacterial activity found in different concentrations of NaOCl. A 2000 study by Siqueira et al reported no differences in the antibacterial activity of 1%, 2.5%, and 5% NaOCl.19 Four years later, Vianna et al reported that five concentrations of NaOCl (0.5%, 1%, 2.5%, 4%, and 5.25%) all eliminated Porphyromonas endodontalis, Porphyromonas gingivalis, and Prevotella intermedia within 15 seconds.20

Other studies have reported that the antibacterial activity of NaOCl depends on its concentration. Berber et al found that a 5.25% concentration was the most effective solution, followed by a 2.5% concentration, while a 0.5% concentration provided the weakest antibacterial activity.21 According to a 2001 study by Gomes et al, there is an inverse relationship between the concentration of NaOCl and the time required to kill microorganisms.22

**Conclusion**

Within the limitations of the present study, 5.25% NaOCl and Hypoclean were the most effective irrigants against the microorganisms tested. Furthermore, 0.2% chlorhexidine solution demonstrated weakest activity against all tested bacteria.

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Dentsply Tulsa Dental, Tulsa, OK 800.662.1202, www.biopuremtad.com
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Ogna Laboratori Farmaceutici, Muggio, Italy 39.039.278.2954, www.ognalaboratori.it
Oxoid Microbiology Products, Basingstoke, Hampshire, United Kingdom 44.0.1256.841144, www.oxid.com
Vista Dental Products, Racine, WI 877.418.4782, www.vista-dental.com
Exercise No. 318  
**Endodontics**

Subject Code 070  
The 15 questions for this exercise are based on the article *Antimicrobial effect of three new and two established root canal irrigation solutions* on pages 534-537. This exercise was developed by Merlin Ohmer, DDS, FAGD, in association with the General Dentistry Self-Instruction committee.

Reading the article and successfully completing the exercise will enable you to:
- understand the efficacy of various root canal irrigants;
- decide which irrigant to use in clinical practice; and
- understand the various root canal irrigants available for use.

1. Which of the following irrigants has been shown to have residual antibacterial activity for up to four weeks?
   - A. MTAD
   - B. HypoClean
   - C. Chlor-XTRA
   - D. Tetraclean

2. 1.3% Sodium hypochlorite (NaOCl) is the least effective antimicrobial agent against
   - A. A. israelii.
   - B. E. faecalis.
   - C. L. casei.
   - D. C. albicans.

3. The root canal system is easily cleaned and disinfected with thorough instrumentation. Disinfection is easy to accomplish.
   - A. Both statements are true.
   - B. The first statement is true; the second is false.
   - C. The first statement is false; the second is true.
   - D. Both statements are false.

4. *Actinomyces* have all of the following characteristics except one. Which is the exception?
   - A. Non-motile
   - B. Non-spore forming
   - C. Acid-fast
   - D. Rod-shaped

5. The most commonly used root canal irrigant is
   - A. sodium hypochlorite.
   - B. CHX.
   - C. Tetraclean.
   - D. HypoClean.

6. CHX’s action is thought to be
   - A. penetration of the cell wall.
   - B. destruction of the cell wall.
   - C. allowing extra-cellular material into the cell.
   - D. allowing intra-cellular material out of the cell.

7. CHX is a more effective irrigant than sodium hypochlorite. It is effective against fungi.
   - A. Both statements are true.
   - B. The first statement is true; the second is false.
   - C. The first statement is false; the second is true.
   - D. Both statements are false.

8. Tetraclean is a commercial irrigant that contains which of the following ingredients?
   - A. Tetracycline
   - B. Minocycline
   - C. Doxycycline
   - D. Chlortetracycline

9. Specifically, how long were the agar plates incubated?
   - A. 12 hours
   - B. 24 hours
   - C. 48 hours
   - D. 72 hours

10. Which irrigant ingredient was the most effective antimicrobial agent?
    - A. CHX
    - B. Sodium hypochlorite
    - C. Antibiotic
    - D. Detergent

11. The agar diffusion test measures
    - A. the spread of bacteria in a culture medium.
    - B. the depth of penetration of bacteria into the tissue.
    - C. the effectiveness of an antimicrobial.
    - D. the virulence of a bacteria.
12. The agar diffusion test is very easy to conduct. It has very few, if any, disadvantages.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false, the second is true.
   D. Both statements are false.

13. The Neglia et al study found Tetraclean to be at least as effective as
   A. sodium hypochlorite.
   B. CHX.
   C. Hypoclean.
   D. Chlor-XTRA.

14. 5.25% Sodium hypochlorite and ______________ were found to be the most effective irrigants.
   A. CHX
   B. Hypoclean
   C. Tetraclean
   D. Chlor-XTRA

15. In the study, which material demonstrated the greatest residual anti-microbial activity?
   A. Sodium hypochlorite
   B. Hypoclean
   C. Tetraclean
   D. CHX

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Answer form is on page 552.
Answers for this exercise must be received by October 31, 2013.

To enroll in Self-Instruction, click here.
Five-year retrospective study of laser-assisted periodontal therapy

Edward R. Kusek, DDS • Amanda J. Kusek, RDH • E. Alex Kusek

This article outlines a five-year retrospective study involving a diode dental laser used on periodontally infected teeth. The present study utilized a specific protocol: scaling and root planing, light ultrasonic scaling, and the use of a diode laser.

The use of dental lasers for the treatment of periodontal disease is accepted in some areas of dentistry, while in others it is thought to be antitodal therapy. This article seeks to show that laser-assisted periodontal therapy is a viable, noninvasive method for treating periodontal disease.

Periodontal disease is a chronic inflammatory disease caused by a bacterial infection. For this reason, the bactericidal and detoxifying effects of laser treatment are advantageous in periodontal therapy. The effectiveness of this therapy involves suppressing certain bacteria such as Aggregatibacter actinomycetemcomitans, an invasive bacterium associated with aggressive forms of periodontal disease that cannot be treated readily with conventional scaling and root planing (SRP). This bacterium is present on diseased root surfaces; as a result, it can invade the adjacent soft tissues as well, making removal by mechanical instrumentation difficult.

It is impossible to achieve success with traditional periodontal methods of treatment due to the great difficulty in terms of completely removing bacterial deposits and their endotoxins from deep areas of periodontal pockets. In addition, antibiotics that are used to prevent bacterial colonization after periodontal treatment help to increase the resistance of the microorganism.

According to the literature, using diode lasers in conjunction with SRP accelerates and enhances wound healing, making it more comfortable, while decreasing gingival bleeding, inflammation, and pocket depths. A 2002 position paper from the American Academy of Periodontology stated that gingival curettage consistently fails to provide any advantage in treating chronic periodontitis compared to SRP alone.

The current article challenges this assertion by describing a five-year retrospective study that shows how laser technology made a consistent difference in the health of chronic periodontal patients. It is the authors’ opinion that the biofilm attaches to the inner lining of the epithelium and bony walls exposed to the bacteria. That biofilm will continue to destroy sulcular and junctional epithelium if it is not eliminated.

Protocol

Patients with pockets of 5 mm or more and those with bleeding and/or suppuration were considered candidates for laser-assisted periodontal therapy. SRP was performed three months before the start of laser-assisted periodontal therapy, due to the maximum utilization of insurance for most patients.

Optimally, patients would return for a series of subsequent appointments to address every pocket that exceeded the healthy 3 mm. For example, a patient whose deepest pocket measured 7 mm would come in for a total of four appointments every 7–10 days. Each time the laser was used to treat that pocket, 1 mm of it would heal from the apical to the coronal. Using this example, all 7-mm pockets would be treated first, while the 6-mm pockets would be treated at the second appointment (7–10 days later). This process would continue for each appointment until all pockets had a healthy depth of 3 mm.

Each appointment began with ultrasonic scaling at a low setting, applied to all pockets in a slow, sweeping motion. This technique is used to smooth the root surface, in addition to the regular cleaning or SRP that the patient had undergone previously. After ultrasonic scaling was completed, a strong topical anesthetic (Cetacaine, Cetylite Industries) was applied. Although the laser is virtually pain-free, some patients might feel an uncomfortable amount of heat. Dentists might also opt to use local anesthetics for patients who have lower pain tolerances.

In 80% of cases, pocket depth of 3 mm or less was maintained. Reprinted with permission from General Dentistry, April 2012, 68(4):181-186.
**Laser setup**

To prevent it from stripping the epithelial attachment, the laser tip should be measured 1 mm less than the deepest pocket being treated. Before placing the tip into the pocket, the laser must be “initiated” with black articulating tape (Accufilm II, Parkell). This initiation pinpoints the laser energy to the end portion of the fiber-optic tip (Fig. 1), making it possible to emit laser energy only to the intended areas rather than laterally.

The diode laser should be set at the lowest possible setting. The laser’s energy is directed to the margin of the infected pocket without actually entering the pocket. The margin will start to turn white, which indicates that the laser setting is correct; it might be necessary to adjust the laser in 0.1 W increments to achieve this result (Fig. 2). Once the correct wattage has been achieved, the clinician should move the laser into the pocket for 5–10 seconds at a time. Each time the laser is removed from the pocket, it might carry a small amount of debris; wet gauze will remove this debris from the fiber-optic tip (Fig. 3 and 4). The clinician should inspect the fiber-optic tip to make sure it is still initiated each time before entering the pocket. The clinician should continue until no more debris can be removed or fresh bleeding occurs (Fig. 5).

After treating the infected pocket, the margins of the pocket must coagulate to help the healing process, as going into the pocket repeatedly with the laser can leave the borders jagged. The clinician needs to return to the lowest possible setting with the initiated fiber-optic tip. The laser energy should be traced along the margins of the pocket (at a distance of 1–2 mm) for approximately 20 seconds (Fig. 6).

Finally, the diode laser is used for biostimulation to aid in healing the damaged cells that line the wall of the inner epithelium. In the authors’ experience, 6 J is the optimum setting for the diode laser.
when it is approximately 4–5 mm from the treated area (Fig. 7). (This is the minimum distance to ensure that the laser energy is diffused sufficiently so that it provides biostimulation only and does no cutting.) Using a microbrush, the clinician should apply liquid vitamin E to the treated pockets (Fig. 8). (The efficacy of vitamin E has not been validated in the literature, but the authors have experienced positive tissue response with its use.)

Patients were instructed to avoid certain foods for at least 24 hours, including crunchy or spicy foods, foods with tiny seeds, and foods that might become lodged in the space created by the procedure. Patients were asked to avoid smoking for at least 24 hours, rinse with warm salt water at least twice daily for three days post-treatment, and avoid flossing and hard brushing for 48 hours post-treatment. If the patient experienced discomfort after the procedure was complete, ibuprofen or a similar pain reliever could be used, but typically this was not necessary. After the initial 48 hours, patients could brush and floss according to their normal routine.

Patients should return three months after the last appointment so that the dentist can determine the progress of pocket healing. Since periodontal disease is a lifelong struggle for most patients, this procedure might need to be repeated every 3–24 months, depending on the patient’s home care regimen.

**Materials and methods**

This study examined the use of diode lasers on periodontal pockets to determine their bactericidal attributes and their ability to improve periodontal conditions.

A total of 70 non-smoking patients with no implants needed SRP, and had been under care for periodontal disease continuously for at least five years. Using the protocol described above, 810 nm and 940 nm diode lasers (Biolase Technology, Inc.) were used. As described
previously, the cases were rescaled at the time of laser treatment using a light stroke and the lowest setting. Some cases were retreated to maintain healthy pockets. In all cases, 400 µ fiber-optic tips were used. As a starting point for tissue interaction, the lasers were set at 0.5 W in continuous wave mode.

Fiber-optic tips were cleaved (that is, the tip was cut to get a straight fiber) and used for 810 nm lasers and both 810 nm and 940 nm lasers were initiated. Each tooth had six measurable pockets (that is, mesial facial, center facial, distal facial, mesial lingual, center lingual, and distal lingual) and teeth were treated in all four quadrants. Four hygienists performed the treatments and did probing readings, while another hygienist did only probing readings.

Results
A total of 2,103 pockets were treated among the 70 patients. Of the 2,103 pockets, 1,278 were found in molars, 556 in premolars, and 269 in anterior teeth. Of the 1,278 molar pockets, 973 (76%) had been restored to a healthy pocket depth of 3 mm after five years of treatment. Of the 556 premolar pockets, 466 (84%) had been restored to a healthy pocket depth of 3 mm after five years of treatment. Of the 267 pockets in the anterior teeth, 240 (90%) had been restored to a healthy pocket depth of 3 mm after five years of treatment.

Conclusion
In all, 80% of the pockets treated using the diode laser were restored to a healthy pocket depth of 3 mm. These results suggest that this treatment modality should become an adjunct for treating periodontal infections.

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Tooth embedded in lower lip following dentoalveolar trauma: Case report and literature review

Antonio Azoubel Antunes, DDS • Thiago Santana Santos, DDS, MS • Allan Ulisses Carvalho de Melo, PhD
Cyntia Ferreira Ribeiro, DDS, MS • Suzane Rodrigues Jacinto Goncalves, PhD • Sigmar de Mello Rode, DDS, MS

One of the most frequent consequences of trauma to the maxillofacial region is damage to teeth and supporting structures. Such damage can occur either in isolation or in conjunction with other fractures and soft tissue lacerations. In emergency situations, the harm caused to teeth could go unnoticed during the clinical examination, depending on the nature and complexity of the trauma and the primary care team’s awareness of orofacial injuries. Fractured incisors often cause lacerations to the soft tissues at the time of trauma. During the diagnosis, particular care must be taken when such a fracture is associated with a soft tissue injury.

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One of the most frequent consequences of facial trauma is damage to the teeth and supporting structures. Such traumas can occur as a result of work- or sports-related accidents, physical violence, automobile accidents, and, most frequently, falls. Following a traumatic injury to the face, a thorough examination of the soft tissues should be systematically performed, including an evaluation of the hard tissues (teeth and bone) through a clinical inspection and radiographic examination, as well as pulp vitality, percussion, and mobility tests. When examining soft tissues, both extraoral and intraoral (lips, gums, cheeks, tongue, oral mucosa, and palate) examinations are necessary. X-rays of tissues with signs of bleeding, laceration, or swelling should always be taken to determine the presence or absence of a foreign body.

Tooth fragments in the lower lip are subject to constant movement due to contractions of the orbicular musculature and can end up distant from the original site of perforation at the time of trauma which can make the diagnosis of such cases more challenging. Fractured incisors are often the cause of soft tissue lacerations at the time of trauma. For this reason, special care must be taken in cases of lacerations occurring with fractured or missing teeth.

This report describes a case of trauma to the maxillary incisors in which tooth fragments remained embedded in the interior of a lower lip wound after primary care. The authors also review and compare similar cases cited in the literature.

Case report
A 17-year-old male came to the clinic at the University of Tiradentes School of Dentistry complaining of a firm mass in the lower lip that was sensitive to the touch. The patient had been referred to the faculty with a preliminary diagnosis of a tumor in the lower lip by a general clinician. The patient’s history revealed that he had fallen from a bicycle one year earlier. At the time, he received primary care at the emergency room.
of a public hospital. The wounds, including a laceration of the lower lip, were sutured, and the patient was discharged the same day.

The extraoral examination revealed fractured maxillary central incisors and visible scars on the cutaneous portion of the lower lip. Increased volume in the lip was also noted (Fig. 1). The intraoral examination revealed an inconspicuous scar on the mucous portion of the lower lip. A firm nodule, measuring approximately 1 cm in diameter with a normal pink color, was palpated in this region (Fig. 2). The periapical radiograph revealed radiopaque structures in the lower lip similar to those of the incisal region of the fractured maxillary central incisors (Fig. 3). The history of trauma and the clinical and radiological findings eliminated the preliminary diagnosis of a tumor.

The patient underwent surgical excision of the fragments under local anesthesia; 1.0 cc of lidocaine in a 2% solution with 1:100,000 epinephrine was administered to the area of tumefaction. The lower lip was incised along the existing mucous scar line. The fragments were identified and carefully removed (Fig. 4). A 4-0 black nylon thread was used to suture the tissue. No antibiotic treatment was prescribed after surgery, as there were no signs of infection. During the surgery, a periapical radiograph was taken to confirm the complete removal of the fragments (Fig. 5).

After suturing, the fragments were reattached to the maxillary central incisors using a composite adhesive technique. The lingual sides of the fragments were perfectly intact, although the buccal aspect exhibited a slight loss of enamel. After the teeth were primed and etched, flowable resin was placed to match both tooth fragments. The buccal gap was microfilled with a composite resin and polymerized. The teeth were polished with rubber points and polishing discs. Follow-up was scheduled at two to four weeks and three to six months to evaluate the esthetic-functional integrity of the traumatized teeth.

At the six-month follow-up visit, the lip exhibited satisfactory healing and the repaired tooth was esthetically pleasing (Fig. 6). The vitality test on both teeth was positive, and neither tooth displayed any signs of discoloration (Fig. 7).

Discussion
The damage caused to teeth and supporting structures is one of the most frequent consequences of maxillofacial trauma. Such damage can occur either in isolation or in conjunction with other fractures and soft tissue lacerations. In emergency

![Fig. 3. Radiograph revealing tooth fragments embedded in the lower lip.](image1)

![Fig. 4. Tooth fragments removed.](image2)

![Fig. 5. Periapical radiograph confirming the removal of the tooth fragments.](image3)

![Fig. 6. Lower lip with satisfactory healing at the six-month follow-up.](image4)

![Fig. 7. Esthetic and functional integrity of the teeth maintained at the six-month follow-up.](image5)
Table 1. Previous cases of tooth fragments embedded in lips reported in the literature.

<table>
<thead>
<tr>
<th>Author</th>
<th>Cases</th>
<th>Age/Sex</th>
<th>Time elapsed since trauma</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Al-Jundi</td>
<td>1</td>
<td>13/F</td>
<td>18 months</td>
<td>Removal</td>
</tr>
<tr>
<td>2 Gill &amp; Fleming</td>
<td>1</td>
<td>46/M</td>
<td>3 months</td>
<td>Removal</td>
</tr>
<tr>
<td>3 Schweizmeyer et al</td>
<td>1</td>
<td>8/M</td>
<td>2 months</td>
<td>Removal and reattachment</td>
</tr>
<tr>
<td>4 Munerotto et al</td>
<td>1</td>
<td>14/F</td>
<td>3 days</td>
<td>Removal</td>
</tr>
<tr>
<td>5 Naudi &amp; Fung</td>
<td>1</td>
<td>11/M</td>
<td>1 hour</td>
<td>Removal and reattachment</td>
</tr>
<tr>
<td>6 Pasini et al</td>
<td>1</td>
<td>18/F</td>
<td>36 hours</td>
<td>Removal and reattachment</td>
</tr>
<tr>
<td>7 da Silva et al</td>
<td>2</td>
<td>10/M</td>
<td>3 months</td>
<td>Removal</td>
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<td>17/M</td>
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<tr>
<td>8 Taran et al</td>
<td>1</td>
<td>7/F</td>
<td>18 days</td>
<td>Removal</td>
</tr>
<tr>
<td>9 de Santana Santos et al</td>
<td>1</td>
<td>17/M</td>
<td>1 year</td>
<td>Removal and reattachment</td>
</tr>
</tbody>
</table>

The bonding of a tooth fragment after fracture was first described by Chosack & Eidelman in 1964; cementing was performed following adequate endodontic treatment.20 Current methods range from simple bonding, depending only on the type of adhesive employed, to different preparation methods for the tooth and fragment.21-23 The advantage of bonding is that it constitutes a more conservative restoration of the tooth injury without impeding the use of a subsequent restorative material in cases of unsuccessful treatment.24 Surgical excision is the treatment of choice for tooth fragments embedded in the lip.25 Depending on the size of the fragments and the length of time they were embedded in the tissue, it might be possible to use the fragments to restore the remaining fractured teeth.26 In the present case, even one year after the cycling accident, it was possible to restore the fractured teeth using the fragments removed from the lower lip.

**Summary**

Knowledge of the patient’s injury, a thorough clinical examination, and a radiographic examination are necessary whenever clinical signs of dental trauma are observed during primary care for trauma to the maxillofacial region. For such cases, an analysis of the intra- and extraoral tissues is critical, especially when there is a laceration in which foreign bodies might be present. These steps will prevent the patient from having to undergo additional surgical procedures for the subsequent removal of remaining fragments.

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References
Large radiolucency of the mandibular body

Douglas D. Damm, DDS
(Case courtesy of Dr. Victor Barresi, Rockford, IL)

A 33-year-old male sought treatment for extensive dental decay and multiple periapical radiolucencies associated with a number of residual root tips. A large mandibular radiolucency on the right side was noted (Fig. 1). Full mouth extractions were performed along with removal of the associated periapical pathoses. At that time, the large lesion was removed from the mandibular body and also submitted for histopathologic examination (Fig. 2).

Which of the following is the most appropriate diagnosis for the large lesion of the right mandibular body?

A. Apical periodontal cyst (periapical cyst)
B. Calcifying odontogenic cyst (calcifying cystic odontogenic tumor)
C. Inflamed odontogenic keratocyst (keratoctytic odontogenic tumor)
D. Glandular odontogenic cyst (sialo-odontogenic cyst)

Diagnosis is on page 550.

Fig. 1. Large radiolucency of the mandibular body on the right side.

Fig. 2. A cystic structure lined by thickened stratified squamous epithelium exhibiting heavy exocytosis and spongiosis (H&E stain, original magnification 10X).
A 16-year-old male sought treatment for failure of eruption of the left mandibular second molar. A panoramic radiograph revealed a deep horizontal impaction of the tooth in association with a large radiolucency within the ascending ramus (Fig. 1). An incisional biopsy was obtained (Fig. 2).

Which of the following is the most appropriate diagnosis?

A. Chondromyxoid fibroma  
B. Myxoid chondrosarcoma  
C. Odontogenic fibroma  
D. Odontogenic myxoma

Diagnosis is on page 550.

Fig. 1. Large radiolucency within the ascending ramus.

Fig. 2. Loose and lightly basophilic connective tissue with numerous spindle-shaped mesodermal cells. (H&E stain, original magnification 10X).

Author information
Dr. Damm is a professor, Department of Oral Health Sciences, Division of Oral Pathology, College of Dentistry, University of Kentucky, Lexington.
Large radiolucency of the mandibular body

Diagnosis:
A. Apical periodontal cyst (periapical cyst)
The histopathologic examination of the large lesion revealed a cystic structure that was lined by thickened stratified squamous epithelium which exhibits heavy exocytosis and spongiosis. The cyst wall consisted of fibrous connective tissue that contained numerous small vascular channels. A heavy mixed inflammatory cellular infiltrate (predominantly neutrophils, lymphocytes, plasma cells, and histiocytes) was present within the wall. Large zones of red blood cell extravasation were noted.

The apical periodontal cyst is the most common odontogenic cyst, with most arising from inflammatory activation of epithelial rests of Malassez. Although some clinicians have little concern for this pathosis, the cyst may demonstrate slow but continuous growth and can become quite large. Conservative enucleation usually is curative. For large lesions, marsupialization often results in significant size reduction, which aids in easier final removal.

Bibliography

Large pericoronal radiolucency

Diagnosis:
D. Odontogenic myxoma
Incisional biopsy revealed a mass of loose and lightly basophilic connective tissue. The tissue is hypercellular with numerous spindle-shaped mesodermal cells. Odontogenic myxomas appear among a wide age range of patients, but are discovered most frequently in young adults with no gender predilection. Although any gnathic site may be affected, the mandible is involved more frequently than the maxilla. Radiographically, the neoplasm creates a radiolucent lesion which may be unilocular or multilocular, often with irregular or scalloped margins. Odontogenic myxomas tend to vary in density. Those with minimal collagenization and abundant ground substance are very loose and difficult to remove. Small odontogenic myxomas generally are treated with curettage and close follow-up. Large tumors and those with a gelatinous consistency often are treated more aggressively. Although the recurrence rate is approximately 25%, the long-term prognosis is good.

Bibliography
### Self-Instruction

#### Exercise No. 291
**November/December 2011, p. 429**

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Antibacterial activity in adhesive dentistry: A literature review

Fereshteh Shafiei, DMD, MS  •  Mahtab Memarpour, DMD, MS

This literature review summarizes the published research regarding the antibacterial agents used in adhesive dentistry. This article provides information about the clinical applications, beneficial effects, and possible disadvantages of antibacterials when used in various bonding situations.

Received: September 15, 2011
Accepted: January 31, 2012

Adhesive systems are used extensively in clinical practice for bonding to tooth structure. Adhesive systems are used for direct and indirect tooth-colored esthetic restorations, amalgam restorations, crowns and fixed partial dentures, luting posts in root dentin, fissure sealant therapy, and enamel bonding when placing orthodontic brackets.

Despite their qualities, adhesive systems cannot prevent micro-gaps from forming at the dentinal margins of composite restorations.1,2 Even when immediate complete marginal sealing is established, the resin-dentin interface can degrade rapidly over time.1,3,4 In addition, microorganisms accumulate on enamel surfaces or other restorative materials.5,6 The accumulation of plaque means that microorganisms are always in contact with the cured adhesives via micro-gaps. The lack of definitive and reliable assessment criteria means that not all microorganisms in carious dentin can be detected and eliminated.7,8 The problem of bacteria remaining in a cavity is more pronounced by an increasing predilection toward minimally invasive, tissue-saving dentistry in which the intact tooth structure is preserved to the greatest extent possible.9 Residual bacteria can survive for more than a year and can proliferate even in the presence of a good seal.10 Adjunctive treatment with antibacterial agents during dentin bonding could prevent the detrimental effects resulting from residual bacteria or microleakage, such as pulp damage, hypersensitivity, and recurrent caries (a major cause of restoration replacement).11 A biologic seal can improve the longevity of the restoration.

Antibacterial effect of adhesive systems

Acid etchants used in etch-and-rinse adhesives and the acidic monomers found in self-etching adhesives with low pH have both demonstrated antibacterial activity.12-19 According to Harper & Loesche, the pH values that completely eliminated bacteria over a three-hour period were 2.3 for Lactobacillus casei and 3.0 for Streptococcus mutans.20 However, certain bacteria are acid-resistant; in addition, the buffering capacity of dentin can limit the effects of the acid.16,20,21 Some monomers that promote adhesion, such as N-methacryloyl 5-aminosalicylic acid (5-NMSA) and Phenyl-P—particularly methylene diphosphonate (MDP)—slightly inhibit bacterial growth, due to the specific antibacterial components (such as glutaraldehyde) that are found in some adhesives.17,18,22-25 However, photocuring self-etching adhesives reduces their antibacterial properties significantly. The literature has reported on the inability of adhesives to inhibit bacterial growth or secondary caries.18,19,25-31

Categorization of antibacterial agents

Antibacterial activity is provided by two types of materials: those that release agents and those that do not (the latter are known as contact antibacterials).18,32,33 The agent-releasing materials are used as a separate disinfecting material or as antibacterial-incorporated materials when the disinfecting step is eliminated.

Separate disinfecting materials

Originally, chemicals such as silver nitrate precipitated with eugenol, phenole, and thymol were recommended for disinfecting cavity preparations prior to placement of restorations. These materials are no longer used due to their irritating effect on the pulp.32 Cavity disinfectants were initially proposed by Brannstrom & Nyborg.33 They recommended Tublicid (Global Dental Products), a benzalkonium chloride-based disinfectant containing ethylenediaminetetraacetic...
acid (EDTA) and sodium fluoride (NaF), for cavity disinfection.34 Tubicid is a quaternary ammioniunm compound with no pulpal reactions.32,35-36 Other disinfectant materials that have been used to disinfect cavities include sodium hypochlorite (NaOCl), hydrogen peroxide (H2O2), and iodine-based oral disinfectants. EDTA and NaOCl were used primarily for their other properties, including the ability to serve as a calcium chelator, remove the smear layer, and help to remove collagen. Based on evidence from a study by Anderson & Charbeneau on residual bacteria in the cavities, cavity disinfectants were recommended.12,36,37 However, adjunctive use of disinfectants during bonding procedures could have an adverse effect on the bonding ability of different adhesive systems.32,36,38-41

Chlorhexidine gluconate (CHX), a bisphenol component containing chlorine, has been used for many years as a safe antiseptic with a broad spectrum of action. Studies have shown that CHX reduces the number of microorganisms in plaque and saliva and also reduces the level of S. mutans in occlusal fissures and root surfaces.42-43 CHX has been used as an irrigant for the nonsurgical treatment of periodontal diseases and adjunctively used in endodontic treatment.44,45 It is bacteriostatic in low concentrations and bactericidal in higher concentrations.46 These effects have been reported primarily on Gram-positive bacteria and less on Gram-negative bacteria, such as S. mutans and S. sobrinus, both of which contribute to initial caries development and are more sensitive to the antibacterial effect of CHX.42,43,47

CHX has strong cationic activity, allowing it to be absorbed easily into (and thus disrupt) the negatively charged bacterial cell wall.36,46,47 This chemical charge also allows CHX to adhere to oral cavity surfaces and tooth structure, which results in longer antimicrobial activity (ranging from 48 hours to 12 weeks) compared with other disinfectants.32,36,48,49 Fardal & Turnbull recommended CHX as a cavity disinfectant in 1986.42 CHX, benzalkonium chloride, and cetlypyridium chloride have been used as additives to phosphoric acid; the latter is capable of cross-linking to collagen.50-52 A considerable decrease in the number of bacteria in the dentinal tubules was reported following application of 0.2% CHX for five minutes.53

At least two solutions containing 2% CHX are available commercially: Cavity Cleanser (Bisco, Inc.) and Consepsis (Ultradent Products, Inc.). A 1% CHX gel (Drogsan Pharmaceuticals) is also available. These products have been used to disinfect cavity preparations in numerous studies and have produced interactions with the bonding ability of adhesive systems used in direct and indirect restorations that appear to be material-specific. These results—in addition to results from other studies regarding the effects of disinfectants on the bonding efficacy of adhesive systems—are summarized in Table 1.

The CHX binding to phosphate groups might act as a co-surfactant on the etched surface and increase the surface free energy; however, it can also have an adverse effect on bond strength to primary dentin.52,44,47,48,54 CHX has been applied in different sequences, including before etching, after etching (with or without rinsing), or CHX-containing phosphoric acid.41,50,54-55 A number of authors and a manufacturer of a commercial product, Consepsis (Ultradent Products, Inc.), recommend applying CHX for 60 seconds after etching, then removing excess moisture prior to applying a hydrophilic adhesive or a rewetting agent.55,58,64-68 CHX could conserve and regulate the structural integrity of the collagen matrix.50 Furthermore, removing the smear layer during etching eliminates most of the bacteria as well.12,37,58

CHX was applied on the smear layer in association with self-etch adhesives that have no separate etching and washing steps; however, it can affect the bonding ability of the adhesives.41,56,60,69-70 The adverse effect of CHX on some self-etch adhesives is related to residual moisture (a 2% CHX solution is composed of 98% water), which contaminates the bonded surface.71-72 The gel form of CHX could have a limited penetration depth and therefore would not affect the bond.60 Self-etch adhesives containing MDP might have been adversely affected by CHX bonding to loose, superficial apatites within the smear layer.72 A 1996 study used SEM analysis and reported that CHX creates a acid-resistant layer, inhibiting acidic monomers from penetrating the dentin.41

Even at a very low concentration (0.2%), CHX functions as a matrix metalloproteinase (MMP) inhibitor that can prevent both degradation of collagen and disintegration of the bonding interface.73-75 MMPs are a class of metal-dependent endopeptidases that remain latent in the dentin matrix during tooth development and can be activated during dentin demineralization.74,76,77 CHX can bind to the dentin matrix; in addition, it can be retained in the dentin and covered or sealed with adhesive.62-78,79

Long-term use of CHX solution can result in brown staining of the teeth; however, studies that used CHX for a short time during
restorative procedures reported no such staining.\textsuperscript{59,62} CHX can reduce postoperative sensitivity and increase bonding durability as an additional therapeutic primer, as long as it has no adverse effect on the adhesive’s immediate bond.\textsuperscript{80}

<table>
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**Antibacterial-incorporated materials**

Antibacterial components such as antibiotics, dodecylamine, bipyridine, tannic acid derivatives, polyhexanide, amphilic lipids, silver, and fluorides have been added to dental resins.\textsuperscript{81-85} These agents can extend the antibacterial effect beyond the immediate area of the adhesive restoration; however, they could also compromise the mechanical and bonding properties of the carrier material.\textsuperscript{18,86}
Also, a strict control of release kinetics is difficult, and long-term antibacterial effects are not to be expected.18,86-88 CHX has been added to restorative materials, provisional and permanent conventional cements, and polymethyl methacrylate-based resin cements.18,87,89-92 The literature has reported that adding CHX to self-etching primers did not compromise bonding ability and might even preserve bond strength to dentin.93-95 Conversely, a 2009 study by Cadenaro et al demonstrated that CHX had an adverse effect on the physical property of a primer.96 Furthermore, CHX release can be affected by water sorption and hydrophilic characteristics of resin composites.97

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<td>Incorporated into acid gel/Adper Single Bond, Rely X ARC (3M ESPE)</td>
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To provide cariostatic and antibacterial effects, fluoride has been incorporated into restorative materials, sealants, and adhesive systems; however, the beneficial effect of fluoride has more to do with inhibiting demineralization and enhancing remineralization than any antibacterial activity.\(^{21,85,98,99}\) According to Franci et al, released fluoride has little or no effect on the inhibition of \textit{S. mutans}.\(^{100}\)

**Non-agent releasing (contact) antibacterial materials**

Methacryloyloxydodecyl pyridinium bromide (MDPB) is a unique monomer that was developed to provide resin-based materials with long-lasting antibacterial activity without releasing the antibacterial agent. After curing, MDPB is covalently bonded to the polymer network and acts as a contact inhibitor against the bacteria that comes in direct contact with the polymer.\(^{35,101,102}\) In 2008, Xiao et al developed a similar monomer, methacryloyethyl cetyl dimethyl ammonium chloride (DMAE-CB), a compound of the antibacterial agent quaternary ammonium with a methacryloyl group.\(^{103}\) The adsorption of the positively charged agent onto a negatively charged bacterial surface can disrupt cell membranes.\(^{36,38}\) Both of these monomers have been

---

**Table 1 cont’. In vitro studies regarding the interaction of cavity disinfectants and adhesive systems.**

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Cavity disinfectant(s)</th>
<th>Experimental design</th>
<th>Procedure/adhesive</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bansal &amp; Tewarsi</td>
<td>CHX, Iodine-based, NaOCl</td>
<td>Dentin leakage</td>
<td>Before etching/Prime &amp; Bond; before self-etching</td>
<td>Positive effect on Xeno III</td>
</tr>
<tr>
<td>Erhardt et al</td>
<td>CHX</td>
<td>Dentin bond strength</td>
<td>After etching/Adper Scotch Bond 1 (3M ESPE)</td>
<td>No effect</td>
</tr>
<tr>
<td>Catalbas et al</td>
<td>CHX, CHX gel</td>
<td>Enamel bond strength</td>
<td>After etching/Prime &amp; Bond</td>
<td>Negative effect</td>
</tr>
<tr>
<td>Ersin et al</td>
<td>CHX</td>
<td>Primary dentin bond strength</td>
<td>After etching/Prime &amp; Bond</td>
<td>No effect</td>
</tr>
<tr>
<td>Hiraishi et al</td>
<td>CHX</td>
<td>Dentin bond strength</td>
<td>After etching/Adper Single Bond-RelayX ARC</td>
<td>No effect</td>
</tr>
<tr>
<td>Siso et al</td>
<td>CHX</td>
<td>Enamel leakage</td>
<td>Before etching/Clearfil SE Bond</td>
<td>Negative effect on enamel</td>
</tr>
<tr>
<td>Ercan et al</td>
<td>CHX</td>
<td>Dentin bond strength</td>
<td>After etching/Prime &amp; Bond NT (Dentsply Caulk); before self-etch/Clearfil SE Bond</td>
<td>Negative effect on self-etch</td>
</tr>
<tr>
<td>NaOCl, H(_2)O(_2), CHX gel</td>
<td>Dentin bond strength</td>
<td>After etching/Prime &amp; Bond NT; before self-etch/Clearfil SE Bond</td>
<td>Negative effect on self-etch</td>
<td></td>
</tr>
<tr>
<td>Saber &amp; El-Askary</td>
<td>CHX</td>
<td>Dentin bond strength</td>
<td>Before self-etch/Clearfil S3 Bond</td>
<td>Negative effect</td>
</tr>
<tr>
<td>NaOCl, H(_2)O(_2), CHX gel</td>
<td>Dentin bond strength</td>
<td>After etching/Prime &amp; Bond NT; before self-etch/Clearfil SE Bond</td>
<td>No effect</td>
<td></td>
</tr>
</tbody>
</table>
incorporated into resin composite and adhesive systems.

Although studies have demonstrated the antibacterial effect of the incorporated composite even after a year of water storage, other reports have described the loss of this effect. The adsorption of proteins on the surface could account for the reduced antibacterial effect. While the antibacterial effects of composite restorations primarily involve inhibiting surface plaque accumulation, the antibacterial effect of adhesives involves disinfecting the cavity and rendering inactive any bacteria that might enter through marginal microleakage. A self-etch primer containing 5% MDPB killed S. mutans within 30 seconds of contact before curing. Following copolymerization with other monomers, this self-etch primer had an inhibitory effect on the growth and adherence of bacteria on its surface.

MDPB has demonstrated antibacterial activity against various bacteria isolated from both root and dentin caries. Studies have reported that incorporating antibacterial monomers does not compromise bonding efficacy and stability, curing ability, cytotoxicity, or marginal adaptation.

### Table 1 cont. *In vitro* studies regarding the interaction of cavity disinfectants and adhesive systems.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Cavity disinfectant(s)</th>
<th>Experimental design</th>
<th>Procedure/adhesive</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campos et al (2009)</td>
<td>CHX</td>
<td>Dentin bond strength</td>
<td>After etching/Adper Single Bond</td>
<td>No effect</td>
</tr>
<tr>
<td>Lindblad et al (2010)</td>
<td>CHX</td>
<td>Root dentin bond strength</td>
<td>After etching/All Bond 2, Duolink (Bisco, Inc.), Perma Flow DC (Ultradent Products, Inc.)</td>
<td>No effect</td>
</tr>
<tr>
<td>Kustarci &amp; Sokucu (2010)</td>
<td>CHX</td>
<td>Enamel leakage</td>
<td>After etching/Transbond XT</td>
<td>No effect</td>
</tr>
<tr>
<td>Shafiei &amp; Memarpour (2010)</td>
<td>CHX</td>
<td>Dentin bond strength</td>
<td>After etching/Variolink 2 (Ivoclar Vivadent Inc.)</td>
<td>No effect</td>
</tr>
<tr>
<td>Shafiei et al (2011)</td>
<td>CHX</td>
<td>Enamel and dentin leakage</td>
<td>After etching/Nexus 2 (Kerr Corporation)</td>
<td>No effect</td>
</tr>
<tr>
<td>Shafiei et al (2010)</td>
<td>CHX</td>
<td>Enamel and dentin leakage</td>
<td>After etching/Scotchbond Multi-Purpose (3M ESPE), Excite (Ivoclar Vivadent Inc.)</td>
<td>No effect</td>
</tr>
</tbody>
</table>

CHX = Chlorhexidine solution

Note: Four other studies (Stanislawczuk et al, Ricci et al, Breschi et al, and Carrilho et al) demonstrated the preservative effect of CHX (after etching) on dentin bonding and showed no adverse effect on immediate bond strength; these studies are not included in Table 1.
Antibacterial activity in adhesive dentistry

Antibacterial activity in enamel bonding

**Enamel bonding in fissure sealants**

Little information is available regarding antibacterial activity in sealants. An antibacterial adhesive under a sealant might exhibit antibacterial action on the original bacteria in pits and fissures and inhibit caries formation following microleakage or a partial loss of the sealant. A 2005 study placed an adhesive associated with sealant and composite resin on uncut enamel and reported that the bond was comparable to that of a total-etch adhesive.²²

**Enamel bonding in orthodontic brackets**

Demineralization is a major side effect of fixed appliance orthodontic treatments, with prevalence reports of 50–70%.³⁰,³¹,³² Demineralization around fixed orthodontic appliances results from gap formation due to polymerization shrinkage, more retention sites, and increased plaque accumulation.³²,³³ Fluoride and CHX are the most common preventive approaches; however, their effects are limited in duration and are not completely effective. The antibacterial-incorporated type could compromise the bonding ability of some adhesives and are not completely effective. The antibacterial-incorporated type could compromise the bonding ability of the adhesives.³⁶,³⁷,³⁸ Furthermore, the ability of fluoride-releasing adhesives to inhibit demineralization is still in doubt, since the low pH environment created by bacteria prevents remineralization; for this reason, the combination of fluoride and antibacterial agents has been suggested.³⁹,⁴⁰ Studies that used Clearfil Protect Bond have reported promising results in terms of bond strength and sealing ability.³³,³⁴,³⁵ The low bond strength reported in some studies could be attributed to an insufficient etching pattern on unground enamel because Clearfil Protect Bond is a mild self-etch adhesive with a pH of 2.³⁶ Some studies performed enamel etching for 10 seconds, while others suggested that etching might not be necessary and did not recommend it.³⁷,³⁸

Other antibacterial agents that have been added to the adhesives used in bracket bonding include benzalkonium chloride (as a releasing agent) and silver nanoparticles (as a non-releasing agent). The latter has the disadvantage of a discoloration problem related to silver ions.³⁹,⁴⁰ Randomized controlled clinical long-term trials should be conducted to confirm the positive effect of these agents on enamel decalcification during orthodontic treatment.

**Antibacterial effect of lasers**

A 1997 article by Klinke et al proposed using lasers to decontaminate cavities or root dentin.⁴¹ Although laser pretreatment might not affect the bonding ability of some adhesives, it does represent a more expensive and complex treatment modality in respect to getting a homogenous laser application with suitable irradiation parameters to all parts of the cavity.⁷⁰,¹⁴⁵-¹⁴⁷

**Antibacterial effect of ozone**

According to the literature, applying ozone for 20 seconds can kill 99.9% of microorganisms found in primary caries lesions.⁴² Studies have suggested that ozone gas can disinfect the cavity prior to performing restorative procedures, without affecting the enamel or dentin bond strength.⁵⁰,⁵¹

**Summary**

According to the *in vitro* and limited *in vivo* data found in the literature, CHX can be used with etch-and-rinse adhesives as a cavity disinfectant while improving bonding durability; however, long-term clinical studies are necessary to confirm these advantages.

Clearfil Protect Bond appears to offer long-lasting antibacterial activity in adhesive dentistry; however, additional testing is needed to determine its effect on bacteria invading the adhesive interface *in vivo*. In addition, long-term *in vivo* evaluations using standardized protocols should be conducted to determine the practical application of mechanical and biologic sealing.
Disclaimer
The authors certify that they do not have any commercial interest that represents a conflict of interest in connection with the manufacturers listed in this article.

Author information
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www.agd.org General Dentistry November/December 2012 e353
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Oper Dent 2010;25(6):577-582.

Prevention of postoperative tooth sensitivity: The effect of 2% chlorhexidine gluconate in fixed prosthodontics. 

Dent Mater J 2005; 

Dent Mater J 2005; 

Retention and marginal leakage of provisional cements entering amphiphilic resins. 

Retention and marginal leakage of provisional cements entering amphiphilic resins. 

Retention and marginal leakage of provisional cements entering amphiphilic resins. 
Dental Materials

Antibacterial activity in adhesive dentistry


Manufacturers

Bisco, Inc., Schaumburg, IL
800.247.3368, www.bisco.com

Den-Mat, Santa Maria, CA
800.445.0345, www.denmat.com

Dentsply Caulk, Milford, DE
800.522.2855, www.caulk.com

Dentsply Ltd., Aaddlestone, Surrey, United Kingdom
44.1932.853422, www.dentsplymea.com

Drogan Pharmaceuticals, Ankara,Turkey
90.312.287.74.10, www.drogan.com

GC America, Inc., Alsip, IL
800.323.7063, www.gcamerica.com

Global Dental Products, North Bellmore, NY
516.221.8844, www.gpdental.com

Heraeus Dental North America, South Bend, IN
800.431.1785, www.heraeus-dental-us.com

Ivoclar Vivadent Inc., Amherst, NY
800.533.6825, www.ivoclarvivadent.us

Kerr Corporation, Orange, CA
800.537.7123, www.kerrdental.com

Kuraray America, Inc., New York, NY
800.879.1676, www.kuraraydental.com

Parkell, Inc., Edgewood, NY
800.243.7446, www.parkell.com

Pulpdent Corporation, Watertown, MA
800.343.4342, www.pulpdent.com

Sun Medical Company, Ltd., Moriya City, Shiga, Japan
81.77.582.9978, www.sunmedical.co.jp

Syntac Coated Products, New Hartford, CT
860.738.2600, www.sytacausa.com

Ultradent Products, Inc., South Jordan, UT
801.230.1420, www.ultradent.com

3M ESPE, St. Paul, MN
888.364.3577, solutions.3m.com

3M Unitek, Monrovia, CA
800.634.5300, solutions.3m.com
Exercise No. 319
Dental Materials

Subject Code 017
The 15 questions for this exercise are based on the article Antibacterial activity in adhesive dentistry: A literature review on pages e346-e356. This exercise was developed by Gustav Gates, DDS, MAGD, in association with the General Dentistry Self-Instruction committee.

Reading the article and successfully completing the exercise will enable you to:
• describe different types of antibacterial agents used in adhesive dentistry;
• understand the clinical applications and beneficial effects of antibacterial agents;
• understand the clinical effects of antibacterial agents in various bonding situations; and
• describe the difference between the two main categories of antibacterial agents.

1. Residual bacteria under restorations have been found to survive and proliferate for more than ____ months.
   A. 6
   B. 12
   C. 18
   D. 24

2. Plaque accumulation on the composite surface is less than that on an enamel surface. This leads to fewer microorganisms around the potential microgap.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.

3. The antibacterial property of self-etching adhesive was short-lived and less effective
   A. because the self-etching adhesive was photocured.
   B. because some bacteria are acid resistant.
   C. due to the buffering capacity of the dentin.
   D. due to a limited amount of application time.

4. Materials that have been used to disinfect the cavity preparation prior to placing the restoration include all of the following except one. Which is the exception?
   A. Tubulicid
   B. Alcohol
   C. Hydrogen peroxide
   D. Eugenol

5. Chlorhexidine gluconate (CHX) has been used for years as a safe antiseptic because of all of the following properties except one. Which is the exception?
   A. Site-specific action
   B. Bacteriostatic at low concentrations
   C. Bacteriocidal at high concentrations
   D. Effect on gram-positive bacteria

6. The antibacterial effect of CHX is attributed to its
   A. cationic activity.
   B. low pH.
   C. high alcohol content.
   D. high solubility in saliva.

7. CHX can lead to longer lasting antimicrobial substantivity compared to other disinfectants. This period of time can be from 48 hours to ____ weeks.
   A. 6
   B. 8
   C. 10
   D. 12

8. Most authors and manufacturers of commercial products recommend the use of CHX as a cavity disinfectant for ____ seconds after etching.
   A. 30
   B. 40
   C. 50
   D. 60

9. The percentage of CHX in commercially available products for cavity disinfection is ___%.
   A. 1
   B. 2
   C. 3
   D. 4
10. Fluoride has been incorporated into restorative materials for its antibacterial effect on *S. mutans*. Another beneficial effect is the inhibition of demineralization of the surrounding tooth structure.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.

11. What is the correct range of prevalence of demineralization around fixed orthodontic appliances?
   A. 10 - 30%
   B. 40 - 60%
   C. 50 - 70%
   D. 70 - 90%

12. The adverse effect of a 2% solution of CHX on self-etch adhesives was related to which of the following?
   A. High alcohol content
   B. Residual moisture
   C. Depth of penetration
   D. Removal of smear layer

13. Antibacterial agents that have been used to prevent demineralization around orthodontic appliances include all of the following except one. Which is the exception?
   A. Methacryloyloxy dodecylpyridinium bromide
   B. Silver nanoparticles
   C. Benzalkonium chloride
   D. Cetylpyridinium chloride

14. Using One Step Plus as the adhesive in a restorative procedure with CHX as a cavity disinfectant, one would expect the effect on the bond strength to be a
   A. negative effect on etch-and-rinse.
   B. negative effect on self-etch.
   C. positive effect on self-etch.
   D. positive effect on etch-and-rinse.

15. CHX gel as a cavity disinfectant had a negative effect on the enamel bond strength of Transbond XT. The enamel bond improved when the CHX was applied before etching.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.
Appliance design and application

Keith A. Yount, DDS, MAGD

Today's dental practice can increase patient satisfaction, as well as profitability, through the use of emerging technologies in the realm of dental appliances. Appliances can aid in an array of pathologies; however, many dentists struggle in their prescription of appliances due to a lack of scientific literature on the devices themselves. Blindly choosing an appliance can create a legal liability; therefore, undergirding selection with accurate information is critical for proper use and quality of care. The aim of this article is to serve as a quick reference for the practitioner in his selection of the appropriate dental device.

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After graduating from dental school, dentists typically have gaps in their knowledge of the extensive list of dental services a general practice can provide, especially in the area of appliances. At best, the four-year curriculum provides limited teaching regarding services that a caring, quality practice can provide. However, in the real world of dentistry, there is a need to provide an expanded number of services to establish a quality practice. In this regard, an inordinate amount of time and money are spent educating doctors on expanded services not covered in dental school.

Dental appliances have become a multimillion dollar industry, including such devices as: Nociceptive Trigeminal Inhibition (NTI) devices (Therapeutic Solutions International, Inc.), soft nightguards, soft/hard appliances, splints, deprogrammers, orthotic and suckdown appliances, retainer-type appliances, neuromuscular appliances, and store-bought mouth guards. These appliances are available for treating parafunction, muscle pain, partial disc displacements, complete disc displacements, and osteoarthritis. However, knowing which appliance to use in a given situation can be challenging (Fig.1). Many postgraduate doctors rely on the one appliance covered in dental school (the soft nightguard), due to a lack of time or money for further exploration of the options available. Or they rely on the one guru-driven appliance stumbled upon in early CE courses and tend to use it indiscriminately for all patients in all situations.

To provide the best service, a doctor must know both the patient and their pathology. As Dr. Mahan wrote in 1991, one must "never treat a stranger in pain by using irreversible therapies." This statement applies not only to understanding the service, anatomy, physiology, and the latest research and science, but also understanding the patient. Until the purpose of each appliance and the science of the pathology being treated are understood, much of the appliance therapy should be referred to a specialist. Each appliance has a specific purpose and it is important to know them well.

Fig. 1. A wide variety of dental appliances.
Table 1. Appliances and their purposes.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Design</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthotic</td>
<td>Passive, flat plane, full coverage, shallow anterior guidance</td>
<td>Reduce joint and muscle pain, reduce parafunction, decrease loading of the joint in osteoarthritis</td>
</tr>
<tr>
<td>Emergency</td>
<td>Retainers, suckdown, Aqualizer®</td>
<td>Reduce muscle recruitment, reduce parafunction, retain teeth</td>
</tr>
<tr>
<td>Acute trauma appliance</td>
<td>Directing appliance, full, hard, used less than one month</td>
<td>Trauma, joint effusion</td>
</tr>
<tr>
<td>Soft appliance</td>
<td>Soft, full coverage</td>
<td>Parafunction</td>
</tr>
<tr>
<td>Soft/hard</td>
<td>Hard out, soft in, full coverage</td>
<td>Parafunction, MPD</td>
</tr>
<tr>
<td>Deprogrammer (anterior segmental)</td>
<td>Segmental, anterior, quick, emergency appliance (NTI &amp; Best Bite Discluder)</td>
<td>Muscle pain and partially displaced disc, help CR bite, emergency and episodic treatment</td>
</tr>
<tr>
<td>Posterior segmental appliance</td>
<td>Covers only posterior teeth</td>
<td>Parafunction, reduce power</td>
</tr>
<tr>
<td>ARS-LVI appliance</td>
<td>Anterior repositioning design, forward bite, bite set by TENS</td>
<td>Relieve retrodiscal pain, change bite</td>
</tr>
<tr>
<td>OTC nightguard</td>
<td>Soft guards, full, heat-adapted athletic guard</td>
<td>Reduce tooth damage from parafunction, athletics</td>
</tr>
</tbody>
</table>

Making an informed decision

Using scientific data as the background for appliance selection is critical to quality of care and practice safety. However, for many years there was a virtual vacuum in scientific knowledge concerning appliances. As recently as 1996, the National Institutes of Health (NIH) reported “little scientific literature exists on how appliances work.” This vacuum created a fertile ground for promoting and selling “magic plastics” that would cure everything as an all-in-one appliance. Successfully, the 1996 NIH paper created a demand for an increased number of studies offering insight into how and why dental appliances work, a greater understanding of which appliances should be used for which pathologies of the chewing system, and the benefits and side effects of each appliance.

A 2003 retrospective study concluded that the problems cited in earlier studies still exist, such as clearly defining both chewing system and multifaceted pathologies, applying uniform descriptions of appliances, using clinical guidelines in measuring results, and lack of standardization of outcomes, which make the results difficult to interpret. Studies also indicate the longer the duration of the pathology, the more difficult it becomes to define successful study results. This is due to outside factors associated with long-term chronic pain such as higher rates of depression, somatization, and health care use, which some patients were not able to cope with as well as patients in the study group.

In a study by Wedel & Carlsson, results tend to emphasize the heterogeneity of patients who have differing factors underlying their particular functional disturbance of the masticatory system. For example, articular disc disorder can result from multiple factors such as clenching, muscle tension, bite discrepancies, traumas, muscle splinting, dual bites, subluxation, and even cervical muscle hyperfunction. Three different appliances (the nightguard, orthotic, or deprogrammer) may be effective in cases involving pure clenching or grinding at night (that is, with no pain or joint damage). It is important to understand—as recent scientific studies have made clear—appliances do have side effects. They are not benign tools and they have the potential to damage other parts of the chewing system. Both scientific and legal case literature show appliances can be and are being used inappropriately or indiscriminately.

The practitioner must properly critique the current literature to make an informed choice. This article offers a review of the literature with the goal of indicating the correct usage for each appliance.

Reviewing choices

Dental appliances need to be evaluated from a scientific perspective. An appliance is deemed correct if it fulfills a chosen purpose without significant side effects. Not only should the right appliance be used for the right purpose, but the provider should never imply or hint that an appliance can deliver more than it was designed to do. This is particularly true when dealing with dysfunctional patients who often have unrealistic expectations of what an appliance can provide.
The choice of orthotics from a sampling of U.S. general dentists in 1995 included: 14% soft night-guards, 59.4% hard appliances, and 26.1% varied in selection of appliances. A 2011 survey reported that 43.04% of dentists chose a stabilization splint for treating bruxism (not including jaw pain or restricted openings), while 8.63% utilized an unadjusted hard splint, 7.28% employed a soft splint, 5.22% utilized an anterior repositioning splint (ARS), and 1.2% used a reflex splint with anterior ramp.

Table 1 defines the various types of appliances and their purposes.

Orthotic appliances

The orthotic appliance is a passive, hard appliance with a flat plane in the posterior, evenly supported posterior contacts, and shallow anterior guidance (slope). The orthotic was developed as part of orthopedic therapy to treat significant pain and dysfunction of partial displaced disc cases, complete displaced disc cases, and osteoarthritis (Fig. 2). Orthotics can also be used for simpler chewing system damage cases (such as chewing muscle pain and nocturnal bruxers/clenchers), on destructive bruxers for protection, to protect temporary crowns and bridges, reduce pain in jaw joint damage, help achieve an accurate bite, and help with many chewing system pathologies.

An example of orthotic use is with patients who have dystonia of the jaw. Dystonia is a movement disorder that causes the muscles to contract and spasm involuntarily. In these cases, an orthotic can be used to protect the teeth. The orthotic is essential in osteoarthritis cases to decrease the muscular loading of the joint; however, the accuracy required in the placement of the appliance goes beyond the standard training and skills taught in most orthotic didactic courses or participation courses. An orofacial pain resident spends 2-3 years in training for the appliance use in osteoarthritis cases.

Popular literature promotes the misconception that the orthotic is the “magic plastic” appliance. Simply stated, the orthotic was one of the first appliances created to protect the joints and muscles from parafunctional damage at night. One of the problems in analyzing the effectiveness of orthotics is determining their main functions or benefits. Is the goal pain relief, reducing parafunction, or fixing the dysfunction? Does it stop clenching? Does it have a positive effect on occlusal relationships, tooth position (retention), tooth wear, jaw joint loading, and so forth?

Many scientific studies on dental appliances, especially the early ones, are unclear in terms of the definition or design of the appliance used, type of treatment utilized, sample size, or the study’s definition of success. In a 1992 study of disc displacements without reduction, Lundh et al indicated that there was no significant benefit of patients treated with an orthotic (a flat occlusal splint) over control subjects with no orthotic treatment. If perceived fatigue, pain, sleep dysfunction, and anxiety are primary targets for muscle-based pain, then management of these factors would be the primary interventions. None of these factors are actually related to the performance of the appliance; this suggests the orthotic may not cure all the aspects of pain associated with articular disc disorders. However, in a 1978 study by Carraro & Caffesse, the use of only an orthotic (full-coverage occlusal splint) improved both pain and dysfunction symptomology.

If a patient has jaw pain and is a significant grinder or clencher at night, the orthotic appliance will provide some pain reduction. A 2011 study by Badel et al found that orthotics reduced pain in 83% of the cases examined, which echoes the 1998 study by Ekberg et al that reported a reduction in pain due to orthotic use.
In restricted opening cases, the orthotic has been purposed by some to recapture the disc.\textsuperscript{15} In actuality, the orthotic may assist with relaxing the superior lateral pterygoid muscle, but as stand-alone therapy, it is not likely to provide enough muscle relaxation to recapture the disc. It would have to shorten the lateral ligament to the disc and repair the retro-discal elastin tissue to affect such an outcome, which is unlikely to work as a stand-alone appliance or therapy. In a 1991 study, Kirk observed the orthotic did reduce inflammation in the joint and joint loading, and did improve movement (disc condyle translation), but concluded that, “the concept of disc capture is a clinical term only, and does not indicate that an actual change in intra-articular anatomic relations has occurred.”\textsuperscript{14}

The challenge in determining the effectiveness of an orthotic appliance comes from the fact that articular disc disorders, myofascial pain dysfunction (MPD), bruxism, and osteoarthritis are different multi-factorial pathologies. For example, a 1984 literature review reported a 90% success rate when using orthotics and occlusal therapy to treat temporomandibular joint disorder (TMJ); however, a mixture of treatments were utilized and the specific role of the appliance in treatment was indistinct.\textsuperscript{15} Even when the focus is on a single variable, the actual effectiveness may be hard to gauge, since some factors (such as clenching) vary from day-to-night, from night-to-night, and even from person-to-person. Clenching can occur both day and night. As a result, an appliance worn only at night may not address the complete problem.

Since the 1980s, science has tried to document the effectiveness of the orthotic for treating disc displacements, osteoarthritis, MPD (jaw pain), jaw dysfunction, dystonia, destructive bruxism, and even restorative cases with difficult bite.\textsuperscript{16} A wide variety of pathologies can affect a specific joint. To achieve usable results, the definition of the pathology must be clear.

The widespread effectiveness of orthotics for relieving myofascial pain (that is, pain in the chewing muscles) is indicated in two separate reviews of literature by Clark and by Major & Nebbe.\textsuperscript{17,18} These reviews show that many studies report the effectiveness of orthotics in relieving symptoms of pain and dysfunction.\textsuperscript{17-37}

A 1998 study by Canay et al reported an orthotic produced no change in electromyography (EMG) from maximum biting but did reduce complaints of pain significantly. In this study, the defining success via “lower pain perception reports” was a problem in analyzing the effectiveness of orthotics.\textsuperscript{28} In a 2010 meta-analysis, Fricton et al examined 44 random controlled trials (RCTs) and found that the orthotic improved jaw joint/muscle pain compared to no treatment at all or treatment using non-occluding appliances.\textsuperscript{39} Conversely, Okeson reported that EMG activity decreased for most patients wearing orthotics.\textsuperscript{36} Dahlström et al found that patients who either used an orthotic or underwent biofeedback demonstrated equal reductions in terms of EMG activity.\textsuperscript{41}

The orthotic reduces the power of the bite by opening the vertical. Maximal clenching on an occlusal splint is significantly lower than the maximum bite in tooth contact position.\textsuperscript{29} The maximum power occurs when teeth make maximum contact; opening the bite with a piece of plastic will reduce the power, which is why different appliance designs may provide some or slight benefits in muscle/joint related cases. The studies of occlusion, sleep, and EMG in appliances with proper anterior guidance of the orthotic produced the least muscle recruitment.\textsuperscript{42} Other studies have reported that an orthotic reduces EMG activity in bruxing patients.\textsuperscript{33-47} Elsewhere, it has been reported that an occlusal orthotic tends to reduce the level of EMG activity in masseter muscles during maximum clenching.\textsuperscript{28,44,48,49}

Different parameters, such as the length of time of a particular study, can affect a study’s results. Kovaleski & De Boever reported that orthotics reduced muscle activity, but it took days or even weeks before the reduction in symptoms were apparent.\textsuperscript{50} To properly evaluate the success of any one particular study, the pathology must be clearly defined. A 2003 study by Ekberg et al reported that an orthotic was more effective in myogenous cases than in disc displacement cases.\textsuperscript{34}

In a critical evaluation, Clark reported that orthotics offered 70%-90% effectiveness in treating joint muscle damage cases.\textsuperscript{17} More recently, Kuttila et al reported a reduction in clinical signs when an occlusal splint was used by individuals with osteoarthritis (secondary otalgia was reduced as well).\textsuperscript{51}

The non-directive, passive, reversible, flat-planed, and shallow anterior guidance orthotic is used to protect muscle and joints at night, but it can protect other structures of the stomatognathic system as well, particularly the teeth and tooth bone. One of the great benefits of the orthotic is that the units are reversible and conservative. The ADA presently recommends using reversible therapy for joint muscle pathologies. Many authors using reversible therapy place the effectiveness of the orthotic at higher than 70%.\textsuperscript{34,52-54}
The orthotic is one of the few appliances that require anterior guidance, which can range from steep to shallow, rough to smooth, and short- to full-range motion, all of which can make assessing the success of treatment difficult. This pattern of equal posterior tooth contact and shallow anterior guidance on the canines and centrals causes a progressive shutdown of power as it goes further into lateral or protrusion distance (Fig. 3).42,55 The overall largest percentage of patients (87%) had some degree of improvement in TMD symptoms (joint sounds or jaw pain) with an orthotic.32

Suvinen & Reade found that the stabilization of occlusal patterns was a good indicator of successful treatment in most patients with orthotics.36 Beard & Clayton used a pantographic reproducible index and found that the muscle activity in chewing muscles decreased with orthotic use.33 A study by Santander et al found the orthotic reduced EMG activity in cervical muscles.57 A 2008 study by Nascimento et al reported that wearing an orthotic for 60 days significantly decreased TMD signs and symptoms among sleep-bruxing patients.58 Other studies have reported that orthotic use reduced EMG activity in the right and left temporalis during maximum clenching, and in the anterior temporalis by inserting a well-adjusted splint.33,59,60 The literature has indicated that the longer symptoms were present, the longer it took to achieve results with an orthotic.33,35

It has been discovered that the orthotic can also reduce intra-articular pressures (IAPs). Nitzan et al found that clenching teeth creates an increase in pressure inside the jaw joint that stops the flow of nutrients into the jaw. The author measured IAP in 28 females and 7 males. The pressure inside the jaw joint ranges on open mouth were from -10 to +30 mm/Hg, while the pressure inside the joint on clenching teeth ranged from 20 to 200 mm/Hg (the highest readings were in females, which could help explain the considerably higher proportion of women with TMJ problems); while the maximum pressure inside the jaw joint when clenching on the orthotic ranged from 0 to 40 mm/Hg.61,62 The center of the TMJ disc has no blood vessels and receives its nutrients from diffusion via an efficient lubrication system involving phospholipids.63 A problem arises in dysfunctional TMJs after clenching is released, when a sudden rush of oxygen back into the joint space produces free radicals that cleave the lubricant molecules, which produces friction between the articular disc and the fossa.63,64 This may be a major causative factor in articular disc displacement.63

In the past, the occlusal splint was thought to stop parafunction (for example, clenching and grinding). The orthotic has now been purposed to reduce clenching or grinding at night, as well as offering some protection against damage from bruxism, and in most cases this has been proven.35,58,65-67 For example, a 1984 study found that of the subjects wearing orthotics, nocturnal muscle activity was reduced in 52%, increased in 20%, and 28% of the subjects reported no change.66 In a 1993 study involving 31 patients, Holmgren et al reported that 61% still clenched or ground teeth at night after orthotic therapy, indicating the continued need for some sort of protection.65 One must remember that the design and accuracy of the appliance does affect the outcome.

In a small percentage of cases, the orthotic can actually increase parafunction activity. Clarke et al reported that 20% of subjects reported an increase in neuromuscular activity.66 This result of the increase in clenching can cause havoc in determining success when using an orthotic. The increase in clenching occurs in all appliances; some appliances may cause more of this effect than others.67 This possible increase in clenching reinforces the need for multifaceted treatment of articular disc disorders from several different angles, including the use of an orthotic. These studies reveal that the orthotic is not the “magic plastic” appliance because parafunction activity (clenching is the most prevalent type) may occur during the day or night.65-67 However, by placing an appliance that wears quicker than enamel, the orthotic offers protection of the teeth.65-67 This is not the primary purpose of the orthotic, but is a positive side effect.

In cases where occlusal trauma is suspected as the reason for tooth pain, the orthotic can provide reversible evidence of the cause and effect (diagnosis and recommended treatment). One should avoid the temptation to use a bur to make occlusal or crown/bridge adjustments, as a prolonged open mouth procedure might have been the cause of increased pain or discomfort in teeth.

Some doctors find the reversibility of the orthotic offers some legal protection in cases of jaw pain where a dysfunctional (and possibly litigious) patient might otherwise
receive equilibration, orthodontics, or reconstruction: If the orthotic cannot reduce the pain, the dental effort is unlikely to resolve it either. Making this discovery at an early stage stops the dentist from promising relief from alteration of tooth structure that may not be attainable. The orthotic reduces the damage resulting from the prolonged repetitive loads of parafunctional activity on teeth; such activity can lead to traumatic damage and pain. The overall interpretation of the scientific literature suggests that the orthotic is an appropriate appliance for reducing damage to the joint muscle complex due to nighttime parafunctional activity. The orthotic, along with an NTI (deprogrammer), appear helpful in achieving centric relation (CR) (jaw joint bite) in a few rare cases where the jaw joint instability disallows proper centric occlusal (CO) position. Most dentists who challenge CO (that is, tooth bite) by restoring many cases are familiar with measuring CR against CO in a small percentage of cases, yet the subject of CO is not covered in most dental schools. A great deal of literature on CR=CO is found in the post-dental school education of Spears, Pankey, and Dawson, especially the latest edition of Dawson’s book, Functional Occlusion. When the jaw joint is pulled downward/forward to fit the tooth-protected bite, the muscles have to splint the condyle on the slick incline. It is analogous to holding a bowling ball on a slanting board with oil on it. When the jaw muscles are recruited to hold any position for a period of time, the chewing muscles will eventually fatigue, lactic acid builds up, and pain results. The value of measuring CR against CO seems to be related to the size of the difference and the amount of clenching (parafunction) in CO (Fig. 1 and 2). A small difference (0.01 mm) is not significant enough to cause much muscle splinting, but a large CR=CO difference (3 mm) will produce a significant amount of muscle splinting. In other words, muscle activity increases as the difference between the ideal jaw joint position and the tooth protected bite (CR and CO) increases. An ARS or neuromuscular appliance would increase the CR and CO difference, thus making the problem worse; therefore, a moderate to large CR and CO difference is definitely a contraindication for a neuromuscular appliance or ARS. The multifactorial nature of muscle and disc displacement cases means that a dentist must consider more than jaw joint position and the tooth protected position when determining what aggravates the chewing system. Again, one factor alone, such as the measurement of CR against CO, usually needs to be combined with other muscle recruiting activities in order to fully breach the adaptive capacity of the chewing system. If the patient experiences tension in chewing muscles, clenches, cervical hypercontraction, muscle splinting, or bite inefficiencies, measuring CR against CO may overstimulate the chewing muscles, overload the jaw joint, and result in pain. The teeth are hotwired to the brain to control the chewing muscles and therefore the brain can use its memory in engrams to control the tooth-protected bite. The orthotic binds the teeth together, intercedes between contacting teeth, and alters the ability of the teeth to control the muscles. The use of the orthotic improves the jaw joint’s ability to direct the muscles to the bone-braced position (that is, CR), which anatomically refers to the most posterior superior position of the jaw joint. The anatomical description does not adequately define CR.

The CR position is where the least muscle activity occurs and the ideal position for the jaw joint to reduce muscle recruitment at night. The fifth nerve is much larger than the other cranial nerves because it contains the bundles of fibers from the plexus of nerves around all 28 teeth and combines with the other important head structures it innervates. The teeth have power over muscles to control the tooth-protected bite because the teeth are so important to survival. Therefore, a person’s teeth being hotwired to the brain may be viewed as an evolutionary advantage. The orthotic can redirect or deprogram the muscles or dissipate muscle activity by allowing the jaw joint to go to the position where there is the least muscle activity and allows those muscles to be controlled more by the jaw joint.

The majority of patients have a difference between CR and CO that is small enough not to worry about, but in a few patients, the difference is large enough for the case to fail in terms of patient comfort. If a crown and bridge case succumbs to jaw pain, it must be managed appropriately with an orthotic and orthopedic therapy.
Orthotics can be used for other purposes, such as: allowing dentists to test patient comfort following an increased vertical dimension; removing occlusion from a cracked tooth (thus relieving pain); determining if parafunctional activity has injured a tooth (thus ruling out occlusal trauma and avoiding the need for root canal surgery); assessing the patient’s psychological stability during the adjustment stage; protecting porcelain crowns, bridges, or implants from bruxism/bracing damage at night; resisting tooth movements or retaining teeth after braces (especially in cases where bruxism/bracing exists or in jaw damage cases); managing tension headaches; tracking condylar bone loss in osteoarthritis cases; and protecting teeth in dystonia. Table 2 summarizes the benefits provided by an orthotic.

Emergency appliances
Some appliances may serve as an emergency tool for acute jaw pain (that is, joint or muscle pathologies). Like medications, these emergency appliances have specific purposes (primarily to deprogram muscles and decrease muscle activity) along with side effects. Emergency appliances can be produced quickly and inexpensively for treating sudden onset muscle pains, simple partial disc displacements, or minor traumas. The primary purpose of emergency appliances is to decrease muscle activity or deprogram muscles.

Deprogrammers
The word deprogrammer refers to an appliance used to reduce the use or recruitment of muscles, leading to reduced muscle inflammation and pain. The insertion of an NTI in bracing patients leads to significant reduction in EMG activity of the jaw-closing muscles. The deprogrammer is an anterior segmental appliance or piece of plastic placed in the front of the mouth to keep back teeth apart (Fig. 4). Deprogrammers have been used for years in orofacial therapy for emergency cases involving muscle pain. In orofacial pain therapy, the use of the deprogrammer in emergency pain cases is preferred to the orthotic for long-term care (Fig. 5). In a study by Van Eijden et al, clenching on the incisor teeth resulted in significant decline in EMG activity as compared to clenching in maximum contact of teeth. Published research concerning deprogrammers primarily involves case reports such as the 2010 report concerning a 61-year-old whose short-term jaw pain was relieved by using the deprogrammer. In cases involving osteoarthritis or completely displaced discs, emergency appliances will increase joint loading on the condyle. This loading presses on the innervated retrodiscal tissue, thus increasing jaw pain.

According to McKee, one can test a deprogrammer on a completely displaced disc by load testing the jaw joint to confirm that the condyles are not pressing on retrodiscal tissue. One dilemma is that load testing a jaw joint is not part of the formal training in dental school. To avoid failure with a deprogrammer, practitioners should initially inform the patient it is a diagnostic device to differentiate the partial displaced disc from the complete displaced disc. A deprogrammer will fulfill its purpose if it increases the pain in the joint pain case, helping diagnose a completely displaced disc.

The deprogrammer can also help define the proper bite to manufacture and deliver the large bridge in moderate difficult bite cases. For instance, if the lateral pterygoid is not relaxed enough to give the proper bite for
manufacturing a second molar crown/bridge, a deprogrammer may be enough to relax the muscles.

When a deprogrammer is used 24 hours a day for extended periods, one side effect is the separated posterior teeth can supererupt. This happens when the patient fails to follow directions on the proper times to wear the device. A recently disclosed side effect of a specific deprogrammer, an NTI device, is its ability to relax the lateral pterygoid in cases where the jaw joint bite and tooth bite are different enough to measure setting up open bite by contact on second molars.

Relaxing the lateral pterygoid may create the illusion that the bite has changed: It really is just highlighting the difference between the jaw joint and the tooth bite (CR against CO), in which the majority of individuals do not have a measurable difference. The inexpensive nature of the appliance and its ease of learning are important considerations in its use.

The former deprogrammer was developed into a prefabricated deprogrammer called an NTI (Fig. 6). The prefabricated deprogrammer is realigned chairside to perfect the fit in relatively little time. Two other prefabricated deprogrammers, the Best Bite Disccluder (Whip Mix, Contemporary Product Solutions) and the Kois Deprogrammer (Aztec Orthodontic Laboratory, Inc.), use plastic on the front teeth to disclude posterior teeth, which deprograms the chewing muscles while preventing clenching and grinding.

Both of these appliances allow full range of motion and any particular closure pattern as does their cousin, the NTI. According to a 2001 study by Shankland, the NTI and the orthotic were equally beneficial at reducing clenching, which in turn reduces headache symptoms.

The NTI and the other deprogrammers can help deplore the chewing muscles to reduce muscle pain. In a 2005 study by Jokstad et al., two splint designs were produced: an ordinary stabilization (Michigan type) and an NTI. The splint and the NTI were equally successful at reducing muscle, joint, and head pain.

Muscle inflammation is created by over-use, over-recruitment, or over-stimulation of the chewing muscles. By reducing clenching, reducing power of muscles, and deprogramming muscles, the NTI has a great effect on muscle pain.

Deprogrammers are best for cases involving excessive muscle recruitment and simple partially displaced discs. According to Helkimo, the NTI is superior to other appliances when treating MD, only because of its ease of fabrication.

There are always psychosocial issues that can cause compliance issues or NTI failure. Several studies have reported that a deprogrammer such as an NTI significantly reduced muscle activity. The NTI and other deprogrammers have been marketed for treating bruxism, TMD, tension headache, and even migraines. However, a 2004 study was unable to find evidence for all these claims. A study of Best Bite Disccluders by Goldstein & Gilbert reported that NTIs reduced the severity and frequency of migraine pain from a score of 6.6 to 3.3 on the Visual Analog Scale (VAS). There are few studies concerning deprogrammers (especially in terms of testing specific deprogrammers) on reduction of headaches. By understanding the contribution of muscle inflammation in the pathophysiology of headaches, it makes sense that the deprogrammer could help in some of these cases. It is naive to think the deprogrammer would completely alleviate some headaches, especially as a stand-alone therapy, due to multifaceted sources of the inflammation and many different types of headaches.

Deprogrammers reduce muscle recruiting, especially in the lateral pterygoid, which allows the condyle to seat more in its fossa. In a small percentage of cases where CR does not equal CO, the jaw joint seats more superior and posterior in the fossa, which causes the second molars to pivot off second molars and sets up an anterior open bite (Fig. 6). For moderate to difficult bite cases, the deprogrammer helps determine the proper bite so that a large bridge can be manufactured and delivered accurately. The deprogramming of muscles by the deprogrammer makes the Dawson bimanual technique of load testing and getting CR bite easier to perform. It is well known that errors in recording the terminal transverse horizontal axis can lead to significant errors in occlusion. Enough patients present with muscle tightness, tenderness, or overcontraction to warrant consideration of MPD/TMD as pathologies in the patients’ population.

If a disc is in proper position with the joint, and the joint can be loaded, the deprogrammer can help to relax chewing muscles by...
changing the terminal hinge position. Even though cases in which CR and CO do not match are rare, they occur often enough to need deprogrammers to assist at bite determination in the evolving world of reconstruction (crowns and bridges). In reconstructive dentistry, a few patients are assumed to have a discrepancy between CR and CO that a deprogrammer may reveal during the course of managing TMD/MPD or large reconstruction cases.

For cases of emergency muscle pain, emergency appliances such as suckdown (Fig. 7), Aqualizer (Fig. 8), and other prefabricated emergency appliances may be acceptable. The suckdown appliance is made on a model of the patient with all the cusp and fossa relationships and interferences reproduced in the appliance. The primary purpose for the suckdown is tooth protection in parafunctional situations, but many orthodontists use these for retainers. The side effect, due to reproducing interferences (walls of fossa), is increased muscle activity in clenching. If the bite inefficiencies are a small factor for excessive muscle use, the suckdown will not be effective in reducing muscle activity.

One benefit of the suckdown is the ease of making the appliance and the ease of insertion to the patient. Another benefit is the lower cost. Patients also readily accept it due to its thin nature and its similar contours to teeth.

Suckdown appliances are good as tooth protectors and retainers. By molding an appliance to the position where the teeth should be positioned, the suckdown device will help to keep the teeth in place. The reduction in power due to opening bite is minimal since the appliance is very thin. The suckdown appliance can be converted into an orthotic by adapting acrylic precisely to the appliance, but the cost of conversion is not cost effective. The suckdown appliance may be ineffective as partial disc displacement therapy due to its duplicaton of lateral guidance interference, its duplication of poor anterior guidance patterns, and its continuation of clenching; thus, the muscle recruitment deprogramming has not been accomplished.

Aqualizer®

Aqualizer® is a self-contained, disposable splint filled with fluid that can shunt from one side to the other for equalization. It is a ready-to-use, prepackaged appliance for treating MPD/TMD pathologies and for emergency situations involving mostly muscular jaw pain (Fig. 8). A layer of fluid is used to separate the posterior teeth, cushion the bite, and reposition the jaw to produce a more adaptive bite. The appliance was designed to achieve even pressure on both sides of the arch. For muscle cases, this helps to reduce uneven muscle activity due to even posterior contacts; the even pressure from side-to-side and tooth-to-tooth helps to reduce the irregular muscle activity. Like the soft splint, the Aqualizer® still has posterior lateral interference that increases chewing muscle activity. Like a soft appliance, it increases joint loading and produces some increase in muscle activity.

Practitioners and patients should be aware that the Aqualizer® will increase pain in complete disc displacement. In addition, it can rupture in cases of destructive bruxism. Its use is limited due to its ability to help only in muscle cases and also due to the difficulty of patient retention, particularly in cases where the patient has an anxious or nervous tongue.

Athletic guards

Some medical doctors and young dental graduates with a limited knowledge of jaw problems may recommend that a patient purchase a soft over-the-counter (OTC) athletic guard for joint muscle pathologies; however, they were created primarily for tooth protection. The athletic guard is also bulky, which can irritate gums, the tongue, and...
cheeks. Besides the production errors found in any OTC product, an athletic guard may be difficult to keep in place or may not fit the patient’s bite properly. One of the primary benefits of an OTC athletic guard is its low cost. One of its potential negative side effects is relying on patient-directed care, using a tool that may not target the real problem due to incomplete diagnosis. The soft and compressible athletic guards introduce interferences that increase muscle activity and loading of joints (Fig. 9). Whether due to mass production manufacturing errors, the increase in clenching, or the patient acting as doctor with self-directed treatment, the soft athletic guard has a high failure rate as a jaw joint pain appliance. The waste of money and the frustration for the patient is definitely one of the athletic guard’s most negative attributes. Occasionally in an acute muscle pain case, the soft athletic guard interferes with the trauma to teeth enough for the patient to perceive a reduction in discomfort.

The favorite reasons for using emergency appliances are in helping reduce urgent care pain, ensuring less dependence on pain medicines, and the convenience of a fast approach. Emergency appliances are quick (used on the same day), effective (on muscle-based pain), acute (usually used for only brief periods of time), and cheap (as compared to full coverage appliances).

**Acute trauma appliance**

The emergency appliance used for significant acute trauma to the jaw joint is a short-term anterior repositioning appliance. Its primary purpose is to manage pain associated with pressure on retrodiscal tissue in part due to swelling (significant inflammation) in the temporomandibular joint, similar to the treatment of a swollen ankle. The purpose of an acute trauma appliance is to reduce pain without using opioids (Fig. 10). This anterior repositioning appliance pulls the condyle down and away from inflamed retrodiscal tissues. When incorporating steroids, muscle relaxants, and physical therapy, the emergency anterior repositioning device can effectively reduce acute trauma pain in the jaw. The biggest side effect of the anterior repositioning device occurs when the appliance is not stepped back fast enough or is left in the anterior position too long, causing overgrowth of retrodiscal tissue (permanent posterior open bite) making it impossible to return to CR.

Many patients with acute pain in their jaw joints will go to an emergency room for relief of the pain. However, most ER doctors do not fully understand acute trauma to jaw joints and may fail to refer the patient to a specialist in a timely manner, setting the stage for limited use of emergency appliances. A trauma to the jaw causes acute fluid retention in retrodiscal tissue that pushes the disc and condyle downward and forward, so an indication of jaw trauma requires the need for not only timely referrals but also the use of an acute trauma appliance.

**Soft appliances**

Another group of appliances are soft full-coverage appliances (Fig. 11). The majority of dentists use the word *nightguard* to refer to these professionally made appliances; however, the term has been overused to refer to OTC or Internet-ordered soft appliances. True nightguards are full-coverage appliances made with
soft material that can be fabricated by a dental office or laboratory. The grinding of teeth at night is a highly destructive behavior and there is a great need for recommending tooth protection or preventive dental services to this group of patients.\textsuperscript{99} Studies have estimated that 15%-90% of the population suffers from destructive forms of parafunction (such as clenching, grinding, tooth brace, and so forth).\textsuperscript{90-92} Bite forces are much greater during nocturnal activity compared to daytime mastication.\textsuperscript{93} The initial benefit of the soft appliance is its ability to interfere with the power of the grinding of teeth at night. The second benefit of the soft nightguard is to protect the teeth from the destructive wear caused by parafunctional habits.\textsuperscript{94} In 2000, Halachmi et al reported that soft splints were more efficient than hard splints in protecting teeth against damage, despite an increase in compressive force.\textsuperscript{95}

As with comparable dental appliances, the soft nightguard can interrupt muscle activity by interfering with occlusal contacts.\textsuperscript{96} In most cases, the soft nightguard increases lateral interferences due to its compressibility, which in turn increases muscle activity in lateral movement. In addition, a 1987 study reported that a soft nightguard did increase EMG activity in the majority of the patients.\textsuperscript{97} The soft nightguard was more effective for palliative treatment of muscle pain.\textsuperscript{98} In a 1998 study, Pettengill et al found that both soft and hard appliances were effective at reducing muscle pain.\textsuperscript{98} According to Quayle et al, a soft nightguard can even help to reduce tension headaches. When the soft nightguard reduces parafunctional power, it could in turn reduce most of the inflammation in the temple muscle, reducing the pain from tension headaches while increasing EMG activity.\textsuperscript{99}

In a study of soft appliances versus medications, the soft appliances reduced tenderness of muscles and improved mouth opening more than medications.\textsuperscript{100} The soft nightguard may have a periodontal benefit as well, by reducing the lateral forces that could lead to cervical erosion, recession, mobility, or cracking of teeth.\textsuperscript{100}

The biggest complaint about professional soft nightguard appliances is that they are hard to wear due to their bulky nature. The biggest side effect is its inability to disclude the posterior surfaces in lateral and protrusive movements, which increases muscle recruitment.\textsuperscript{95} Soft appliances can be problematic as severe grinders or bruxers can chew through the soft full coverage appliance in a short period of time. On the plus side, soft nightguards are easy to insert and were one of the first appliances used in dentistry. This is the best appliance for parafunction teeth protection due to low cost, ease of production, and ease of delivery.

**Soft/hard appliances**

The recently introduced soft/hard appliance has a hard top and a soft thermoplastic inside surface. Due to ease of delivery to the patient, such appliances reduce delivery time and hassles for the doctor. The occlusal surface of the appliance is hard plastic that allows for adding acrylic to the surface to perfect the contact of the teeth in order to achieve muscle recruitment reduction and decrease loading of jaw joint. The inner surface (adjacent to teeth) is firm thermoplastic material that allows for ease of delivery due to its heat-adaptive quality. This appliance is designed to combine the best of both worlds of soft and hard appliances.

The downfalls of soft/hard appliances include the following:

- A thin, hard outer surface that does not have much room for reducing plastic in cases of adapting to opposing tooth contacts that are not even or equal. The only way to get somewhat ideal contacts in the posterior is to add acrylic. Therefore, this limitation reduces versatility in perfecting the occlusion on the appliance.
- The perfection of the occlusion is more difficult due to the slight compressibility of the soft inside of the appliance.
- Another problem with a soft/hard appliance is if the first insertion of the appliance reveals an instability (pivoting or rocking), it must
be remade because it cannot be relined. Skilled impressions and proficient lab work reduce the chances of this happening, but at times it does occur.

- A fourth problem that occurs is when the patient bites in maximum intercuspation when the goal is to deliver the appliance in centric relations (jaw joint bite). If the opposite arch occlusion is too far off, the thin hard surface and the need for major additions are too difficult to overcome. In this case, the appliance has to be remade. The management of fit and occlusion on a completely hard splint is an accomplished skill that requires major training in order for the appliance to achieve all its purposes, but on an appliance with some compressibility it can be nearly impossible. It is believed the degree of accuracy needed on the appliance goes up as the instability in the jaw joint goes up. This might indicate that the soft/hard appliance is not well-suited for the complete displaced disc or osteoarthritis. No studies are available to confirm this proposition.

The beauty of the soft/hard appliance is that in patients with irregular wear of the appliance, the adaptable inner surface allows for the micro-movements of the teeth and the appliance still fits. The hard material on the outside means a longer life for the appliance due to its resistance to the grinding forces of the chewing system. In addition, this appliance is less compressible than a soft nightguard, increasing its ability to be more accurate on the occlusion, which could help in some muscle cases. Another benefit of soft/hard appliances over soft appliances is their improved adaptability for changes to the anterior guidance, which occur in a small percentage of cases that have CO and CR discrepancies large enough to increase chewing muscle activity. In these cases, there is a need to add acrylic to the front aspect of the appliance.

The main drawback to soft/hard appliances is that, like soft appliances, they aid in some muscle cases but are not very effective in joint damage cases. The posterior discusion on movement would not be adequate enough in all cases for significant jaw joint instabilities such as osteoarthritis or complete disc displacements. Unless the exact status of the disc position is known, the concern for the soft/hard appliance would be using it on a joint muscle case that is more complex than it appears at first. However, the soft/hard appliances can be used for parafunctional cases, muscle-based cases, and even some simple early partial displaced discs.

**Segmental appliances**

Segmental appliances only cover a partial aspect of the occlusal table (Fig. 12). The segmental appliance can be divided into anterior and posterior segmental devices. The anterior segmental devices are also known as deprogrammers.

The posterior segmental appliances cover both sides of the arch, but only posterior teeth. The posterior segmental creates the bite-reducing power with an increase in vertical from the acrylic. These appliances allow for posterior interferences due to the lack of anterior guidance while increasing muscle recruitment in lateral and protrusive movements. The combination of reducing power and increasing muscle activity may equal small improvement in patients with muscle pathologies. The posterior segmental appliance increases joint loading, making it inappropriate for compromised joint tissue pathologies (that is, completely displaced discs or osteoarthritis). They could be used as posterior retainers, provided the anterior teeth are stable and the posterior teeth are not involved.

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Fig. 12. An example of a segmental appliance.

Fig. 13. Long-term wear of ARS produces posterior open bite that must have the occlusion corrected post-ARS. In this case, they have used a partial to restore the occlusion that was changed with ARS. Left: A patient with a posterior open bite wearing an ARS. Right: The same patient without the appliance.
periodontally. A posterior segmental appliance worn constantly (that is, 24 hours a day, seven days a week) can change a patient’s bite by anterior tooth eruption or posterior tooth intrusion. The bite changes occur most often when the patient falls out of care and “forgets” instructions to wear it only at night or for short periods of time. This is especially true in psychologically challenged patients who are not able to listen to or follow instructions, and as a result may be surprised and angry when their bite changes. The posterior segmental can serve as an acceptable parafunctional appliance (Fig. 13). However, clinical observation indicates the posterior segmental is usually less effective at reducing muscle pain than an anterior segmental appliance.

**Anterior repositioning appliance**

The ARS (anterior repositioning splint) reduces pain by repositioning the condyle downward and forward (occlusal splint) reduces pain by repositioning the condyle back under the center of the joint space, and redundant retrodiscal tissue. A 1990 study reported significant reductions in patients’ jaw pain, temporal headaches, and ear pain in disc displacements with reduction; however, 40% of patients experienced joint symptoms after ARS treatment. In addition, while ARS devices can be used to treat partial disc displacements, these constitute only a percentage of MPD/TMD cases. In a study by Hoffman & Cubillos, they found 67% were disc displacement with reduction, 22% were disc displacement without reduction, and 10% were osteoarthritis.

Using an arthrogram study, Tallents et al found that 15% of cases continued to experience displaced discs even after ARS treatment. One must consider that the failure of ARS may be due to inadequate understanding of disc status due to the lack of a clinician’s examination before treatment, inadequate management of the two most prominent causalgia of articular disc disorder (parafunctional and tension in muscles), or the anterior displacement of disc tissue loses its biconcave shape over time. The Gelb appliance, one of the original ARS appliances, was marketed and dispensed before the NIH paper of 1996. The Gelb appliance survived for a number of years by clinical marketing pressure and the fact that appliances do not have to be studied before entering the market (that is, they do not go through double-blinded, randomized, scientific experiments). The Gelb appliances had a negative effect on posterior open bite and redundant retrodiscal tissue. Extended wear of the ARS over time resulted in permanent bite changes (positioning condyle downward and forward), new condylar position, increased posterior superior joint space, and redundant retrodiscal tissue. The reasoning behind the use of the Gelb appliances was that recapturing the disc was a higher priority than the other symptoms, especially long-term pain.

The ability to recapture a partially displaced disc depends on the extent of joint damage, how much of the lateral ligament is torn, or how soon the click occurs on opening. A 2002 study reported that the ARS was effective 83% of the time at recapturing a lateral pole displaced disc, compared to 50% success in recapturing a middle displaced disc and no success in recapturing a completely displaced disc. In fact, in the Kai et al study of 15 ARS cases, of the 10 patients reviewed post-treatment with arthroscopic evaluation, only 4 actually completely recaptured. Interestingly, the theory to recapture as a success criteria was incorrect and the ability of the ARS to recapture disc was wrong. In 1988, Lundh et al chose 63 patients with anarthrographic diagnosis of disc replacement with reduction to carry out their ARS study; they found that not all discs were recaptured.
ARS devices were designed to remove the click in cases with lateral pole partially displaced discs. If the disc was only partially displaced in the anterior and medial direction, the ARS might recapture the lateral pole portion of disc; using the ARS alone will not eliminate the problem unless the factors that caused the lateral ligament tear in disc displacement are eliminated also. The use of this appliance alone seems doomed to failure. However, in an ARS appliance study by Williamson & Sheffield, the patients in that study self-reported improvement of 90% success in three years.117

In the complete displaced disc, the longer the disc is displaced, the more likely it will lose its biconcave shape (in other words, it turns into a blob). This change makes it difficult to recapture the disc, as the three convex surfaces do not fit together or have stability. The ARS is not realistic for treating complete displaced discs or osteoarthritis, but the science in Gelb’s day did not allow for differentiation of partial versus complete displaced disc cases. We presently have enhanced MRIs and are able to see the disc, position and shape, which if used appropriately might help decrease the indiscriminate use of the ARS on all types of disc displacements and osteoarthritis. The biggest mistake in the use of the Gelb or ARS appliance is the one-size-fits-all treatment without the ability to determine the severity of displacement. The amount or degree of displacement and the amount of time the displacement was present are critical factors in how Gelb or ARS therapy could be considered a success (which most studies define as removal of clicking).

A second problem exists regarding the severity of displacement. If the degree of disc displacement is all the way to the medial pole (disc is completely displaced), the distance to move the condyle forward to recapture the disc by the ARS is too great. In other words, if it is necessary to move the mandible forward so much that the lower incisors are near or past end-to-end, all anterior guidance (overjet and overbite) will be removed, which helps reduce muscle recruitment. If you move the condyle downward and forward, so that the condyle is at or past the eminence, you remove all the translational ability of the chewing system, which is approximately half of the opening distance. If, in fact, the displaced part of the disc at the lateral portion or even middle disc area has turned into a blob shape, the disc cannot be recaptured because the three convex surfaces do not fit together (Fig. 14 and 15). Using MRI, Eberhard et al reported that the ARS appliance could not recapture a non-reducing disc or a severely degenerated disc.115

Neuromuscular appliance
Despite its side effects, lack of research (science), and potential for lawsuits, the ARS appliance is still being used today as the neuromuscular appliance of choice. The neuromuscular dentist uses a transcutaneous electrical neural stimulation (TENS)-induced outside chewing muscle-fatigued bite.52 The TENS-induced bite moves the condyle downward and forward so that the neuromuscular bite is forward to the patient’s tooth bite (maximum intercuspation). In this way, the neuromuscular appliance becomes an anterior repositioning appliance. The high cost of neuromuscular therapy is due to the need to crown or orthodontically reposition.
posterior teeth to the new bite. Not even considering the significant cost of ARS therapy, the side effect of the posterior open bite makes ARS a less likely consideration due to the ADA’s position of more reversible and conservative approaches.

As with the ARS or Gelb appliance, the neuromuscular appliance relieves pain initially in joint-related cases by pulling the condyle away from inflamed tissues, thus decreasing blood flow. A study by Lundh et al reported better results with neuromuscular appliances than flat plane splints using arthroscopically chosen disc displacement with reduction cases. However, the ARS group was given counseling. Another study by Mazzetto et al in 2009 found that ARS appliances better reduced joint vibrations in internal derangements (disc displacements with and without reduction) than did stabilization appliances. It makes sense that recapturing of the disc by the lateral pole in partial disc displacements would have a reduction in joint sounds. Most of every study cohort is comprised of partial disc displacement cases due to its high prevalence in pain groups.

The theory of TENS-induced bite is that by fatiguing the outer chewing muscles, a proper bite will be determined. This TENS-induced bite is downward and forward to maximum intercuspation. Multiple studies indicating the use of surface electrodes to accurately evaluate muscles and bite position are flawed. A 2006 review by Klasser & Okeson provided more information on the use of surface EMG to diagnosis and treat jaw joint problems. A 2008 study by Tecco et al reported that ARS reduced the EMG activity in masseter and temporalis muscles over a 10-week period; however, clenching increased EMG activity. In a study by Cooper & Kleinberg, the success criteria (using self-reported improvements in jaw related pain) resulted in flawed data. A 2008 case study involving left internal derangement (partial disc displacements) with a significant discrepancy between CR and CO reported that the ARS was not effective. The irreversible side effect of pulling the condyle forward is the production of posterior open bite, creating a need for more work on the patient.

The creation of a TENS-induced bite makes no economical sense, even when considering the initial pain reduction, when other conservative, reversible, and scientifically proven methods exist to manage the pain. Moving the condylar muscle downward and forward on a slick incline ignores the good anatomy and physiology of the chewing system.

There is little doubt that the short-term benefit of using an ARS (neuromuscular) device to reduce pain of a partially displaced disc (lateral pole disc displacement) gives it some appeal. The fact that most chewing system pathologies are partial disc displacements increases a neuromuscular device’s initial success rate in reducing pain. However, the appliance is indiscriminately used on complete disc displacements and osteoarthritis, which have shown poor success rates with ARS appliances. In many clinical cases, the neuromuscular dentist does not examine the chewing structures to reveal differentiation of the different damage levels before implementation of the TENS or ARS; they often tend to be used in all cases. Review of scientific literature is where most doctors are able to see past the “smoke and mirrors” of this indiscriminate treatment concept.

Summary
In a 2003 study, nearly 27.2% of the Sardinian population were grinding their teeth and destroying their chewing structures. In studies using a broader definition of destructive habits, the percentage of the population that has parafunctional habits would be much greater. Many of the current studies have focused specifically on grinding or clenching. However, there are more destructive oral habits, such as muscle or tooth bracing. Similarly, there are factors besides bruxism, such as tension in muscles (stress-induced contraction of muscles) that can damage the jaw joint and lead to muscular inflammation. If one wants to be successful in managing pain from the chewing system, one cannot get too focused on just one aspect of care, such as “magic plastic.” In 1990, it was reported that 48% of women and 38% of men suffered from tension headaches. As the majority of tension headache patients were also found to suffer from parafunctional habits, parafunctional protection can help reduce pain for these patients. Kemper & Okeson found that occlusal splint therapy reduced headaches by 30.3% and reduced tension headaches by 63.6%.

The type of appliance used will depend on the structure that is being damaged and the amount of damage involved. For instance, to protect teeth, a nightguard is a good choice, but not an OTC-type sports guard due to its 90% failure rate as related to pain. The orthotic is best for those patients trying to protect the jaw joints. Based on
the literature, the NTI is appropriate for cases involving short-term pain, small amounts of damage, partially displaced discs, and much muscle inflammation. Table 3 summarizes the various appliances and their uses.

In 2010, The National Institute of Dental and Craniofacial Research stated that “reversible treatments such as stabilization appliances are useful in relief of pain.”

There are various appliances for treating acute traumatic jaw pain, tooth protection, occlusal trauma, jaw joint damage, muscle inflammation, osteoarthritis, complete displaced discs, and partially displaced discs. The most important aspect of appliance selection is diagnosing the problem and tailoring the treatment to specifically control the major factor that causes that problem. General dentists with limited diagnostic ability might agree with Greene & Laskin in their study’s conclusion that the conservative and reversible approach yields some of the best results. Dentists should diagnose and treat patients with the instruments that fulfill the treatment objective based on their knowledge of science, common sense, and empathy. Prepare for the world of clinical dentistry with the shield of science, common sense, and empathy. Prepare for the world of knowledge and science. Love your work and care for the patient with all your skills and heart.

**Disclaimer**
The author has no financial, economic, commercial, and/or professional interests related to topics presented in this article.

**Author information**
Dr. Yount maintains a private practice, limiting his care to orofacial pain for cases involving short-term perspective. Acta Odontol Scand 1998;56(2);122-128.

**References**

### Table 3. Appliance types and their effects.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Tooth load</th>
<th>Parafunction</th>
<th>Joint load</th>
<th>Periodontal</th>
<th>Muscle</th>
<th>Bite change</th>
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<tr>
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<td>Increase</td>
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<tr>
<td>Aqualizer®</td>
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<td>Increase</td>
<td>Increase</td>
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<tr>
<td>Soft/hard</td>
<td>Decrease</td>
<td>Increase</td>
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<td>Neither</td>
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<td>No</td>
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<tr>
<td>Posterior segmental</td>
<td>Decrease Slight Increase</td>
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<td>Decrease anterior</td>
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Appliance therapy: Appliance design and application


Manufacturers
Aztec Orthodontic Laboratory, Inc., Tucson, AZ 888.744.1588, www.aztecortholab.com

AGDPodcast
It’s Not Your Grandfather’s Occlusion
www.agd.org  General Dentistry  November/December 2012  e377
Exercise No. 320
Appliance Therapy

Subject Code 185
The 15 questions for this exercise are based on the article *Appliance design and application* on pages e359-e377. This exercise was developed by Thomas C. Johnson, DMD, MAGD, FICOI, in association with the General Dentistry Self-Instruction committee.

Reading the article and successfully completing the exercise will enable you to understand:
• the need for advanced, evidence-based training in appliance selection and use;
• the benefits to patients of the various appliances;
• the side effects of different appliances; and
• the importance of realistic patient expectations related to appliance therapy.

1. Which of the following factors makes interpretation of the results of appliance studies difficult?
   A. A homogenous pool of patients
   B. Standardization of treatment outcomes
   C. Clear definitions of pathologies
   D. Multifaceted pathologies

2. Some appliances may be used for bruxism but not for pain cases. Appliances may have side effects, damaging parts of the masticatory system.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.

3. Which condition will require an orthotic with a design and accuracy that requires advanced training?
   A. Periodontal protection
   B. Trauma with joint effusion
   C. Clenching and grinding with no pain or joint damage
   D. Osteoarthritis

4. Which is the most prevalent form of parafunction?
   A. Clenching
   B. Bruxism
   C. Dystonia
   D. Tongue thrust

5. The orthotic appliance is versatile and may be used with all of the following conditions except one. Which is the exception?
   A. Osteoarthritis
   B. Completely displaced disc
   C. Nocturnal bruxism
   D. Joint trauma with effusion

6. All of the following design components are characteristic of the orthotic appliance except one. Which is the exception?
   A. Evenly supported posterior contacts
   B. Posterior directing ramp
   C. Flat plane posterior
   D. Shallow anterior guidance

7. A small percentage of patients will have increased parafunctional activity with appliance use. This reflects the multifactorial nature of articular disc disorders.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.

8. Which appliance is contraindicated with a moderate to large discrepancy between centric relation and maximum intercuspation?
   A. Soft/hard
   B. Segmental
   C. Neuromuscular
   D. Aqualizer®

9. Which appliance may be used to decrease muscle activity and deprogram muscles?
   A. Aqualizer®
   B. NTI
   C. Soft/hard
   D. Suckdown
10. Load testing the jaw joint can help diagnose a completely displaced disc and osteoarthritis. The NTI appliance decreases joint load and will relieve pain with these cases.
   A. Both statements are true.
   B. The first statement is true; the second is false.
   C. The first statement is false; the second is true.
   D. Both statements are false.

11. Which is a common side effect of soft material appliances?
   A. Posterior interferences in mandibular excursions
   B. Supereruption of posterior teeth
   C. Posterior open bite
   D. Growth of redundant retrodiscal tissues

12. All of the following should be goals of therapy for MPD/TMD except one. Which is the exception?
   A. Improve the function
   B. Stop the clicking
   C. Stop the progression of the disease
   D. Reduce the pain

13. All of the following are side effects of long-term use of an anterior repositioning splint except one. Which is the exception?
   A. Permanent posterior open bite
   B. Redundant retrodiscal tissue
   C. An increase in posterior superior joint space
   D. Posterior interferences in mandibular excursions

14. Which of the following is synonymous with the neuromuscular device?
   A. Orthotic appliance
   B. NTI appliance
   C. Gelb/ARS
   D. Posterior segmental

15. An anterior repositioning splint (ARS) can be used as an acute trauma appliance by pulling the condyle away from inflamed retrodiscal tissue. How soon should the patient be transitioned out of the ARS to avoid permanent joint changes?
   A. 1 week
   B. 1 month
   C. 90 days
   D. 6 months
A case of a benign cementoblastoma treated by enucleation and apicoectomy

Aydin Gulses, DDS, PhD • Gurkan Rasit Bayar, DDS, PhD • Cumhur Aydin, DDS, PhD • Metin Sencimen, DDS, PhD

Cementoblastoma is a rare, benign, odontogenic neoplasm of ectomesenchymal origin, representing less than 6% of all odontogenic tumors. Despite its well-known typical features, there are still controversies regarding the management of the condition. This article presents the case of a benign cementoblastoma in a 17-year-old girl. The lesion was typical and associated with the mandibular right first molar. Endodontic treatment of the involved tooth, enucleation of the cementoblastoma, and apicoectomy of the affected roots were performed. Removal of the tumor while preserving the associated tooth resulted in normal osseous healing and no evidence of recurrence after one year. Based on the findings of the current report, it can be suggested that, in properly selected cases, it is possible to remove cementoblastomas that affect molars without extracting the involved teeth.

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Benign cementoblastoma is a relatively rare, benign neoplasm of odontogenic ectomesenchymal origin that is characterized by the proliferation of the cellular cementum around the root of a tooth.1-4 Benign cementoblastomas are usually slow-growing lesions and develop more commonly around the root of a mandibular first molar.2 Symptoms associated with benign cementoblastomas are variable. They can be totally absent or the lesion can present as a painful swelling. In any case, localized jaw enlargement is a typical feature of the condition.3 Radiographically, benign cementoblastoma appears as a radiopaque mass, surrounded by a thin radiolucent line.4 During early stages of cementoblastoma, the affected tooth can respond normally to vitality tests.5-7 However, during later stages, pulp necrosis can occur. Histologically, the lesion is composed of sheets and masses of paucicellular cementum that have variably prominent reversal lines with an intervening stroma consisting of loose fibrovascular tissue with osteoclast-type giant cells.7

Surgical removal of both the tooth and tumor is one treatment option. Recently, conservative treatment modalities including the endodontic treatment of the affected tooth and the surgical removal of the lesion have also been advocated.3,9

The report presented here describes the case of a patient who had a benign cementoblastoma that affected a mandibular first molar. The patient was successfully treated with endodontic therapy and surgical excision of the lesion.

Case report
A 17-year-old otherwise healthy female was referred to the Department of Oral and Maxillofacial Surgery at Gulhane Military Medical Academy for investigation and management of pain and tenderness affecting the posterior right region of the mandible. Clinical examination showed no extraoral or intraoral abnormalities. The soft tissues, bony structures, and teeth all appeared to be normal. Radiographic examination revealed the presence of a radiopaque lesion 1.8 x 1.5 cm in diameter, surrounded by a thin radiolucent line, attached to the roots of the mandibular right first molar (Fig. 1). No periodontal ligament space separated the radiopacity from the root tips. The tooth responded negatively to an electric pulp test. A provisional diagnosis of benign cementoblastoma was made. After consultations with the Department of Endodontics, it was decided to perform endodontic therapy followed by the surgical removal of the lesion.

The pulp tissue of the affected tooth was extirpated and the root canals were prepared with K-files, irrigated with copious amounts of 2.25% sodium hypochlorite, and dried with paper points. After complete instrumentation, a calcium hydroxide paste (Vision, FKG Dentaire) was placed in the canals using a lateral condensation technique. The intracanal dressing was changed once. The root canals were obturated with gutta-percha (Gapadent Co. Ltd.) and a resin-based root canal sealer (Diaket, 3M ESPE) using the lateral condensation technique. The patient’s symptoms remained unchanged during this period. Surgery was performed using an inferior alveolar nerve block. After

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the lesion was separated from the roots and removed, an apicoectomy was completed.

The excisional biopsy specimen was submitted to the Department of Pathology, where histologic examination revealed that the tissue was relatively acellular but contained relatively large cells identified as cementoblasts; therefore, a diagnosis of a benign cementoblastoma was rendered.

The healing period was uneventful. The patient reported no symptoms during the follow-up period. After one year, the tooth and related tissues were symptom-free and the radiograph revealed that osseous healing was almost complete (Fig. 2).

Discussion
A cementoblastoma (also known as a true cementoma) can be easily misdiagnosed if the clinical and radiographic findings are not considered. Therefore, the diagnosis of a cementoblastoma cannot be made based solely on histopathological examination of the biopsy specimen. The differential diagnosis of the condition might include odontoma, ossifying fibroma, osteoblastoma, fibrous dysplasia, or calcifying odontogenic tumour.

Furthermore, cementum-producing lesions such as periapical cemental dysplasia, cementifying fibroma, and gigantiform cementoma can also be confused with cementoblastoma. In addition to the risk of misdiagnosis, a benign cementoblastoma can be easily overlooked.

However, benign cementoblastoma can be easily distinguished from other lesions based on two clinical characteristics: The presence of an opaque core surrounded by a radiolucent line is a radiographical characteristic of a cementoblastoma, and cementoblastoma is the only cementum-producing lesion that is part of the root structure of the involved tooth. Both of these features were present in the current case.

There is some controversy in the literature regarding the treatment of cementoblastoma. Mader & Wendelburg recommended complete excision and removal of the associated tooth. Jelic et al also argued that extraction of the associated tooth is necessary because of the fusion of the lesion to the root cementum. Brannon et al suggested that cementoblastomas be removed as early as possible, together with the associated teeth. The same authors also reported recurrent cases and found, through a comparison of the initial treatment methods of those cases, that recurrence was more likely when curettage was attempted without extraction of the associated tooth or teeth. However, recurrence also occurred in nine of 26 cases in

Fig. 1. An orthopantomograph revealed the presence of a radiopaque lesion, surrounded by a thin radiolucent line, that attached to the roots of the mandibular right first molar.

Fig. 2. An orthopantomograph taken one year after surgery revealed that osseous healing was almost complete.
which the tumor and tooth were initially removed together. Adkins & Monsour suggested that a conservative approach is justified for functional and aesthetic reasons.

In the current case, the authors performed enucleation with apicoectomy to preserve the tooth. The conservative approach selected for this case was dependent on factors identified by Keyes & Hildebrand in 1987:

- The strategic nature of the tooth and the patient’s desire to save the tooth.
- A correct preoperative diagnosis made by the clinicians to justify performing nonsurgical endodontics before periapical surgery.
- The lesion was intercepted early enough to allow for a sufficient crown-to-root ratio after surgery.
- The tumor was relatively small and localized around the apical end of the molar.

**Summary**

Cementoblastoma is a relatively rare tumor of the jaws. The early and correct diagnosis of this condition might allow conservative approaches in its treatment. Based on the case report presented here, enucleation performed with apicoectomy can be a successful treatment for the management of cementoblastomas.

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**References**


**Manufacturers**

FKG Dentaire, La Chaux-de-Fonds, Switzerland 032.924.22.44, www.fkg.ch
3M ESPE, St. Paul, MN 888.364.3577, solutions.3m.com
The effect of pre-warming and delayed irradiation on marginal integrity of a resin-modified glass-ionomer

Maryam Khoroushi, DDS, MS • Tayebeh Mansoori-Karvandi, DDS, MS • Saeed Hadi, DDS

Recent studies have indicated that the acid-base reactions and polymerization of resin-modified glass-ionomers (RMGIs) compete with and inhibit each other; however, external energy can also influence the properties of RMGIs. This in vitro study evaluated the effect of pre-warming and/or delayed light irradiation on marginal integrity of RMGIs in cervical restorations.

Standard Class V cavities were prepared on the buccal aspects of 60 human maxillary premolars. Each cavity was treated with a cavity conditioner for 10 seconds, rinsed, and gently air-dried. An RMGI was applied to the prepared cavities as dictated by the study protocol. Group 1 samples were treated per manufacturers’ instructions. Group 2 samples were photocured after a delay of 2 minutes. For samples in Group 3, the encapsulated material was pre-warmed (at 40ºC) for 90 seconds; for Group 4 samples, capsules were pre-warmed and photocuring was delayed for 2.4 minutes. Microleakage scores were determined using the dye penetration technique; Kruskal-Wallis and Mann-Whitney U tests were used for statistical analysis (α = 0.05).

The enamel groups exhibited statistically significant differences (P = 0.036), while the dentin groups did not (P = 0.122); however, in both cases, Group 2 demonstrated the highest marginal integrity. Based on the results of this study, pre-warming could jeopardize the marginal integrity of RMGIs in cervical restorations, while delaying the curing process might improve it (particularly for enamel).

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The setting of a glass-ionomer (GI) is mediated through an acid-base reaction between the polymers of polyacrylic acid and fluoroaluminosilicate bases. Disadvantages of GI include low early strength and moisture sensitivity during the setting reaction.

By contrast, resin-modified glass-ionomers (RMGIs) have the unique ability to form a chemical bond with tooth structures, while demonstrating early strength (greater than that found in conventional GIs). RMGIs were developed to improve mechanical properties, decrease setting time, and reduce the moisture sensitivity found in conventional GIs. The major ingredients of RMGIs are fluoroaluminosilicate glasses, photoinitiators, polyacrylic acid, water, and a water-soluble methacrylate monomer such as hydroxyethyl methacrylate (HEMA), which may be grafted onto the polyacrylic acid.

Incorporating low-molecular-weight resin monomers—such as HEMA—into the chemical composition of conventional GIs to initiate the setting reaction in addition to an acid-base reaction has been described as a dual mechanism. The setting processes of RMGIs are time-dependent and the properties of the material undergo significant and rapid changes during the setting.

Conventional GIs contain an ion-leachable glass component and a polyalkenoic-acid component, which initiate the acid-base reactions to produce the cement mass. These components mean that RMGIs have a relatively complex setting reaction chemistry. RMGIs exhibit a dual setting reaction that includes a free-radical polymerization reaction establishing a polymer network, and an acid-base reaction yielding a GI polysalt matrix. Setting time in GIs lasts for some time; nevertheless, further maturation processes continue. However, the resin reaction rate is much faster than the acid-base reaction. The complex, photo-initiated polymerization required for RMGIs eventually produces a diffusion-controlled, polymer chain propagation as the concentration and mobility of monomers decrease concomitant with the formation of cross-linked matrix networks. The final degree of conversion depends upon monomer mobility and diffusion. A prompt curing procedure might retard the acid-base reaction, producing a material with a different structure.

However, delaying the curing procedure might prevent complete polymerization of the resin.
Few studies have discussed the effect of the irradiation regimen on RMGs.6,9,12 Tonegawa et al used ultrasound measurements to evaluate the effect of the power density of the curing unit on the setting reaction and behavior of RMGs.4 In a 2008 study, Yelamanchili & Darvell examined whether changing the irradiation regimen would lead to interferences between the components of an RMGI cement. They found that competition between network-forming reactions resulted in a delicate balance; that is, delaying irradiation and utilizing too much light energy both could have a deleterious effect.12 Therefore, the authors recommended following the manufacturer’s recommendations concerning the duration of exposure.12 A 2010 study by Berzins et al showed that the setting process of RMGs is accomplished through acid-base and polymerization reactions, and each mechanism depends on reactant diffusion before gelation, the reaction kinetics and mechanisms of each setting reaction influence one another.6 The photopolymerization reaction of the resin is much faster than the acid-base reaction; however, it is dependent on the availability of monomer and its mobility/diffusion, which is under the influence of the amount of material already cross-linked in the matrix network by the acid-base reaction. It is, therefore, acceptable to assume that since one reaction influences the extent and pace of the other, if the initiation time of the photopolymerization reaction is modified, the balance of acid-base versus photopolymerization of the material would be altered.10 Delaying irradiation allowed for a more widespread acid-base reaction, reducing resin polymerization extent and producing an RMGI with a different structure.6 Other studies have suggested that increasing the temperature of resin composite leads to a higher degree of conversion, increases flow, and improves adaptation with cavity walls—all of which can be advantageous when placing composite.13-17 Other studies have confirmed that pre-heating composite resin before irradiation improved adaptation without altering the mechanical properties and monomer conversion.18-21 Furthermore, pre-heating the resin composite up to 54°C and 60°C decreased the means of microleakage values when a quartz-tungsten-halogen (QTH) light was used at low power.18 These findings contradict a 2009 study that showed that pre-heating composite resins could have a negative effect on restoration margins because polymerization shrinkage would increase.22 A 2006 study by Daronch et al showed that rapid setting reactions due to heat or ultrasound energies shortens the setting time of RMGs and significantly increases bond strength to enamel.7 More recently, O’Brien et al reported that using external energy sources on a GI cement (including pre-heating the capsules, applying light to the surfaces from a high irradiance light source, or using an ultrasonic scaler) significantly improve upper surface hardness during the initial setting stages.23

RMGs are a hybrid of GIs and composite resins. In simple words, RMGs are a combination of traditional GIs and composite resins; therefore, they are considered complex materials and the acid-base and components amenable to polymerization must exist together in one formulation. It is, therefore, acceptable to assume that since one reaction influences the extent and pace of the other, if the initiation time of the photopolymerization reaction is modified, the balance of acid-base vs. photopolymerization of the material would be altered.
which is referred to as network competition." The concept requires evaluation in order to determine the marginal integrity of RMGIs in cervical restorations. This study sought to evaluate the marginal microleakage of RMGI cervical restorations using two different modalities in which photocuring began after RMGI mixing and/or pre-heating. It was hypothesized that delaying the irradiation procedure and/or warming the material would not influence the microleakage from RMGI cervical restorations.

Materials and methods
Sixty sound human premolars were stored in 0.2% thymol solution for 90 days after extraction. After all tooth surfaces were cleaned with a brush and pumice/water slurry, a cylindrical diamond bur (0.8 mm in diameter) was used to create Class V cavities (3 mm width × 2 mm length × 1.5 mm depth) on the buccal aspect of each tooth at the cemento-enamel junction (CEJ). The margins of the cavities were butt-jointed, with 50% of the margin in the enamel and 50% in the root dentin. The samples were randomly and equally divided into four groups (n = 15).

All the cavities were treated with Cavity Conditioner (GC America Inc.) for 10 seconds, washed and gently dried according to manufacturer’s instructions (see Table 1). The restorative material (Fuji II LC Improved Version, GC America Inc.) was mixed per manufacturer’s recommendations in a mechanical mixer for 10 seconds at 4,000 rpm. For samples in Group 1 (control group), the material was mixed, injected into the cavities, and allowed to set; curing light was used per the manufacturer’s instructions. For Group 2 samples, the material was mixed, placed in the cavities, and allowed to set for 2 minutes before it was photocured according to manufacturer’s instructions. For Group 3 samples, RMGI capsules were immersed for 90 seconds in a water bath (40° ± 1°C); at that point, RMGI was activated, mixed, and placed into the cavities. Group 4 underwent the same protocol as Group 3, except that the samples were photocured after setting for 2 minutes, as in Group 2.

Using a halogen light unit (Coltolux 2.5, Coltene/Whaledent Inc.), the Fuji II LC was photocured for 20 seconds (with a light intensity of 480mW/cm²). Irradiance was checked daily with a radiometer (Optilux 100, Kerr Dental). All restorative procedures were performed at room temperature (22° ± 1°C) and restorations were stored in distilled water (at 37°C) for 24 hours. At that point, the restorations were finished with fine diamond drills and polished with disks (Soflex, 3M ESPE) under constant and copious water spray. The specimens in all groups were then thermocycled at 5°C/55°C for 500 cycles with a dwell time of 30 seconds and 15 seconds for transfer. The apices of all the samples were sealed using utility wax and all tooth surfaces (except for restorative materials) were covered with three coats of nail varnish 1 mm from the margins. Each group was immersed in 2% basic fuchsin solution and incubated at 37°C for 36 hours; at that point, each specimen was bisected longitudinally through the center of the restoration in a bucco-lingual direction, using a cutting machine and diamond discs. All the sections were examined under a stereomicroscope (magnification 16X) and observed by two experienced operators in a blind manner. A standard scoring system was applied (see Table 2).

Data was analyzed by SPSS 11.5 software program (IBM) using Kruskal-Wallis and Mann-Whitney U tests (α = 0.05).

Results
Tables 3 and 4 summarize the microleakage scores of the study groups for enamel and dentin

<p>| Table 3. Frequency of marginal microleakage in enamel margins (N = %). |</p>
<table>
<thead>
<tr>
<th>Group</th>
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<td>1</td>
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<tr>
<td>2</td>
<td>4 (26.6)</td>
</tr>
<tr>
<td>3</td>
<td>2 (13.4)</td>
</tr>
<tr>
<td>4</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

<p>| Table 4. Frequency of marginal microleakage in dentin margins (N = %). |</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>Scores</th>
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<tr>
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margins. The mean scores of microleakage are shown in the chart. Group 2 demonstrated the lowest microleakage scores at both the enamel and dentin margins. The Kruskal-Wallis test did reveal significant differences in the integrity of enamel margins ($P = 0.036$); however, the integrity of dentin margins did not increase significantly for any group ($P = 0.122$). The Mann-Whitney U test revealed that the integrity of the enamel margin increased significantly for Group 2, while it decreased in Groups 3 and 4.

**Discussion**

In the present study, an RMGI was evaluated under two different conditions of warming the material before mixing and delaying the photocuring procedure. In both experimental conditions, both enamel and dentin margins of the cavity were treated using the cavity conditioner of the material itself, which consisted of 20% polyacrylic acid and 3% aluminum chloride. None of the cavity enamel margins were beveled.

The mean microleakage scores in the control group for enamel was 1.53, compared to 1.66 for dentin. GI cements form chemical bonds with enamel and dentin; the amount of heat and material shrinkage during setting is considered to be insignificant. An ion-enriched layer forms at the tooth structure-cement interface so that the cement can establish a bond with both enamel and dentin without microleakage at the margins. RMGIs form similar bonds with dentin in the same manner. Secondary ion mass spectrometry depth profiles have exhibited the ion-exchanged process between the photocured cement and the dentin surface.

RMGIs have the potential to form direct bonds with resin composite. They produce a catalyst-rich, air-inhibited layer that is polymerized with the composite, rendering it suitable for GI/composite laminate restorations. Adhesion can be increased by etching the enamel with acid. McLean reported that since RMGI contains HEMA, it has the potential of adhering to tooth structures and there is no need for dentin bonding agents prior to material placement. However, it appears that the use of phosphoric acid and probably placing a small bevel at enamel margins is necessary due to a 3% shrinkage of hybrid GI, resulting in significant microleakage at enamel margins.

If RMGI is to be photocured immediately after placement in the cavity (similar to the placement and curing of composite resins), the results of this study indicate a stronger acid-etching procedure is necessary, especially in the case of enamel substrate. This consideration is especially clear when the results of Group 2 are taken into account: In the groups in which the material was treated in the same manner as GI, the acid-base reaction might have had the opportunity to proceed. RMGIs are hybrid versions of GI cements; they are photocured because their chemical composition contains small quantities of resin components, such as HEMA or bisphenol A-glycidyl methacrylate (BIS-GMA). In some cases, the polyacid of RMGIs has been modified with side chains that can be polymerized by light. Different manufacturers use slightly different formulations, but the amount of resin in the final restoration is approximately 4.5-6%.

In the present study, the enamel samples of Group 2 demonstrated a significant decrease in microleakage. Delaying the photocuring procedure by 2 minutes allowed the material to undergo more acid-base reaction, preventing the rapid formation of polymer networks. The results can be explained by the fact that enamel is a highly mineralized tissue, which is replete with hydroxyapatite and calcium. Based on the results of the present study, the authors believe that etching the enamel with
phosphoric acid and exposing the RMGI to a curing light can produce a proper mechanical interlocking and lead to the formation of more resin tags with higher strengths. These conditions are ideal for the dental practitioner in the oral environment, in which moisture contamination is possible.\textsuperscript{6,12}

Similar results were observed with dentin samples in Group 2, where the mean microleakage scores decreased from 1.66 to 1.26; however, the differences with other dentin groups were not statistically significant. It appears that as with enamel, delaying the photocuring procedure has a positive effect on dentin; however, the histologic differences of dentin substrates (including the nature of dentin, the age of the teeth under study, and the type and quality of dentin) influenced the results. Conversely, it is probable that acid-etching the dentin surface increased surface permeability, which accelerated and facilitated the acid-base reaction due to increased surface moisture.\textsuperscript{3}

When photocoluring is delayed, polymerization shrinkage due to immediate light activation is eliminated and a better marginal seal is achieved. However, additional research is necessary to confirm these results.

In the present study, the overall microleakage at both enamel and dentin margins was relatively higher than previous studies. The literature has reported that using more than one operator to place the restorations may affect microleakage; by contrast, one operator placed all the restorations under identical operating conditions in the present study, which made it possible to compare the results of various groups.\textsuperscript{25,27}

In 2006, Knight et al pre-heated resin composite before placing it in the cavity, which improved the degree of conversion, reduced viscosity, and improved marginal adaptation of the restoration.\textsuperscript{18} In the present study, pre-warming RMGI increased enamel and dentin margin microleakage. The material was heated for 90 seconds (up to 40°C) based on a method used by O’Brien et al.\textsuperscript{25} No previous study has ever evaluated the effect of RMGI pre-warming on microleakage. The literature has reported that pre-warming composite resins increases linear shrinkage (due to an increase in the degree of polymerization); however, pre-warming composite resin up to 60°C has no effect on cavity microleakage.\textsuperscript{18-21}

When the effects of pre-warming on composite resin and RMGI are compared, the physical properties and chemical composition of the materials should be taken into account. Composite resins have a paste consistency that has been established chemically by the coupling agents between the fillers and resin component. With encapsulated RMGI, the powder and the liquid are kept separate from each other before mechanical mixing and the chemical reaction is initiated after mixing. It is likely that warming the material increases molecular movement, decreases working time, accelerates the setting reaction, and increases the rate of poly-HEMA formation, which deprives the operator of the opportunity to properly adapt the material to cavity walls.\textsuperscript{4}

In addition, the possibility for the evaporation of HEMA increases after injection into the cavity, which results in a brittle restoration with poor adaptation. Further, in Group 4, although noticeable, the deleterious effect of pre-warming on marginal integrity was less than that in Group 3 due to a delay in the photocuring procedure. Therefore, it seems that pre-warming has a detrimental effect on marginal adaptation of the material contrary to delaying the photocuring procedure. Based on the results of the present study, pre-warming the RMGI is not recommended.

It has been assumed that polymerization shrinkage results in restoration margin defects, leading to microleakage, margin discolorations, and tooth hypersensitivity. Hygroscopic expansion can compensate for the shrinkage to some extent.\textsuperscript{2} Absorption of water by RMGI produces an acid-base reaction, hygroscopic expansion, and decreased cavity margin gaps.\textsuperscript{25} Previous studies have noted that the bond strength between RMGI and enamel or dentin increased at three- and six-month intervals.\textsuperscript{28,29}

**Conclusion**

Under the limitations of the present study, enamel microleakage of cervical cavities restored with Fuji II LC RMGI decreases when photocoluring is delayed. Pre-warming the material before mixing has a detrimental effect on the restoration’s marginal integrity. This observation might apply to dentin margins as well; however, additional studies are required to verify the results of this study.

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Disclaimer
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Open apex Type III *dens invaginatus*: A rare case report of an endodontic retreatment with an anatomical redesign

Emmanuel Joao Nogueira Leal Da Silva, DDS, MSc • Alexandre Augusto Zaia, DDS, MSc, PhD

*Den s invaginatus* is a critical condition for endodontic treatment. It frequently presents a complex internal anatomy and might be associated with incomplete root and apical development. This article presents one of the few reported cases of endodontic retreatment of Type III *dens invaginatus*. First, the internal anatomy was modified using burs under an operating microscope. Next, conventional chemical and mechanical preparation with hand files and 2.5% sodium hypochlorite was performed. Finally, an intracanal dressing with calcium hydroxide was used for nine months, at which point the anatomical features in the root canal system could be accessed. Adequate periradicular healing was observed and regression of the lesion was noted at the two-year follow-up. This case reinforces the idea that knowledge about the biologic aspects of endodontics, combined with adherence to technical standards, is helpful in resolving complex cases.

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*Dens invaginatus* (DI) is a developmental anomaly resulting from invagination of enamel organ into the dental papilla, beginning at the crown and sometimes extending into the root before calcification occurs. Incomplete lateral fusion of two germs has been described as one of several theories that explains the morphogenesis of invaginated teeth. DI seems to be an appropriate nomenclature, because it reflects the infolding of the outer portion (enamel) into the inner portion (dentin), with the formation of a pocket space. The incidence of this anomaly is reported to range from 0.04% to 10.00%. It commonly occurs in permanent maxillary lateral incisors, followed by maxillary central incisors, premolars, canines, and less often, molars. Occurring in 43% of all cases, bilateral presence is common. Permanent teeth are usually involved; however, there are reports of this anomaly occurring in primary teeth. DI can be classified according to severity, with the most commonly accepted classification created by Oehlers, who described the following three types of DI for anterior teeth:

- **Type I** – invagination confined within the crown; and
- **Type II** – invagination invading the root as a blind sac, with possible connection to the dental pulp; and
- **Type III** – invagination penetrating through the root to open in the apical region.

In Type III DI, any infection within the invagination can lead to an inflammatory response within the periodontal tissues, giving rise to peri-invagination periodontitis.

Radiographically, DI shows a radiopaque invagination similar in density to dental enamel and extending from the cingulum into the root canal. It can be identified easily because infolding of the enamel lining is more radiopaque than the surrounding tooth structure. The clinical appearance of the crown can vary, ranging from a normal form to more unusual forms such as greater labiolingual or mesiobuccal diameter, peg-shaped, barrel-shaped, and conical. Dental treatment is often required because the invagination allows the access of irritants into the pulp space or into an area connected to the periradicular tissues. The literature has reported various techniques for the treatment of teeth with DI, including nonsurgical root canal therapy, endodontic surgery, and extraction.

In the present case, an immature maxillary lateral incisor was discovered to have Type III DI associated with a periradicular lesion and a normal clinical crown. Endodontic retreatment was performed to achieve resolution of a substantial periradicular lesion and apexification.

**Case report**

A 15-year-old girl with no general health problems was referred by her dentist for the retreatment of her maxillary left lateral incisor. The patient reported that the tooth had been treated with root canal therapy 18 months earlier. The patient
complained of painful swelling on the mucosa over the maxillary left anterior teeth. Clinically, the tooth was hypersensitive to percussion and palpation, the soft tissues around the tooth were free of pathologic signs, and there was a large composite filling on the lingual surface. Radiographic examination revealed a large periapical radiolucency and complex canal anatomy with a Type III DI. Periradicular radiolucency was evident around the root apex. The previous endodontic treatment had been performed only in the invagination and was insufficient to remedy the condition (Fig. 1). Radiographic examination of the patient’s contralateral teeth confirmed that the condition was unilateral. The patient was informed of the diagnosis and the need for root canal retreatment.

After local anesthesia using 2% lidocaine with 1:100,000 epinephrine was administered, the cavity was accessed using diamond burs in high-speed rotation in an attempt to reach the root canal. A rubber dam was placed and all of the

Fig. 1. Initial radiograph.

Fig. 2. Radiograph after anatomical redesign and insertion of calcium hydroxide paste.

Fig. 3. Radiograph showing the apical closure after nine months.

Fig. 4. Radiograph showing inverted master gutta-percha cone positioned in the canal.

Fig. 5. Radiograph after lateral condensation and vertical condensation with warmed carriers.

Fig. 6. Two-year follow-up radiograph.
the gutta-percha and sealer were removed. In light of the complexity of the internal anatomy and the challenges it presented for the cleaning and sealing of the individual canal spaces, it was decided to remove the central dentinal core and create a single canal space. Under magnification and illumination, the root invagination was removed using a spherical diamond bur. Next, the root canal was prepared using Gates-Glidden burs and manual endodontic files. A 2.5% sodium hypochlorite solution was used for irrigation and renewed at each change of instrument. Following chemomechanical preparation, the root canal was dried with sterile paper points and dressed with a calcium hydroxide paste, which was replaced monthly to induce apexification (Fig. 2).

Coronal restoration was completed with glass ionomer cement. After nine months, a radiograph showed apical closure (Fig. 3). Obturation was performed using Sealapex (SybronEndo Corporation) and an inverted master gutta-percha cone, with lateral condensation followed by additional vertical condensation with warmed carriers (Fig. 4 and 5). At that point, it was evident that periapical healing was almost complete.

The patient returned for clinical and radiographic examinations at six months and two years following endodontic retreatment. At the two-year follow-up, the patient was asymptomatic and reported no postoperative pain. A periapical radiograph revealed complete periapical healing around the root end (Fig. 6).

Discussion
DI is an anomaly of dental development that could precipitate a connection of the pulp space with the oral cavity. As a result, it is common for the affected tooth to require endodontic treatment, which often is complicated due to the complex anatomy of teeth with DI. Endodontic treatment of teeth with Type III DI associated with apical pathosis generally involves complicated procedures that require accurate diagnosis and appropriate treatment planning. The invagination frequently communicates with the oral cavity, allowing the penetration of irritants and microorganisms either directly into the pulp tissues or into an area separated from the pulp by a thin layer of enamel or dentin. For this reason, early diagnosis is critical to prevent pulp necrosis and periapical inflammation.

Few cases of endodontic retreatment of DI have been described in the literature. The clinical appearance of DI varies considerably. The crowns of affected teeth can have either normal morphology or abnormal forms. In the present case, the crown had a conoid morphology. Careful radiographic evaluation can lead to identification of abnormal anatomical conditions.

The current case demonstrated that anatomical difficulties can lead to endodontic failure and the development of periapical pathology requiring endodontic retreatment. Due to the complexity of the root canal system, access cavity preparation and all endodontic treatment was done under an operating microscope.

The treatment of a tooth with Type III DI, an immature apex, and an associated large periapical lesion is usually complicated. Surgical treatment is indicated only when nonsurgical root canal treatment has failed. In the current case, the authors used calcium hydroxide to induce an apical formation and achieve disinfection of canals, which has been reported as a successful approach in the literature. Apical closure took nine months in the current case, but that time period can range from 6 to 14 months.

The two-year follow-up radiograph demonstrated normal periradicular bone structure and continued apical development.

There is no consensus on a post-treatment follow-up period for DI and open apex in the literature; it can range from four months to six years. Favorable tissue healing responses have been observed for the treatment of DI in maxillary lateral incisors, even after long periods of evaluation. All efforts must be made to obtain an adequate apical seal with obturation or retrofilling, complemented by the placement of a definitive coronal restoration to avoid reinfection of the root canal system.

Summary
A lack of knowledge about possible root canal anatomical configurations can be a disadvantage for dentists, resulting in unsuccessful endodontic treatment outcomes. The present case report showed the importance of a correct diagnosis for successful endodontic treatment. Nonsurgical root canal retreatment of DI proved successful in promoting the healing of an associated periradicular lesion.

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Microhardness and sealing ability of materials used for root canal perforations

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Samira E. Camargo, MSc, PhD • Flavia G. Cardoso, MSc • Marcia C. Valera, MSc, PhD

Root perforations may lead to a loss of integrity in the root and periodontium, violations of the biologic periodontal distance, and injuries to periodontal tissue. This study sought to analyze the effect of root canal biomechanical preparation on the microhardness and the marginal sealing ability of different materials used to treat root perforations. Standard root perforations were performed in 96 bovine incisors. The teeth were divided into four groups (n = 24) based on the material used to treat those teeth: Mineral trioxide aggregate (MTA) (Group 1), MTA protected with cyanoacrylate (Group 2), MTA protected with glass ionomer (GI) cement (Group 3), and castor oil bean (COB) cement (Group 4). After root perforations were closed, the root canals were prepared biomechanically and teeth were sectioned longitudinally. Microleakage and microhardness of sealed perforations were assessed; microleakage data were submitted to analysis of variance (ANOVA) testing, while microhardness data were submitted to Dunnet and Tukey tests (p < 0.05). Group 4 reported the lowest amount of microleakage (0.65 mm), followed by Group 3 (1.02 mm), Group 1 (1.14 mm), and Group 2 (1.30 mm); however, no difference was detected among the groups. Groups 1-3 demonstrated significantly higher microhardness values compared to COB. It was concluded that the chemical and mechanical agents used during root canal preparation did not affect the sealing procedures. Administering surface protection to MTA did not improve microhardness or sealing.

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preparation might chemically influence some characteristics of the sealing materials and also the endodontic files can displace the sealing material. According to Lee et al, the use of ethylenediaminetetraacetic acid (EDTA) affected the hydration process of MTA, decreasing microhardness and biocompatibility.9

Determining the best time to seal a root perforation can be a challenge. Sealing perforations prior to root canal preparation may lead to removal of the sealing material. One might expect that if root perforations previously sealed with MTA or COB undergo biomechanical preparation, the sealing material may be affected by the action of the endodontic instruments and irrigating solutions.

The experimental hypothesis of the study asserted that surface protection materials used for sealing perforations would improve the microhardness and microleakage in comparison to non-protected materials. This study simulated root perforations and performed biomechanical preparation to evaluate the microleakage and microhardness of COB and MTA (on its own and with surface protection).

**Materials and methods**

Ninety-six bovine lateral incisors were used. The teeth were cleaned, stored in saline solution (Glicolabor Industria Farmaceutica), and frozen prior to the testing procedures. Using double-sided diamond discs, the crowns were sectioned 3 mm apically from the cemento-enamel junction (CEJ). The complete removal of the pulp tissue was performed with No. 50 Hedstroem files (Dentsply Maillefer). Root perforations were performed 3 mm below the CEJ at the buccal surface using a No. 20-94 diamond bur (KG Sorensen). This procedure was standardized using a modified microscope. Large gutta-percha points were inserted into the root canals to seal the access between the perforation and the root canal. The specimens were divided into four groups (n = 24) according to the material used.

Group 1 samples were treated with MTA (MTA-Angelus Industria de Produtos Odontológicos). Group 2 samples were treated with MTA protected with cyanoacrylate (Loctite Super Bonder 3G, Henkel Corporation). Loctite Super Bonder 3G was applied over the surface of the sealing material inside the root canal, using a microbrush (Microbrush International). Group 3 samples were treated using MTA protected with glass ionomer (GI) cement (Vidrion R, SS White Burs Inc.), while Group 4 samples were treated with COB cement (Poliquil Araraquara Polimeros Quimicos), which was placed in the perforation area using a No. 7 wax spatula (SS White Burs Inc.).

Roots were maintained at 37°C (±10°C) and 100% humidity for 24 hours after perforations were sealed. Root canals were prepared up to Kerr file #50 (Dentsply Maillefer) followed by step-back technique up to Kerr file #80 (Dentsply Maillefer) by anatomic diameter to the coronal direction.

Roots were irrigated with 3 mL of 2.5% NaOCl solution (Bioformula Farmacia de Manipulacao) at each change of instrument, with final irrigation performed with 2 mL sterile saline solution. Following root canal preparation, all roots were sectioned longitudinally; the buccal hemi-section containing the perforation was used for this study. The specimens of each group were subdivided into two groups (n = 12) to assess microleakage and microhardness values.

**Microleakage test**

One root was taken from each subgroup and used as a positive control (totally sealed) while another root from each subgroup was used as a negative control (not sealed). For each subgroup, the surfaces of the buccal root hemi-sections were isolated with two layers of nail polish, leaving a standardized exposed buccal area (2 mm).

The dye solution was prepared by dissolving 2 g of rhodamine into 100 mL of water. All specimens were immersed into a 2% buffer rhodamine solution for a period of 24 hours, and rinsed for 12 hours in running water. Specimens were sectioned with steel discs in dry conditions to prevent dye from penetrating into dentin or the restorative material at the central portion of perforation. Microleakage was assessed at the tooth-restoration interface on the internal wall surface of the root. Data were analyzed by two calibrated evaluators using stereomicroscopy (STEMI 2000, Carl Zeiss Microscopy) at 20X magnification at different periods. Data were recorded (mm) for further evaluation.

**Microhardness evaluation**

Forty buccal hemi-sections (10 from each group) were embedded in resin blocks, so that only the external root surfaces were exposed. The external surface of the specimens was polished with silicon carbide sandpapers of 80 grit, 320 grit, 600 grit, 800 grit, and 1200 grit (Norton, Saint-Gobain Abrasives). Final polishing was performed with polishing paste and felt discs. Microhardness was assessed (using the indentation technique) with a Vickers microhardness tester (Digital Microhardness Tester DL200 FM-ARS, Future-Tech) under a load of 50 kgf for 10 seconds, according to the
manufacturer’s instructions. Eighty-eight data points were obtained for both investigated variables (microleakage and microhardness). Data were submitted to ANOVA and Dunnet’s tests ($P < 0.05$), using Minitab (Version 14.12, Minitab) and STATISTICA (Version 5.5, StatSoft Inc.) softwares.

**Results**

The microleakage values for the COB specimens (Group 4) did not differ significantly from the protected MTA specimens in Groups 2 and 3 ($P = 0.7466$) (Chart 1). In terms of microhardness values, significant differences were observed among the tested materials; Groups 1-3 demonstrated higher microhardness values than Group 4 (Chart 2). The microhardness values in Group 1 were similar to those in Groups 2 and 3, showing that there were no differences regarding surface protection ($P = 0.8937$). No sealing material was displaced from any specimen at any time.

**Discussion**

To the authors’ knowledge, there are no published reports in the literature that have assessed microleakage and microhardness of a filled perforation to determine how mechanical instrumentation and chemical irrigating solutions affect the MTA or tooth interface.

It is common sense that high-quality sealing should be an important target to avoid microleakage between sealing materials and dental tissues. Based on the recommendation by Lamb et al., materials used in the present study for quality seal of a perforation were placed in thicknesses of at least 3 mm. MTA in clinical applications, such as sealing root perforations, is reported to undergo dissolution and misplacement if surface protection is not provided.

The authors are unaware of any previously published reports in the literature regarding the need to use MTA to protect the surfaces of areas that would come into contact with chemical agents (for example, irrigating solutions) and mechanical instrumentation (for example, endodontic files) during endodontic treatment. However, Hardy et al. used a microleakage fluid test to determine perforations in the area of the molar furcation sealed using MTA protected with one of two bonding agents. The results showed higher MTA (Group 1) displacement compared to the other groups: MTA protected with cyanoacrylate.
(Group 2), MTA protected with GI cement (Group 3), and COB cement (Group 4). The higher displacement is due to MTA’s low adhesive property in comparison to One-Up Bond (Tokuyama Corporation) or to the association of both materials.

In the present study, microleakage testing was performed for all groups (through dye penetration) with no significant differences between the four groups (Table 1).

According to Leite & Ramalho, COB cement is a proven biocompatible material, a mixture of fatty acid and diphenylmethane diisocyanate, and thus not recognized by the tissues as antigens. Camargo et al used a kristal violet test in human pulp fibroblasts and detected no cytotoxicity; in addition, no genotoxic activities were detected when using the micronuclei test in V79 fibroblasts. Moreover, COB could be a promising option for several dental procedures, such as retrofitting material, as endodontic cement and in root perforation. Despite its porous surface (which is due to air incorporation detected during the setting phase), the lowest microleakage values observed for the COB group were not statistically significant, suggesting that COB’s high sealing quality is due to its adhesive property.

In the present study, the indentation technique was used and microhardness was recorded by means of a tester under a 50 kgf load for 10 seconds. Different load values—100 g for 30 seconds and 98.07 mN for 6 seconds—are also reported in the literature. The present study evaluated three measurements to assess each specimen, compared to other studies that utilized five indentation measurements. The present study employed 10 specimens per group.

The microhardness of cements depends on their components, the particles’ characteristics, the powder/liquid ratio, and the amount of incorporated air. The amount of potassium can also improve the hardness of materials, leading to the assumption that an MTA structure might be harder, as detected in the present study (the MTA-Angelus has potassium, while ProRoot MTA does not) (ProRoot, Dentsply Ltd.). Studies have reported that MTA cement might exhibit negative microhardness changes at a low pH, which can be observed during tissue inflammation. However, all inflammatory processes should be treated before use of MTA.

In the present study, Group 1 demonstrated a microhardness mean value of 94.69 HV, a value that is greater than reported dentin values (70 HV) (Table 2). By contrast, a 2006 study by Danesh et al reported a microhardness value 39.99 HV for MTA.

Conclusions MTA and COB fillings were not affected by chemical or mechanical agents, suggesting that these materials can be used as root perforation sealants. No significant differences in microhardness and microleakage were detected between unprotected MTA and MTA with surface protection. Although voids were detected in the structure of COB, it had excellent sealing properties and low microhardness values. Additional studies are needed to investigate COB’s long-term sealing properties when treating root perforations.

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### Table 1. Mean values (mm) of microleakage.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (MTA)</td>
<td>1.143</td>
</tr>
<tr>
<td>2 (MTA + C)</td>
<td>1.302</td>
</tr>
<tr>
<td>3 (MTA + GI)</td>
<td>1.029</td>
</tr>
<tr>
<td>4 (COB)</td>
<td>0.652</td>
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### Table 2. Mean values (HV) of microhardness.

<table>
<thead>
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<th>Group</th>
<th>Mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (MTA)</td>
<td>94.69</td>
</tr>
<tr>
<td>2 (MTA + C)</td>
<td>92.25</td>
</tr>
<tr>
<td>3 (MTA + GI)</td>
<td>97.68</td>
</tr>
<tr>
<td>4 (COB)</td>
<td>8.48</td>
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</table>
references


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Esthetic consideration for alveolar socket preservation prior to implant placement: Description of a technique and 80-case series report

Ahmad Kutkut, DDS, MS • Sebastiano Andreana, DDS, MS • Edward Monaco, DDS

An esthetic restoration supported by dental implant rehabilitation is a major challenge to restorative dentists. The ultimate goal of a dental implant is to restore missing or extracted teeth by placing implants in anatomically, esthetically, and long-term functional restorations.

Alveolar ridge preservation and site enhancement following tooth extraction has a major impact on the hard and soft tissue volume. Extraction socket preservation is technique sensitive, not 100% successful, and at times unpredictable. Current techniques may delay surgical implant placement for a few months, and the quality of new bone regeneration is questionable.

The aim of this report was to describe a minimally traumatic extraction socket preservation technique using different types of bone graft as a preserver prior to implant placement applied in 80 consecutive cases.

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Extraction socket wound healing is characterized by resorption of the alveolar bone volume at the extraction site. This bone resorption results in esthetic and restorative challenges that reduce the bone volume available for implant placement.

Major changes in an extraction socket occur during the first year after tooth extraction with two-thirds of bone loss occurring within the first three months. The literature documents an average of 0.7 to 1.5 mm vertical bone resorption following extraction procedures without any socket preservation graft performed and an average of 4 to 4.5 mm horizontal bone resorption.1-5

Preservation of alveolar bone following tooth extraction has a major impact on the functional and esthetic outcomes of subsequent prosthetic treatment; this has been long studied yet it remains an unresolved problem.6-12

The extraction socket preservation technique implies preservation of the alveolar architecture including cortical bone and soft tissue. Prevention of hard and soft tissue collapse can minimize or eliminate the necessity for future augmentation procedures.13-19

The use of resorbable bone fillers have been shown both clinically and histologically to improve new bone formation in intact extraction sockets before implant placement.20-34

When incorporated as part of the site preparation for an implant restoration, placing a graft into an extraction socket provides a scaffold for the in-growth of cellular and vascular components to form new bone of acceptable quality and quantity.35-37

Extraction socket preservation however, is technique sensitive, not 100% successful, and can at times be unpredictable. Current techniques may delay implant placement for months, and the quality of regenerated bone is questionable.38

This report describes a minimally traumatic alveolar socket preservation technique using different types of bone graft as a preserver prior to implant placement applied in 80 cases.35-46

Materials and methods
Eighty nonrestorable teeth were extracted and followed by implant placement as documented in the technique described below. The indications for tooth extraction included root or crown fractures, nonrestorable caries, residual roots, and root resorption (Fig. 1 and 2). Several types of resorbable bone grafts and fillers were used such as calcium sulfate, allograft, xenograft, and collagen resorbable plug, or a combination of two bone grafts mixed with platelet-rich plasma (PRP). The grafts were covered with resorbable collagen membrane or, for limited cases, with polytetrafluoroethylene (PTFE) barriers and secured with PTFE reversed figure-eight sutures. Follow-ups for patients were scheduled at 14 days for the suture removal and at three months for implant placements.
Surgical procedure

Patients’ vital signs were determined and assessed prior to commencing surgical treatment. After administration of a local anesthesia (Xylocaine 2% injection with 1:100,000 epinephrine, Dentsply Pharmaceutical), a sulcular incision was performed using a 15C surgical blade around the nonrestorable teeth to separate the gingival fibers and also coronal periodontal ligaments (Fig. 3). This incision was accomplished carefully to preserve the attached gingiva and papillae. The teeth were carefully and gently luxated from the mesial and distal using periotomes (QC Orthodontics Lab Inc.) (Fig. 4). Extraction of the luxated teeth was performed with surgical forceps (QC Orthodontics Lab Inc.) to minimize the amount of mechanical pressure applied to the buccal bone. The extraction sockets were debrided of any granulation tissue using a curette (Fig. 5).

The bone graft material was packed in 3-4 bulk amounts until the extraction sockets were completely filled to the gingival margin. In the cases of collagen resorbable plug, the plugs were packed into the sockets. The extraction socket graft was covered with a resorbable collagen membrane (ACE ConFORM™ Membrane 15 mm X 20 mm, (ACE Surgical Supply Company) to perform guided bone regeneration (GBR) and to protect the bone graft from the intrusion of undesired soft tissue growth and oral debris (Fig. 6). The membrane was secured using a reverse cross mattress resorbable suture (Fig. 7).

Patients were advised to clean the surgical area gently with a Toothette® Oral Swab (Sage Products Inc.) saturated with 0.12% chlorhexidine gluconate (PerioGard®, Colgate) four times daily for two weeks.

Patients returned 14 days after the surgical procedure. At this visit, the sutures were removed and wound healing was evaluated (Fig. 8). Patients returned approximately three months after the surgical procedure when healing of the bone grafting had been achieved (Fig. 9). Vital findings were collected and reported. After local anesthesia was administrated (Xylocaine 2% injection with 1:100,000 epinephrine), a papilla-saving crestal incision was made and full thickness flap reflected (Fig. 10). Osteotomy for implant insertion was prepared according to implant manufacturer recommendations and a dental implant (70 cases: Nobel Replace, Nobel Biocare; 10 cases: SLActive Bone Level Straumann Implant, (Straumann USA LLC) was placed (Fig. 11 and 12).
Healing was uneventful, and at the time of implant placement no additional grafting procedures were needed to either improve the esthetics or cover any implant’s body exposure for proper implant prosthetic restoration.

Healing abutments for one-stage surgery or cover screws for two-stage surgery were placed, and flaps were secured with 4-0” PTFE sutures. Patients were advised to clean the surgical area gently with a Toothette® Oral Swab moistened with 0.12% chlorhexidine gluconate four times daily for two weeks.

**Clinical outcome**

Clinical healing was uneventful and free of infection or other symptoms in all cases. No patient reported any postoperative pain or discomfort nor was any pain medication prescribed or used by any patients. Soft tissue healing of the grafted areas was visually assessed as quick and mature in all cases. It was observed that soft tissue closure was almost complete at 14 days postextraction in all cases. After three months of healing, when implant placement was performed, all examined sockets were completely filled by dense bone; when the osteotomies were prepared by the pilot drill, bone exhibited a great resistance during the osteotomy preparation.

The treatment was considered successful if sufficient bone was present for implants to be placed after three months of healing. Treatment failure was indicated when after three months of healing, there was not enough bone present for implant placements. Radiographically, the bone regenerated in the extraction sites showed high density in all cases and the success rate was 100%.

At the time of implant placement, a complete alveolar bone bridge formation was observed with a minimal amount of horizontal and vertical bone resorption. Minimally traumatic extraction technique of non-restorable teeth, flapless elevation, and an application of guided bone regeneration principle using a resorbable collagen membrane barrier secured by sutures were applied to all sites in this technique protocol. This may explain why all of the grafted sockets showed minimal marginal bone resorption and no further soft tissue manipulation in the 80 cases with esthetic final restorations (Fig. 13-24).

**Discussion**

This technique aimed to place different types of graft material in fresh extraction sockets and to evaluate the clinical healing three months postextraction. It has been reported that most morphologic extraction socket changes take place within this time frame.1-5 Socket preservation procedures are effective in limiting horizontal and vertical ridge alterations in postextraction sites and are accompanied by varying percentages of bone formation.
This depends on the materials and techniques used. There is no evidence to support the superiority of one technique over another.\textsuperscript{35-46}

This described technique was effective in enhancing bone maturation and in minimizing vertical and horizontal alveolar bone resorption within the fresh extraction sockets without further soft tissue managements. In these 80 cases, the operators did not elevate flaps in order to avoid mucogingival changes and to reduce the bone remodeling activity that mediates resorption of the surface layer of the alveolar bone in the exposed area.\textsuperscript{40, 43} This is of particular concern at the buccal aspects of the maxillary alveolar ridge, where the cortical plate is often extremely thin. The present operators used resorbable collagen membrane in the majority of cases to cover the grafting materials and secured the site with a cross mattress suture during the early healing process.\textsuperscript{49} Complete epithelial closure was achieved at 14 days when the sutures were removed.

The observation of enhanced epithelial wound healing, as well as the observation of complete bone fill, would support the clinical use of this technique in fresh extraction sockets without flap mobilization. This technique has the advantage of avoiding the necessity of soft tissue remodeling. The use of membranes without primary closer may optimize treatment outcomes. This procedure has been recognized as a necessary treatment step in order to maintain and restore adequate bone volume for implant placement.\textsuperscript{45, 47, 48}

This concept is applicable also to the technique of creating a pouch between buccal and palatal bone to insert the membrane. This, by default, leads to elevation of the periosteum from the alveolar crest. Elevating the periosteum leads to bone resorption.\textsuperscript{49} In this 80-case series, operators did not elevate the pouch; this fact may be the key to the successful outcome achieved in this report.

Tooth position may affect the amount of horizontal bone resorption due to the buccal bone thickness. Forty-two anterior teeth (36 in the premaxilla and six in the symphysis area) and 38 posterior teeth (21 in the posterior maxilla and 17 in the posterior mandible) were followed up. More horizontal bone resorption was observed in the premaxilla than in other regions.

One of the most important conditions related to socket grafting procedure is the number and thickness of the bony walls surrounding the extraction site. A thick labial plate (no less than 1.5 mm) and completely intact bony walls will regenerate bone using almost any resorbable graft material.\textsuperscript{14, 15} However, when the buccal plate is extremely thin, pronounced bone resorption in width is greater than the resorption in height after extraction, to a degree that may affect the implant placement.\textsuperscript{40, 43}
These findings demonstrate the importance of extraction socket graft technique using different types of bone grafts and fillers to regenerate new bone and to reduce the amount of bone resorption.

Summary

The 80 cases presented in this report indicate that the extraction socket preservation technique was successful in preserving the alveolar ridge after extraction for implant placement. Any resorbable bone replacements applied by guided bone regeneration will generate clinical healing process with favorable clinical results when used in fresh extraction sockets. Although the sample size investigated in this case series was small, the findings are clinically relevant.

Conclusion

Extraction socket preservation is technique-sensitive, not 100% successful, and can be unpredictable. Current techniques may delay implant placement for months, and the quality of regenerated bone is questionable. The aim of this report was to describe a minimally traumatic alveolar socket preservation technique using different types of bone graft as a preserver prior to implant placement in 80 cases.

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Manufacturers
ACE Surgical Supply Company, Brockton, MA
508.588.3100, www.acesurgical.com
Colgate, New York, NY
212.752.2357, www.colgate.com
Dentsply Pharmaceutical, York, PA
717.699.1400, www.dentsplypharma.com
Nobel Biocare, Yorba Linda, CA
800.322.5001, www.nobelbiocare.com
QC Orthodontics Lab, Inc., Fuquay-Varina, NC
919.577.2250, www.qcortho.com
Sage Products, Inc., Cary, IL
800.323.2220, www.sageproducts.com
Straumann USA, LLC, Andover MA
800.448.8168, www.strauman.us
Maxillary first molar with three buccal roots evaluated with cone-beam computed tomography: A rare case report

Jojo Kottoor, MDS • Suresh Nandini, MDS • Natanasabapathy Velmurugan, MDS

This case report describes the nonsurgical endodontic management of a maxillary first molar with the unusual morphology of three separate buccal roots. An accurate assessment of this morphology was made with the help of cone-beam computed tomography (CBCT). This report also describes the varied root morphology associated with maxillary first molars and the role of CBCT as a diagnostic tool for managing these complex cases successfully.

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From both a technical and a microbial point of view, the major challenge of root canal treatment is the complexity of the root canal system. It is important to be familiar with variations in root and canal anatomy and the characteristic features of various racial groups, as untreated root canals can lead to endodontic failure. Many teeth display anatomical variation; some teeth possess as many as eight separate root canals to clean and shape.

The largest tooth in terms of volume and the most complex in terms of root and canal anatomy, the six-year molar is perhaps the most frequently treated and least understood posterior tooth. It is generally accepted that the maxillary first molar has three roots and three canals. The most common variation is an extra mesiobuccal canal, seen in 18–96.1% of cases. Cases involving morphologic variations, an abnormal number of roots, or the existence of a C-shaped canal in the maxillary first molar have all been reported previously in the literature. Case reports of maxillary second molars with three buccal roots have also been reported; however, this anomaly has not been documented in the maxillary first molar to date.

This article describes the rare case of a maxillary first molar with an additional mesiobuccal root that was confirmed using cone beam computed tomography (CBCT) and its successful non-surgical endodontic management.

Case report

A 23-year-old man was referred with the chief complaint of tooth decay in his left posterior maxilla for the previous two months. The patient’s medical history revealed intermittent pain localized to the same tooth during mastication and was deemed non-contributory. Clinical examination revealed a grossly decayed asymptomatic left maxillary first molar (tooth No. 14). There was no pain or tenderness to palpation and no tooth mobility. The tooth was tender to percussion, and electric and thermal pulp tests showed a negative response. Radiographic examination revealed a slightly widened periodontal ligament space in relation to the palatal root apex and the distinct probability of an extra root (Fig. 1). Based on the clinical and radiographic findings, a diagnosis of pulpal necrosis with symptomatic chronic apical periodontitis was made, and endodontic treatment was initiated.

The tooth was anesthetized using 1.8 mL (30 mg) of 2% lidocaine containing 1:200,000 epinephrine. Following caries excavation (to allow for optimal isolation), the mesial and distal surfaces of the tooth were restored with composite resin. A rubber dam was placed and a conventional endodontic access opening was made. Using an endodontic explorer (DG16, Hu-Friedy Mfg. Co.), a clinical evaluation of the pulpal floor revealed three root canal entrances: mesiobuccal (MB), distobuccal (DB), and palatal (P). Careful inspection of the pulpal floor using a dental operating microscope (Seiler Instruments) disclosed the presence of a second orifice, located 3 mm mesio-palatal from the MB canal, or the palato-mesiobuccal canal (P-MB).

At first, it was believed that the second mesiobuccal canal was located within the mesiobuccal root. A radiograph with the K-file in place revealed that this was an extra canal located in a separate mesiobuccal root, henceforth referred to
as the palato-mesiobuccal root canal (P-MBR) (Fig. 2).\textsuperscript{13} Coronal flaring was performed using a rotary file (ProTaper SX, Dentsply Maillefer) to improve the straight line access. Working length was determined with the help of an apex locator (Root ZX, J. Morita USA, Inc.) and confirmed radiographically (Fig. 3, 4).

Multiple working length radiographs were taken at different angles; however, the radiographs did not clearly reveal the morphology or number of root canal systems. The authors performed multi-slice scans of the mandible after receiving informed consent from the patient. A CBCT scan (Simulix Evolution, Nucletron Corp.) obtained morphology of the first molar in transverse, axial, and sagittal sections (each section 1 mm thick). CBCT axial images revealed that the right maxillary first molar had four roots and four canals. Interestingly, the contralateral first molar also had a similar configuration. Four canal orifices were located: a mesiobuccal canal in the first mesiobuccal root, a mesiopalatal canal in the second mesiobuccal root, a canal in the distobuccal root, and a canal in the palatal root (Fig. 5–7).

All root canals were cleaned and shaped using ProTaper Ni-Ti rotary instruments (Dentsply Maillefer) with a crown-down technique. Irrigation was performed using normal saline, 2.5% sodium hypochlorite solution and 17% EDTA. After completing the biomechanical preparation, calcium hydroxide was placed as an intracanal medicament with a Lentulo spiral and the access cavity was sealed with Cavit G (3M ESPE). At the next appointment, the patient was asymptomatic.

Final rinsing of the canals utilized 2% chlorhexidine digluconate coupled with ultrasonic agitation.
The canals were dried with absorbent points (Dentsply Maillefer); at that point, obturation was performed using cold lateral compaction of gutta-percha and resin sealer (AH Plus, Dentsply International) (Fig. 7). The tooth was restored with a posterior composite resin core. The patient could not come in person to the clinic; however, a verbal consultation did not reveal any postoperative pathology.

**Discussion**

A 2006 article by Cleghorn et al reviewed the root and root canal morphology of the maxillary first molar from four anatomical studies and found that 96.2% of maxillary molars have three roots while 3.2% have two roots. The authors concluded that the incidence of either one root or four roots is very rare.14

An extensive ex vivo study by Rwenyonyi et al examined 221 maxillary first molars and found none with four roots.15 However, case reports of four-rooted maxillary first molars have been documented in the past, with each reporting the presence of an additional palatal root; an overview of these reports can be found in the table.8,9,16-22 A 1994 report by Sabala et al discovered that aberrations occurred in less than 1% of the cases and 90% of these aberrations were bilateral.23 In the present case, CBCT images revealed a similar configuration in the patient’s contralateral maxillary first molar; in addition, the second mesiobuccal root was shorter than the other three principle roots of maxillary first molars (Fig. 6 and 7).

Although the incidence of root variations is rare, their importance should not be underestimated. Therefore, giving adequate importance to both the roots and their canal systems is imperative for long-term success of endodontic treatment. Accordingly, Kottoor et al and Valerian Albuquerque et al proposed a new anatomically

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**Table. Case reports of maxillary first molar with unusual root morphology.**8,9,16-22

<table>
<thead>
<tr>
<th>Root configuration</th>
<th>No. of canals</th>
<th>Root canal anatomy</th>
<th>Method of diagnosis</th>
<th>Reference</th>
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<tr>
<td>1 root</td>
<td>1</td>
<td>Single canal</td>
<td>Single canal</td>
<td>Single canal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 roots</td>
<td>2</td>
<td>1</td>
<td>C-shaped canal</td>
<td>C-shaped canal</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>C-shaped canal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 roots (1 palatal and fused buccal root)</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3 roots (2 palatal roots and fused buccal root)</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Presumably fusion of teeth No. 3 and 4</td>
<td>5</td>
<td>3 buccal</td>
<td>3 buccal</td>
<td>2</td>
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<tr>
<td>4 roots (MB, DB, MP, DP)</td>
<td>4</td>
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<tr>
<td>4 roots (MB, DB, MP, DP)</td>
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<td>1</td>
<td>C-shaped</td>
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<td>6</td>
<td>MB, MP, M, P, DP</td>
<td>DB</td>
<td>Radiograph</td>
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DB=Distobuccal, DP=Distopalatal, M=mesial, MB=Mesiobuccal, MP=Mesiopalatal, P=Palatal
based nomenclature for root canals that provides a clear picture of any existing root and canal aberrancies in maxillary and mandibular molars. In the present case, root canal orifices were named according to this nomenclature.13,24
At present, radiographic examination usually is limited to two-dimensional periapical images where overlying structures are superimposed. Even with the best intentions and paralleling techniques, essential information related to the three-dimensional anatomy of the tooth/teeth and adjacent anatomy is not visible. Recent innovations in high-end diagnostic technologies—such as CBCT and spiral computerized tomography (SCT)—could improve access to the internal root canal morphology and affect the management of potentially complex endodontic problems. However, when exposing patients to ionizing radiation, it is essential that the radiation dose is kept as low as reasonably achievable (ALARA).25 Exposure to radiation must be justified and therefore the patient’s radiation dose must be optimized. In our case, CBCT was used over SCT because of its low effective radiation dose.

Summary
The present case report discusses the endodontic management of an unusual case of a maxillary first molar with four roots and four canals. The presence of an extra mesiobuccal root was confirmed with CBCT. Evaluating CBCT images can lead to a better understanding of root canal anatomy, which in turn can help the clinician investigate the root canal anatomy and to clean, shape, and obturate it more efficiently.

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References
Effect of curing unit and adhesive system on marginal adaptation of composite restorations

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Luis Roberto Marcondes Martins, PhD, MD, DDS

This study sought to evaluate how a curing unit and adhesive system affected the marginal adaptation of resin composite restorations. Class V cavities were prepared in bovine teeth with a gingival margin in dentin and an incisal margin in enamel. The cavities were restored with a micro-hybrid resin composite using one of four adhesives: Single Bond 2, Prime & Bond NT, Clearfil SE Bond, Xeno IV. The light-activations were performed using a quartz-tungsten-halogen (QTH) lamp or a second-generation light-emitting diode (LED). Restorations were finished and polished and epoxy replicas were prepared. Marginal adaptation was analyzed by using scanning electronic microscopy (magnification 500X). The widest gaps in each margin were recorded, and data were submitted to Kruskal-Wallis, Mann-Whitney, and Wilcoxon tests ($\alpha = 0.05$). Differences between the adhesives were observed only when the dentin margins were evaluated: Clearfil SE Bond demonstrated better marginal adaptation than Prime & Bond NT or Single Bond 2 (which demonstrated the widest gaps in the dentin margin). The type of curing unit only affected the results for Xeno IV when the enamel margin was analyzed; the LED lamp promoted smaller gaps than the QTH lamp.

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Despite the improvements of restorative material in recent decades, the marginal integrity of restoration remains a challenge for dentistry. Poor marginal adaptation may lead to marginal discoloration, postoperative sensitivity, and secondary caries, the most frequent reasons to replace or repair an adhesive restoration.1-3 Marginal failure of composite resin restorations is due primarily to the stress generated by polymerization shrinkage of composites and to the quality of bonding to the dental structure; a stress higher than bond strength results in gap formation.4,5

Resin composites contain (di)methacrylates that polymerize under irradiation with visible light. These composites shrink because of the reduction in intermolecular distance that takes place between monomer units during the polymerization process.6 In other words, a high degree of conversion is related to increased polymerization shrinkage and, consequently, increased stress generated by shrinkage.6,7 If stress exceeds the bond strength between the dental substrate and the adhesive system, a gap will form, jeopardizing the longevity of the restoration.5,9

For many years, quartz-tungsten-halogen (QTH) lights have been used as the primary curing unit for photopolymerization of dental composites. This unit generates a broad wavelength (usually between 370 and 520 nm).10 Some factors may compromise the performance of QTH units, such as line voltage fluctuation, long-term degradation of the bulb and filter, light guide contamination, damage to the fiber-optic bundle, and bulb overheating within the unit.11,12

Light emitting diodes (LEDs) are becoming increasingly popular among clinicians, as they consume little power and do not require filters to produce blue light.11,13 LEDs have a narrower wavelength spectrum (usually centered at 470 nm).13 Differences in the emissions spectrum can affect polymerization. Adhesives usually have different comonomers than resin composites; in addition, they may have organic solvents that can affect polymerization.12 A high degree of adhesive conversion is important to improve their cohesive strength and, consequently, the bond strength to dental substrate.15 Despite these differences, the effect of curing units on the marginal integrity of restorations treated with adhesive systems has seldom been evaluated. The substrate to which the adhesive is applied also can influence the marginal integrity of the restoration. Traditionally, the dental substrate is etched with phosphoric acid and rinsed prior to application of the adhesive agent.16 Subsequently, simpler adhesives were introduced with the development of self-etching primers/adhesives, eliminating the need for conditioning, rinsing, and drying; however, this simplification did not improve bonding.17,18
This study sought to evaluate how the marginal integrity of composite restorations was affected by curing lights and adhesive systems. Three null hypotheses were proposed: First, the type of curing light (that is, LED or QTH) has no effect on the marginal adaptation of composite restorations; second, that the location of the restoration margin (that is, enamel or dentin) has no effect on marginal adaptation; and third, that the adhesive system has no effect on the marginal adaptation of composite restorations.

**Materials and methods**

One week after extraction, 40 sound bovine incisors were cleaned, polished, and examined under a light microscope (Eclipse E 600, Nikon, Inc.); incisors with cracks were excluded. Teeth were stored in distilled water (at 5°C) for less than one month before the restorative procedure. Standard-shaped Class V cavities (3 mm height x 3 mm width x 2 mm depth) were prepared using a 169L carbide bur (KG Sorensen) on the buccal surface. Each preparation was designed so that the incisal margin was located in enamel and the gingival margin located in dentin. Within these dimensions, the cavity had a C-factor of 3.7. The cavities were made with a water-cooled, high-speed turbine using a standard cavity preparation device that permits the control of bur penetration. A new bur was used for each of the five preparations.

The cavities were restored using one of three types of adhesive systems: a two-step, self-etching adhesive (Clearfil SE Bond, Kuraray America, Inc.); a single-step, self-etching adhesive (Xeno IV, Dentsply Maillefer); and two different two-step, etch-and-rinse adhesives: Single Bond 2 (3M ESPE) and Prime & Bond NT (Dentsply Caulk). Two different adhesives were used for this last category to evaluate both ethanol- and acetone-based adhesives. All adhesive systems were applied according to the manufacturers’ recommendations. The cavities were restored with a microhybrid resin composite (Filtek Z250, 3M ESPE), filled in one (bulk) increment of 2 mm and cured for 20 seconds. The curing procedures were performed with either a QTH light (Optilux 501, Kerr Dental) or an LED light (Radii-Cal, SDI North America). For the same cavity, only one light curing unit was used. All restored cavities were stored in distilled water (at 37°C) for 24 hours and polished using a water spray and flexible aluminum oxide disks (Sof-Lex Pop-On, 3M ESPE).

Impressions were taken by using a polyvinyl siloxane impression material (Express, 3M ESPE) and replicas were made with epoxy resin (Epoxide, Buehler). Replicas were divided into three regions each for SEM analysis. The margins were analyzed (magnification 500X) and the maximum length of the marginal gap of each region was recorded. A nonparametric statistical analysis was performed because the Kolmorogov-Smirnov test showed $P < 0.05$, indicating absence of normal (or Gaussian) distribution of data. A Kruskal-Wallis test was used to compare the adhesive systems in each level of substrate/curing light. The effect of the curing light was analyzed using a Mann-Whitney test. A Wilcoxon test was used to compare the substrates in each experimental condition. The level of significance of all analyses was established at 5%.

**Table 1. Median gap measurements (µm) based on the adhesive and curing unit used.**

<table>
<thead>
<tr>
<th>Margin location</th>
<th>Curing unit</th>
<th>Single Bond 2</th>
<th>Prime &amp; Bond NT</th>
<th>Clearfil SE Bond</th>
<th>Xeno IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enamel</td>
<td>LED</td>
<td>0.0</td>
<td>1.2</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>QTH</td>
<td>0.0</td>
<td>1.3</td>
<td>0.0</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>$P$</td>
<td>0.168</td>
<td>0.562</td>
<td>0.670</td>
<td>0.034*</td>
</tr>
<tr>
<td>Dentin</td>
<td>LED</td>
<td>5.6</td>
<td>5.8</td>
<td>0.0</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>QTH</td>
<td>5.8</td>
<td>7.8</td>
<td>0.0</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>$P$</td>
<td>0.648</td>
<td>0.273</td>
<td>0.078</td>
<td>1.000</td>
</tr>
</tbody>
</table>

*Indicates statistical difference between curing unit for each adhesive/margin location according to the Mann-Whitney test ($\alpha = 0.05$).
Table 2. Median gap measurements (µm) based on margin location.

<table>
<thead>
<tr>
<th>Curing unit</th>
<th>Margin location</th>
<th>Adhesive</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Single Bond 2</td>
<td>Prime &amp; Bond NT</td>
<td>Clearfil SE Bond</td>
<td>Xeno IV</td>
</tr>
<tr>
<td>LED</td>
<td>Enamel</td>
<td>0.0</td>
<td>1.2</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Dentin</td>
<td>5.6</td>
<td>5.8</td>
<td>0.0</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>P = 0.016</em></td>
<td><em>0.044</em></td>
<td>0.250</td>
<td>0.074</td>
</tr>
<tr>
<td>QTH</td>
<td>Enamel</td>
<td>0.0</td>
<td>1.3</td>
<td>0.0</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>Dentin</td>
<td>5.8</td>
<td>7.8</td>
<td>0.0</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>P = 0.025</em></td>
<td><em>0.004</em></td>
<td>1.000</td>
<td>0.492</td>
</tr>
</tbody>
</table>

*Indicates statistical difference between the margin location for each adhesive/curing unit according to the Wilcoxon test (α = 0.05).

regardless of the curing light used. The type of curing light used only demonstrated a significant effect on gap measures for Xeno IV, when enamel margins were evaluated; samples treated with the Optilux 501 QTH light demonstrated a larger gap than those treated with the Radii-Cal LED.

Table 2 presents the results based on the margin location, which only had a significant effect for samples treated with Single Bond 2 or Prime & Bond NT, regardless of the curing light used. For both adhesives, gap measure values were lowest when the margin was located in enamel.

Discussion

Microleakage in composite restorations often is related to polymerization shrinkage, which causes stress in the interface between the cavity wall and the restoration. This stress can disrupt the bond and cause gap formation. A proper bond between an adhesive and dental tissue helps prevent marginal microleakage.

In the present study, the curing light, adhesive system, and margin location all had a significant effect on the marginal adaptation of resin composite restorations. As a result, all null hypotheses were rejected.

The effect of the adhesive system on gap formation was observed only for restoration margins located in dentin. The two-step self-etching adhesive Clearfil SE Bond demonstrated lower gap measures than the two-step etch-and-rinse adhesives, regardless of the curing light used. A positive correlation has been demonstrated between gap formation and bond strength. Despite the differences in terms of gap measures, these adhesive systems have shown similar bond strength to dentin.

The results of the present study are due to differences in terms of the layer produced by each adhesive and its ability to absorb and distribute the stress generated by polymerization shrinkage. Unlike Single Bond 2 and Prime & Bond NT, the bonding agent used in Clearfil SE Bond does not include a solvent; as a result, the Clearfil produced a thicker layer, which produced a greater elastic effect, since the shrinkage stress results in a deformed adhesive layer. As a result, the adhesive system that creates a thicker adhesive layer reduces the stress concentration on the adhesive interface and favors the maintenance of gap-free margins.

The curing light only had a significant effect for Xeno IV, and only when enamel margins were evaluated. In this experimental condition, the LED improved the restoration’s marginal adaptation. According to the manufacturers, camphorquinone is the photoinitiator for all materials evaluated in this study. Camphor-quinone absorbs a wide spectrum of wavelengths (360 to 510 nm), with an absorbance peak of 468 nm. For effective photopolymerization, the curing light’s spectral irradiance has to overlap with the absorption spectrum of the photoinitiator as much as possible. Both curing lights used in this study were able to activate the camphorquinone efficiently, so the results of this study are not due to differences in the activation of the adhesives.

Self-etching adhesives require water to ionize the acid monomers that are essential to their etching ability. In addition to the water content in the composition of Xeno IV, the presence of water in dentin increases the potential of acid monomers’ ionization. Thus, a more effective etching is expected for this substrate, resulting in higher bonding to dentin than enamel. The LED used in this study includes an activation mode called soft-start: Activation is initiated at a low intensity, while final polymerization is accomplished at high intensity. This activation mode is able to reduce the shrinkage stress. However, the difference between the light-curing units was observed only with Xeno IV on enamel. This occurred probably due to the low bond strength between Xeno IV and enamel.

Regardless of which curing light was used, Prime & Bond NT and Single Bond 2 presented the largest gap measures in dentin compared to enamel. These outcomes were
expected, since it has been demonstrated that etch-and-rinse adhesives produce greater bond strength with enamel compared with dentin, due to enamel’s high mineral content. By contrast, dentin is a more heterogeneous substrate, consisting of hydroxyapatite, collagen fibrils, and water. During polymerization of resin composite, it is expected that shrinkage stress leads to debonding on the weaker interface, resulting in wider gaps.

Self-etching adhesives do not demonstrate higher bonding ability to enamel than to dentin, primarily because these adhesives have a relatively high pH. As a result, they are unable to produce an acidic environment that will allow for the efficient etching of enamel. The ineffectiveness on enamel etching of self-etching adhesives results in similar bond strength for both enamel and dentin. Single-step adhesives like Xeno IV produce low bond strength for both dentin and enamel; as a result, debonding at both margins would be expected. By contrast, Clearfil SE Bond produces a more effective bond strength that, combined with the elasticity from its adhesive layer, makes it possible to maintain a marginal seal in both the dentin and enamel margins.

A proper margin seal is essential to improve the longevity of resin composite restorations. A sealed margin avoids marginal discoloration and secondary caries, while this last occurrence is the main reason for replacing restorations. Class V cavities were chosen for this study due to their cavity configuration, which impairs resin composite flow during polymerization shrinkage. Moreover, these cavities often have gingival margins in dentin, which produces an additional barrier to a proper margin seal. Based on the results of the present study, the curing unit, adhesive system, and margin location have an important effect on marginal adaptation of composite restorations.

Summary
The occurrence of marginal gaps in restorations of composite resin seems to be dependent on the interaction between such factors as the adhesive system, light-curing unit, and location of the margin (dentin or enamel).

Disclaimer
The authors have no financial, economic, commercial, and/or professional interests related to topics or products presented in this manuscript.

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Buehler, Lake Bluff, IL
800.283.4537, www.mybuehler.com

Dentsply Caulk, Milford, DE
800.532.2855, www.caulk.com

Dentsply Maillefer, Tulsa, OK
800.924.7393, www.maillefer.com

JEOL USA, Inc., Peabody, MA
978.535.5900, www.jeolusa.com

Leica Microsystems, Buffalo Grove, IL
800.248.0123, www.leica-microsystems.com

Kerr Dental, Orange, CA
800.537.7123, www.kerrdental.com

KG Sorensen, Sao Paulo, Brazil
55.11.4195.3275, www.kgsorensen.com.br

Kuraray America Inc., New York, NY
800.879.1676, www.kuraraydental.com

Nikon Inc., Melville, NY
631.547.4200, www.nikonusa.com

SDI North America, Bensenville, IL
800.228.5166, www.sdi.com.au

3M ESPE, St. Paul, MN
888.364.3577, solutions.3m.com
Bond strength of resin-modified glass ionomer restorative materials using a no-rinse conditioner

Rian W. Suihkonen, DDS, ABGD • Kraig S. Vandewalle, DDS, MS, MAGD, ABGD • Jon M. Dossett, DMD, MAGD, ABGD

A paste-paste resin-modified glass ionomer (RMGI) restorative material has been introduced recently with a new conditioner that requires no rinsing. The purpose of this study was to compare the shear bond strength of an encapsulated RMGI (Fuji II LC) and a new paste-paste RMGI (Fuji Filling LC) to dentin conditioned with 20% polyacrylic acid (Cavity Conditioner), a new no-rinse conditioner (Self Conditioner), or no conditioner. Mounted human third molars were flattened and the dentin surface was conditioned. The RMGI restorative materials were mixed and incrementally inserted into a mold and photocured. The specimens were loaded until failure in a universal testing machine after 24 hours storage in distilled water. Fuji II LC had significantly greater bond strength to dentin than Fuji Filling LC. The use of Cavity Conditioner or Self Conditioner resulted in bond strengths that were not significantly different from each other; however, both produced greater bond strengths than those in the non-conditioned groups.

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Resin-modified glass ionomer (RMGI) materials were introduced to the dental market to overcome the disadvantages of conventional glass ionomer and to expand clinical applications. RMGI materials are similar to conventional glass ionomers with an ion-leachable fluoroaluminosilicate glass, but they are modified by the inclusion of resin monomers, particularly 2-hydroxyethylmethacrylate (HEMA), and initiators. The material sets via an acid-base reaction and free-radical polymerization.\(^1\) RMGI materials are easier to use and more esthetic than conventional glass ionomers because of their resin content. These materials are marketed as restorative materials for small Class 1, Class 3, and Class 5 restorations, and for use as a liner, core buildup material, or luting agent. RMGI materials are available in a liquid-powder, paste-paste, or encapsulated delivery system.\(^2\)

RMGI bonds to tooth structure through both an ion exchange and micromechanical interlock.\(^3\) Controlled clinical studies have shown a superior or comparable retention rate of glass ionomer-based materials compared to adhesive-retained resin-based composite restorative materials in Class 5 restorations.\(^4,5\) Chemical bonding of the glass ionomer to the hydroxyapatite in dentin and enamel could be responsible for the enhanced stability of the bonded interface.\(^1\)

Conditioning agents for bonding of RMGI to tooth structure have historically consisted of a 10% or 20% polyacrylic acid. The purpose of the conditioner is to remove the smear layer from the dentin without chemically etching it, allowing an ionic bond of the restorative material to the tooth substrate.\(^3\) The significance of surface conditioning on the performance of RMGI materials has been demonstrated in multiple studies, proving that it is essential for the success of an RMGI restoration.\(^5,6,7\) With the advent of newer generations in bonding materials, self-etch bonding agents have been introduced to adhesively bond composite resin to tooth structure. A study by Besnault \textit{et al} showed that various self-etch adhesives increased the bond strength of RMGI restorative materials to dentin compared to the conventional etch-and-rinse approach with polyacrylic acid.\(^8\) One major advantage of a self-etch adhesive is the elimination of the need to rinse the tooth after conditioning. Not only does it save time, it reduces the potential contamination of the freshly conditioned dentin surface.

Cavity Conditioner (GC America) is a 20% polyacrylic acid solution, and Self Conditioner (GC America) is a new no-rinse conditioning solution that contains primer components similar to resin-based adhesive bonding agents. Both Cavity and Self Conditioner are used to condition the bonding surface of the tooth prior to using glass ionomer materials, but Cavity Conditioner must be rinsed off the tooth surface. The new Self Conditioner is specifically recommended for use with Fuji Filling LC (GC America), while Cavity Conditioner is recommended for use...
Bond strength of resin-modified glass ionomer restorative materials using a no-rinse conditioner

Table. Application technique and composition of materials used in this study.

<table>
<thead>
<tr>
<th>Material</th>
<th>Application</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuji II LC</td>
<td>Triturate for 10 seconds, place with applicator,</td>
<td>Powder: alumino-silicate glass; Liquid: polyacrylic acid, HEMA, initiators, water</td>
</tr>
<tr>
<td></td>
<td>photocure for 20 seconds</td>
<td></td>
</tr>
<tr>
<td>Fuji Filling LC</td>
<td>Dispense, mix for 10 seconds, place with instrument or syringe tip, photocure</td>
<td>Paste A: alumino-silicate glass, HEMA, UDMA; Paste B: polyacrylic acid, UDMA, silica dioxide, initiators, water</td>
</tr>
<tr>
<td>Cavity Conditioner</td>
<td>Apply, wait 10 seconds, rinse with water, dry, do not desiccate</td>
<td>Polyacrylic acid, aluminum chloride, water</td>
</tr>
<tr>
<td>Self Conditioner</td>
<td>Apply, wait 10 seconds, dry gently for 5 seconds, do not rinse</td>
<td>Ethanol, HEMA, 4-META, water</td>
</tr>
<tr>
<td>HEMA: 2-hydroxyethyl methacrylate; UDMA: urethane dimethacrylate; 4-META: 4-methacryloyloxyethyltrimellitate anhydride</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

with Fuji II LC (GC America).\(^{10,11}\) Fuji II LC is an encapsulated RMGI restorative material, whereas Fuji Filling LC is a new paste-paste, hand-mixed material. Both are marketed for Class 3 and 5 restorations, Class 1 restorations in primary teeth; and as a base or core buildup material. The new Fuji Filling LC reportedly has increased adhesion and superior esthetics with the inclusion of dimethacrylate monomers and silica filler particles.\(^{12,13}\)

One concern with RMGI materials that require manual mixing is a potential loss in cohesive strength due to an increase in porosity.

Very little research has been published that compares the traditional polyacrylic acid conditioner to a new commercially available, no-rinse conditioner, nor has much been published comparing encapsulated and hand-mixed RMGI restorative materials on the bond strength to dentin. The purpose of the present study was to determine the shear bond strength to dentin of a new no-rinse self-conditioner as compared to that of the conventional polyacrylic acid conditioner or no conditioner (control) using encapsulated or hand-mixed RMGI restorative materials. Two null hypotheses were evaluated: There was no significant difference in bond strength to dentin based on surface treatment, and there was no significant difference in bond strength to dentin based on RMGI restorative material.

Materials and methods

One hundred twenty extracted human third molars were stored in 0.5% chloramine-T and used within three months following extraction. Teeth were randomly divided into two groups based on the restorative material to be evaluated (Fuji II LC or Fuji Filling LC). For each restorative group there were three surface treatments (Cavity Conditioner, Self Conditioner, or no surface conditioner), creating a total of six group combinations with 20 teeth per group.

Teeth were mounted in dental stone supported with a PVC pipe matrix to keep the crown exposed and accessible. A diamond saw (Isomet, Buehler) was used to remove at least 2 mm of coronal tooth structure to ensure dentin exposure. Each specimen was examined with a stereomicroscope to ensure complete exposure of the dentin surface with no residual enamel. The dentin was finished with 600 grit silicon-carbide paper to create a uniform smear layer.

All surface conditioning steps were performed according to manufacturer’s instructions (See Table). Six different group combinations were created:

1. Fuji II LC/Cavity Conditioner
2. Fuji II LC/Self Conditioner
3. Fuji II LC/No surface conditioner
4. Fuji Filling LC/Cavity Conditioner
5. Fuji Filling LC/Self Conditioner
6. Fuji Filling LC/No surface conditioner

Specimens were placed in an Ultradent jig (Ultradent Products, Inc.) and secured beneath a white nonstick Delrin insert (DuPont de Nemours & Co.). The bonding area was limited to a 2.4 mm diameter circle determined by the Delrin insert. The RMGI was mixed and applied in 2-mm incremental layers to a height of 3–4 mm as recommended by the manufacturer. Each layer was cured for 20 seconds using the Bluephase 16i photocuring unit (Ivoclar Vivadent, Inc.). Irradiance of the curing light was monitored with an LED Radiometer (Kerr Corporation) to verify irradiance levels of at least 1,200 mW/cm². All specimens were stored for 24 hours in distilled water at 37°C.

The specimens were loaded perpendicularly with a customized probe (Ultradent Products, Inc.) in a universal testing machine (MTS Systems) using a crosshead speed of 1.0 mm/min. Shear bond strength values were calculated from the peak load of failure divided by the specimen surface area. Means
and standard deviations were determined for each group. The data were analyzed using a two-way ANOVA and a Tukey multiple comparison test to evaluate the effects of restorative material (two levels) or surface treatment (three levels) on the shear bond strength of RMGI to dentin ($\alpha = 0.05$).

After testing, each specimen was examined using a stereomicroscope at 10X magnification to determine failure mode as either adhesive fracture at the RMGI-dentin interface, cohesive fracture in RMGI or dentin, or mixed (combined adhesive and cohesive) in RMGI or dentin.

**Results**

A significant difference was found based on surface treatment ($P < 0.001$) and RMGI restorative material ($P < 0.001$), with no significant interactions ($P = 0.847$). Chart 1 displays the bond strength to dentin of the different groups. No significant differences were found among the two restorative materials when comparing Cavity Conditioner to Self Conditioner, but both conditioners produced significantly higher bond strengths than no conditioner. Fuji II LC showed higher bond strengths among the different surface treatments than Fuji Filling LC. Chart 2 shows the failure modes of the various groups. Groups with Self Conditioner had the greatest incidence of cohesive failures, followed by Cavity Conditioner, then no conditioner.

**Discussion**

New restorative materials are continuously being introduced to the dental profession, often without clinical research. Clinical trials require long observation times, so in vitro testing of newly developed materials is recommended to evaluate their performance, at least initially. The shear bond strength test is one method of evaluating the new no-rinse conditioners, specifically their ability to retain the RMGI restorative material in an environment where it might be subjected to significant forces. Although the shear test does not actually assess the adhesive bond, it still remains the most common technique to measure bond strength.$^{14}$

The first null hypothesis was rejected. The shear bond strengths to dentin using Self Conditioner and Cavity Conditioner were significantly greater than with no conditioner, but they were not
significantly different from each other. The results of this study agree with those of a study by Coutinho et al, who found no significant difference between a polyacrylic acid conditioner and an experimental no-rinse conditioner when bonding RMGI materials to dentin. However, the quality of the bond to dentin should not be based solely on bond strength values. The type of bond failure can provide additional information regarding the potential performance of the materials subjected to forces experienced clinically. Groups in the present study that used Self Conditioner had more cohesive failures, suggesting a more stable interface. Studies have shown that conditioning of the dentin is a crucial step in the bonding process of RMGI, and that RMGI materials bond primarily through a dual-fold mechanism that includes micromechanical retention and chemical interactions of carboxyl groups from the polyalkenoic acid and calcium from the partially demineralized dentin. Although a hybrid layer forms and micromechanical bonding is possible, a recent study found minimal evidence of micromechanical bonding through resin tags. Self Conditioner has a similar composition (HEMA, 4-META, ethanol) to primers and solvents in resin-based composite adhesive bonding agents, potentially producing a stronger hybrid layer and increasing micromechanical bonding. The no-rinse conditioner might have increased the number of cohesive fractures compared to the use of polyacrylic acid found in Cavity Conditioner.

The second null hypothesis was also rejected. Fuji II LC had significantly greater bond strength to dentin compared to Fuji Filling LC. Mixing the paste-paste material of Fuji Filling LC might have created a more porous material than capsule-mixed products. These porosities could have contributed to the lower cohesive strength of Fuji Filling LC compared to Fuji II LC. A previous laboratory study found a significant increase in porosities and decrease in bond strength to dentin after the manual mixing of an RMGI adhesive compared to an encapsulated RMGI restorative material. Also, it can be speculated that the inclusion of the cross-linking dimethacrylate monomers in the new Fuji Filling LC might have contributed to the reduction in the chemical adhesion to dentin of the glass ionomer components of the material.

The present study showed stronger bond strength to dentin utilizing Self Conditioner compared to Cavity Conditioner with either Fuji II LC or Fuji Filling LC, but not to a statistically significant level. However, in the interest of time management, a no-rinse self-conditioner might be appealing to dental professionals. In addition, the encapsulated Fuji II LC might be easier to mix and apply, with the additional benefit of greater strength compared to Fuji Filling LC.

Conclusion

Fuji II LC had significantly greater bond strength to dentin than Fuji Filling LC and was less technique-sensitive. There was no significant difference in bond strength to dentin among the RMGI materials with the use of either Cavity Conditioner or Self Conditioner; however, both conditioners showed significantly greater shear bond strength than non-conditioned dentin surfaces.

Disclaimer

The views expressed in this article are those of the authors and do not reflect the official policy of the Department of Defense or other departments of the United States Government. The authors do not have any financial interest in the companies whose materials are discussed in this article.

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Ivoclar Vivadent, Inc., Amherst, NY
800.533.6825, www.ivoclarvivadent.us
Kerr Corporation, Orange, CA
877.685.1484, www.kerrdental.com
MTS Systems, Eden Prairie, MN
800.328.2255, www.mts.com
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