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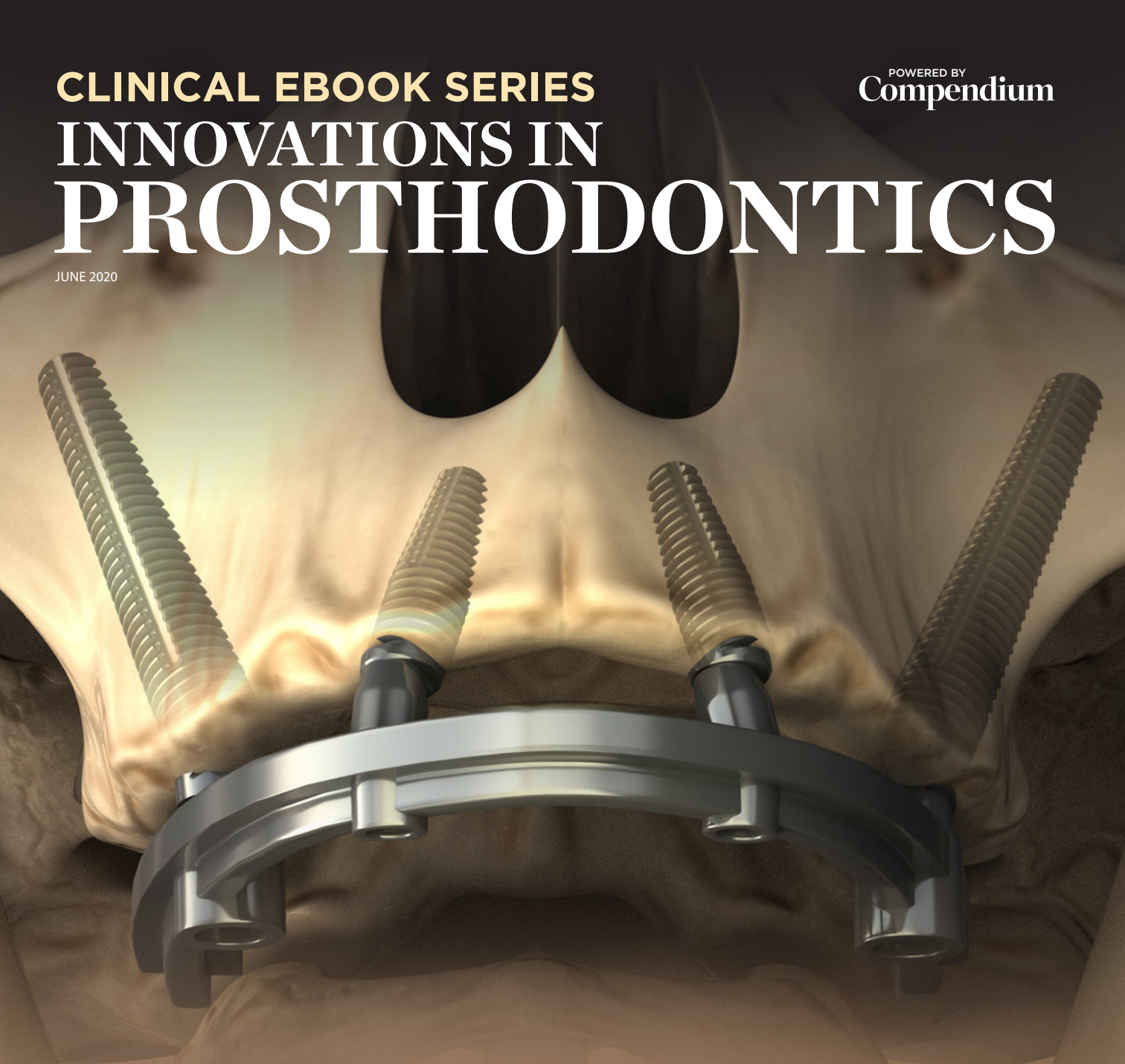

2 CE CREDITS

EDENTULOUS MAXILLA TREATMENT

Systematic Treatment Planning Protocol of the Edentulous Maxilla for an Implant-Supported Fixed Prosthesis

Edmond Bedrossian, DDS; and
Edmond Armand Bedrossian, DDS

2 CE CREDITS

TISSUE MANAGEMENT

Local and Systemic Effects of Mechanico-Chemical Retraction

Mark Donaldson, Pharm D; and
Jason H. Goodchild, DMD

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Means to an End

Although the optimal end result of prosthodontics is for a patient to have functional, esthetic, and long-lasting prosthetics, arriving at that goal may depend on what happens at the beginning. This special *Compendium* eBook features two continuing education (CE) articles that explain the importance of starting out right. The first article describes a systematic treatment planning protocol of the edentulous maxilla for an implant-supported fixed prosthesis. The second article reviews local and systemic effects of mechanico-chemical retraction for fixed prosthodontic impressions.

For patients who will receive implant restoration of a completely edentulous maxilla with a fixed prosthesis, many surgical approaches are available, including graftless strategies that use tilted or zygomatic implants. The first CE article describes a pretreatment screening method that considers the presence or absence of a composite defect, the visibility of the residual soft-tissue crest, and the availability of bone in three radiographic zones as guidelines for the selection of three potential fixed implant restorative designs. The differential diagnosis criteria will allow an early determination to be made of the treatment that will meet patient expectations, before significant investment is needed.

The second CE article reviews mechanical and chemical tissue retraction for fixed prosthodontics, including the use of retraction cord with or without chemicals to control sulcular hemorrhage and moisture. Methods of tissue management for recording fixed prosthodontic impressions include mechanical, chemical, surgical, and a combination of techniques. Regardless of technique, threat of injury to surrounding gingiva is possible; consequently, as the authors explain, practitioners must understand the risks and benefits of the various systems.

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Systematic Treatment Planning Protocol of the Edentulous Maxilla for an Implant-Supported Fixed Prosthesis

Edmond Bedrossian, DDS; and Edmond Armand Bedrossian, DDS

ABSTRACT: Patients who are candidates for implant restoration of a completely edentulous maxilla may benefit from a fixed prosthesis rather than a removable tissue-supported overdenture prosthesis. Multiple surgical approaches are available to provide this type of care. Graftless strategies, such as those that utilize tilted implants, including zygomatic implants, allow the surgeon to establish adequate support for a fixed prosthesis without bone grafting by establishing sufficient anterior-posterior distribution of implants, thereby reducing or eliminating the use of distal cantilevers. For surgeons who may prefer to use a grafting approach for bone reconstruction in this group of patients, adjunctive procedures such as sinus grafting, maxillary osteotomies, and horizontal augmentations also are available. Being able to determine early in the consultation process the type of final prosthesis and surgical approach needed to provide the optimal functional and esthetic results is advantageous. Therefore, a systematic treatment planning protocol is essential for the evaluation of edentulous patients and those with terminal dentitions.

LEARNING OBJECTIVES

- Discuss the evaluation of patients with "tooth-only defects" versus those with "composite defects."
- Identify indications for the use of axial, titled, and zygomatic implants based on the zones of the maxilla.
- Describe a systematic treatment planning protocol for patients with maxillary terminal dentition and/or edentulism.

The predictability of any implant restoration greatly depends on the treatment team adopting a restoratively driven, or "end-in-mind," approach in treatment planning. Understanding and visualizing the final prosthesis before initiating surgical treatment is key to achieving an anticipated outcome.

Evaluation of edentulous patients, especially those with edentulous maxillae, can be complicated due to the fact that patients may only be missing clinical crowns, ie, a *tooth-only defect*, or they may present with a combination of tooth loss and soft- and hard-tissue loss, ie, *a composite defect*.[1] Patients with terminal dentition typically present with bone and soft-tissue loss having occurred before tooth removal as a result of generalized periodontitis, creating the appearance of long teeth; in the authors' experience these types of patients usually present with a composite

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The type of final prosthesis appropriate for a patient is impossible to determine without first identifying whether a patient has a tooth-only defect or a composite defect.

defect, too. Thus, a systematic treatment planning protocol would be beneficial for the evaluation of both edentulous patients and those who present with terminal dentition.

The loss of teeth and use of a removable prosthesis can result in continued alveolar bone atrophy in both vertical and horizontal dimensions. In a study spanning 25 years, Tallgren observed that the greatest amount of alveolar bone atrophy occurs within the first year of edentulism.[2] Also, changes in the jaw relationship and in facial musculature may result in deformation or other changes in the facial form and morphology.[3] A systematic pretreatment approach allows for improved communication among the implant team and with the patients, which typically helps in achieving a predictable treatment outcome.

Three important factors that can be determined early in the examination process can be key to the successful treatment of the completely edentulous maxilla with a fixed restoration. These factors are: (1) the presence or absence of a composite defect, which helps determine the type of final prosthesis; (2) visibility of the transition line, which is used for evaluation for an esthetic outcome; and (3) the available alveolar bone in the edentulous maxilla, which determines the surgical protocol. While not intended to be a substitute for thorough diagnosis and development of a treatment plan, evaluation of these three factors can provide differential diagnosis information specific to the esthetic, phonetic, and biomechanical requirements of fixed, implant-supported maxillary restorations.

Presence or Absence of a Composite Defect

The clinical decision-making algorithm for ascertaining the type of final prosthesis appropriate for a patient is impossible to determine without first identifying whether a patient has a tooth-only defect or a composite defect. Edentulous patients may present with intact alveolar bone volume and missing only clinical crowns (tooth-only defect), or they may present with alveolar bone resorption, loss of soft tissue, and missing teeth (composite defect). Differentiating between these two types of patients is crucial to creating an esthetic definitive fixed prosthesis.

Patients who present with missing teeth without any resorption of the soft or hard tissues are referred to as having a "tooth-only defect." To confirm that a tooth-only defect is present, the clinician can examine the space between the edentulous crest and the cervical portion of clear denture teeth replicated from the patient's existing denture. The presence of no space as seen through the clear denture, ie, the cervical portion of the teeth resting on crestal soft tissues, confirms the diagnosis of a tooth-only defect. For this group of patients, a fixed "white" ceramo-metal or all-ceramic restoration may be planned.

The use of a clear denture also can aid in establishing the diagnosis of a "composite defect," which is the term describing patients who are missing teeth as well as soft and hard tissues. The presence of space between the edentulous crest and the cervical portion of the clear denture teeth confirms the presence of a composite

defect (Figure 1). For this group of patients, a fixed hybrid prosthesis or an implant-supported overdenture may be planned.

For the clinician to confidently evaluate the relative amount of soft- and hard-tissue deficiency, the clear denture duplicated from the patient's existing denture must have the correct vertical dimension of occlusion as well as the proper anterior-posterior and horizontal tooth position.

Visibility of Residual Ridge Crest: the Transition Line

Once the presence or absence of a composite defect has been established, the transition line must be evaluated for patients for whom a maxillary hybrid prosthesis is planned. If a composite defect is present, it would be inappropriate to plan a metal-ceramic or all-ceramic tooth-only restoration because such a restoration would result in esthetic compromises due to longer-than-normal teeth. Therefore, a hybrid prosthesis, ie, a "pink and white" prosthesis, intended to replace the teeth and missing hard and soft tissues should be planned. To maximize the esthetic prosthetic outcome for this group of patients, the transition line between the hybrid prosthesis and the soft tissue of the edentulous maxillary ridge must be clinically evaluated for potential visibility without the maxillary denture in place.

This evaluation can be done by removing the maxillary denture and then having the patient smile (Figure 2). If the soft tissue of the edentulous ridge cannot be seen, the transition between an implant-supported hybrid prosthesis and the residual soft-tissue crest is considered favorable. Conversely, for those patients who do display the residual ridge while smiling, ie, the smile line is apical to the transition line, the transition between a hybrid restoration and the soft tissue will be visible and, therefore, unesthetic. With a visible residual ridge crest, the junction of the artificial gingiva of the hybrid prosthesis and the natural soft tissue will be

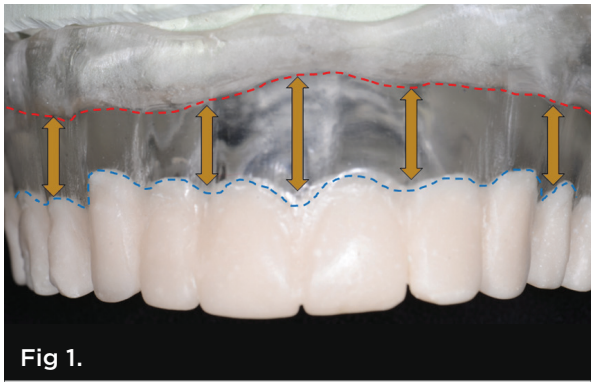


Fig 1.

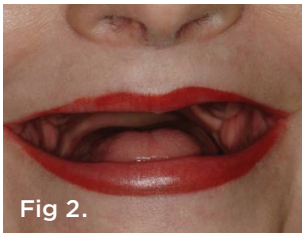


Fig 2.

Fig 1. Space between the cervical portion of the teeth and the crestal soft tissues is indicative of a composite defect. **Fig 2.** If the maxillary edentulous ridge is not visible during animation, the transition line will be hidden. **Fig 3.** Natural emergence profile of the implant crowns and the pontic in a tooth-only defect prosthesis.

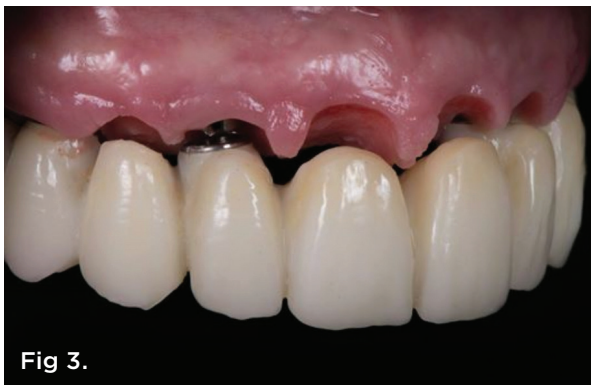


Fig 3.

apparent, and differences in texture and contour between the two may be obvious and unesthetic. However, if the transition line is apical to the smile line, ie, the smile line is incisal to the transition line, a predictable esthetic outcome is possible.

If the crestal soft tissues are visible in the preoperative evaluation, one method to avoid visibility of the transition line in the final hybrid prosthesis is to reduce the residual ridge

height to the point where the crest can no longer be seen and is apical to the smile line prior to placement of implants. Thus, an intentional alveoloplasty in conjunction with implant placement would be planned. If ridge reduction is not possible due to large pneumatized maxillary sinuses, the use of a Marius bridge or any variation of an implant-supported overdenture with a flange that overlaps the gingival junction would be indicated.

In contrast, for patients who are missing teeth only, the visibility or lack of visibility of the transition line is not an issue, because the implants are placed in planned tooth positions, and special consideration is given to anterior ridge lap pontics to improve the appearance of papillae and achieve an esthetic outcome (Figure 3). The emergence profile of the prosthesis from the implant platform should be such that the resultant fixed "white" bridge mimics the emergence profile of the patient's teeth prior to their extraction.

Radiographic Evaluation

Radiographic evaluation of the edentulous maxilla is necessary for determining whether axial, tilted, or zygomatic implants would be indicated to establish optimal posterior support with proper anterior-posterior distribution of implants for a fixed prosthesis. Because the edentulous maxilla is divided into three radiographic zones, a systematic assessment of the residual alveolar bone available for implant placement can be made. In this pretreatment screening protocol, the alveolar bone supporting the maxillary anterior teeth is designated as zone 1, while the premolar region is considered zone 2 and the molar region zone 3 (Figure 4). Analysis of the radiographic results according to this scheme can enable the surgical and restorative team to devise a preliminary treatment plan. In complex situations, 3-dimensional (3D) radiographic evaluation may still be necessary to confirm the preliminary conclusions.

For fully fixed implant-supported maxillary restorations, the distribution of the implants along the arch form is as important as the number of implants used. The goal is to place the posterior implants as far posterior as possible from the anterior implants to achieve the largest anterior-posterior distribution of the implants as possible. A minimum of four implants should be used, although the option to place more than four may be considered.[4,5] As a general principle, cantilevers in fixed maxillary restorations should be avoided or minimized to one tooth to avoid unfavorable load transfer to the prosthetic components, alveolar bone, and existing implants.[6,7]

Evaluation of the various zones of the maxilla will guide the surgical team in determining the type of surgical approach to take for placement of implants. Use of panoramic scout film as well as 3D radiography to evaluate the zones will

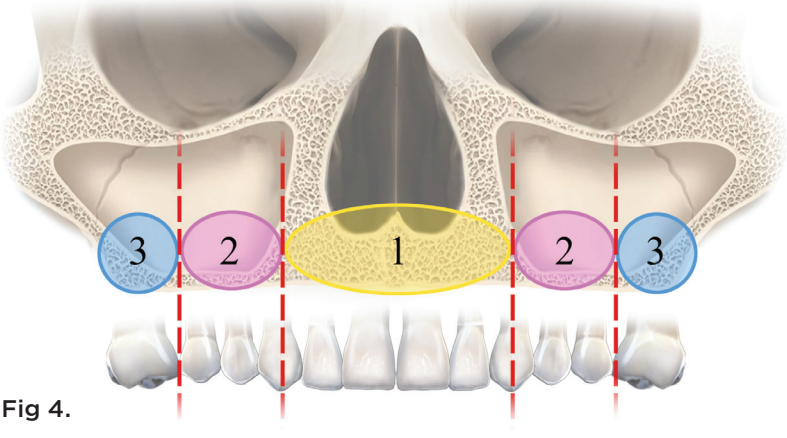


Fig 4.

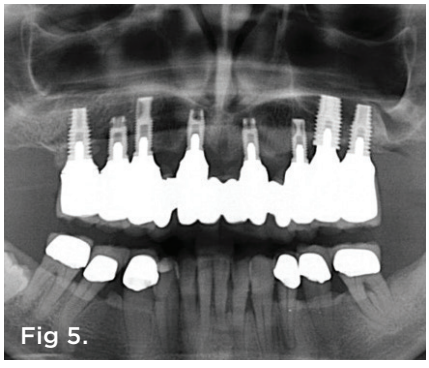


Fig 5.

Fig 4. The zones of the maxilla. **Fig 5.** Axial implant placement, with presence of bone in zones 1, 2, and 3.

help the surgeon understand the quantity of bone available for each intended implant site.

Presence of Zone 1, 2, and 3 Bone

For patients in whom alveolar bone is present in all three zones of the edentulous maxilla, conventional implants may be placed (Figure 5). This should allow for a favorable arch form of anterior, posterior, and possibly intermediate implants for a fixed prosthesis.[8,9]

Presence of Zone 1 and 2 Bone

For patients who have zone 1 and zone 2 bone but lack zone 3 bone secondary to large pneumatized maxillary sinuses, inclining the implants posteriorly along the anterior wall of the maxillary sinus may enable an adequate anterior and posterior distribution of implants to support a fixed restoration while avoiding the need for grafting (Figure 6).[4,10-15] Use of inclined implants also has been shown to be successful with immediate-loading procedures of the completely edentulous maxilla.[5,13,15]

An alternative to the use of inclined implants is sinus inlay grafting, followed by subsequent delayed implant placement. When extensive sinus inlay grafting is performed to provide posterior support, a staged approach that incorporates an allotment of time to wait for graft maturation may be preferable due to lower survival for implants that are simultaneously placed and loaded.[16] This method has the effect of delaying restoration compared with the use of inclined implants and a graftless approach.

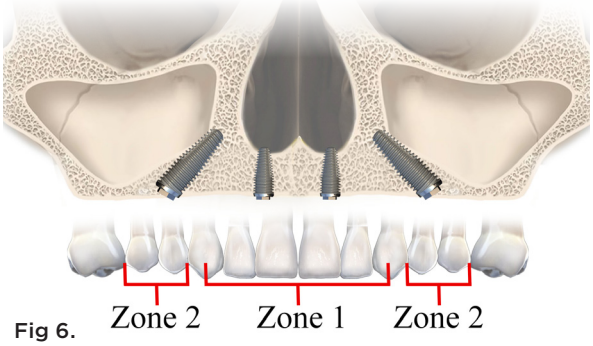


Fig 6.

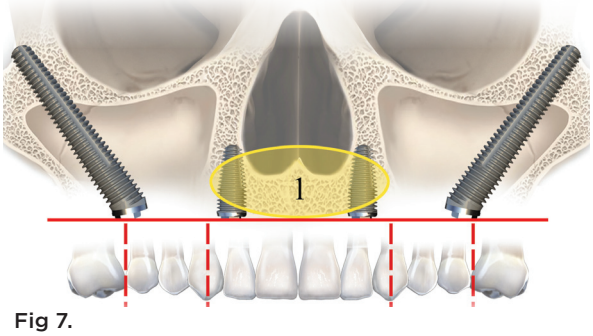


Fig 7.

Fig 6. Tilted posterior and traditional anterior implants, with presence of bone in zones 1 and 2 only. **Fig 7.** The zygoma concept; presence of bone in zone 1 only.

Presence of Zone 1 Bone Only

To establish posterior support for a fixed prosthesis, implants are required in the second premolar or first molar regions. However, placement of implants in these positions is not possible when patients only have bone available in zone 1. Grafting of the sinus with autogenous bone or xenografts is an option in such situations. This approach has shown a 90% overall survival rate with 3- to 5-year follow-up.[17]

If a graftless approach is preferred, zygomatic implants have been shown to provide bilateral posterior maxillary support with a 97% to 100% survival rate.[18-20] These implants have the added benefit of not requiring a staged approach or a period of bone graft maturation. Thus, the overall treatment time required to achieve a fixed restoration can be shortened. Predictable posterior support can be established with the placement of one zygomatic implant in each zygoma.[19,20] When zygomatic implants are used in conjunction with two to four axial anterior implants, a fixed, implant-supported prosthesis may be fabricated (Figure 7).

Bone Missing From Zones 1, 2, and 3

When there is complete resorption of the maxillary alveolus, clinical examination will reveal a flat palatal vault. No maxillary vestibule will be present, and the patient typically is unable to function with his or her conventional complete denture. In the authors' experience such

patients usually present with a significantly thick denture base and a thick circumferential flange, confirming the presence of a significant composite defect.

Physiologic reconstruction of these debilitated patients requires adequate implant support to stabilize an implant-supported prosthesis. To enable prosthetic rehabilitation of such patients, Bränemark introduced the idea of using extensive onlay bone grafts in conjunction with bilateral sinus inlay grafts and placement of six implants.[21] The so-called Brånemark "horseshoe" graft requires hospitalization and harvesting of autogenous iliac bone from the patient (Figure 8). These patients are unable to wear a denture during the 6-month osseointegration period. The social consequence of this form of treatment renders it unpopular with patients.

An alternative, graftless approach is the use of four zygomatic implants (Figure 9). The placement of two such implants in each zygoma allows for the fabrication of an implant-supported fixed maxillary prosthesis without the need for bone grafting and can be accomplished in an office setting. In 2015 Wang et al reported a 96.7% success rate in a systematic review of quad-zygoma implants supporting fixed maxillary hybrid prostheses.[22]

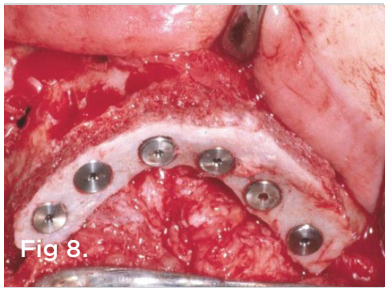
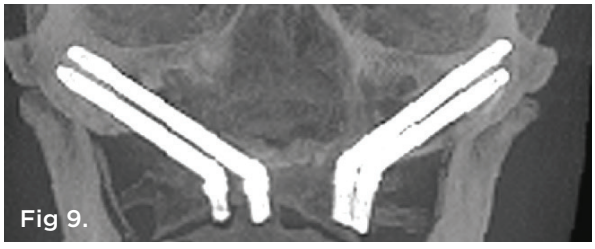


Fig 8. Bränemark horseshoe graft, with lack of bone in zones 1, 2, and 3. **Fig 9.** Quad-zygoma concept, with lack of all three zones of maxilla.



Discussion

Many factors must be considered before implant treatment is performed in a patient with a fully edentulous maxilla. Pretreatment screening can be used to identify early whether or not it is likely that the patient's expectations will be satisfied with a prosthesis option that realistically takes into account not only tooth loss but also the amount of soft- and hard-tissue deficit that must be restored. Additionally, systematic panoramic and 3D radiograph analysis based on available zones of the edentulous maxilla can provide an early indication of how straightforward or difficult the surgical treatment might be.

The combination of prosthodontic and radiographic diagnostic criteria can offer an early indication of treatment possibilities from both surgical and restorative perspectives to help the dental team clarify and communicate the potential treatment requirements and desired outcome. The dental team may then use this information to suggest to the patient to proceed with further, more definitive diagnostics, confident that the anticipated prosthetic outcome may be possible. However, it must be noted that the critical factor of sufficient alveolar ridge width still needs to be verified, and this would only be discovered after a scan. Lack of sufficient ridge width could change the surgical approach significantly.

Clinicians should also bear in mind that these diagnostic criteria still need to be evaluated in relation to the patient's overall health and medical and dental history. Additionally, it must be clearly understood that even with the most thorough planning, deviations from the desired outcome may occur. The criteria presented in this article are best viewed as a preliminary screening apparatus to help guide patient and clinical decisions as more information is gathered. They are subject to change at any time if more definitive analysis or radiographic information does not support the preliminary indication. Also, there may be clinical

situations where the objective is to remove remaining hopeless teeth and simultaneously place implants. While this preliminary diagnostic method is still applicable in these situations, it cannot account for variations in tissue height that may result subsequent to dental extraction.

Conclusion

This article discussed a pretreatment screening method that systematically considers the presence or absence of a composite defect, the visibility of the residual soft-tissue crest, and the availability of bone in three radiographic zones as guidelines for the selection of three potential fixed implant restorative designs: the "all-white" metal-ceramic or all-ceramic prosthesis, the fixed hybrid prosthesis, or the implant-supported overdenture. Additionally, this screening method offers guidance on the optimal implant surgical approach, including the use of axial, tilted, and/or zygomatic implants. By employing these differential diagnosis criteria the dental team is able to make an early determination of the treatment necessary to meet patient expectations before investing a significant amount of time and resources.

A limitation of this protocol is the inability to measure the width of the available residual alveolar bone. While panoramic survey film provides a valuable 2-dimensional scouting radiograph and allows the practitioner to evaluate the height and length of the residual alveolar bone, 3D tomography or spiral computed tomography studies can be used to precisely measure the width of the remaining ridge to aid in making a final determination of the likely outcome of the planned treatment. Adoption of this evaluation method may improve the uniformity of communication among dental colleagues, laboratory support, third-party payment providers, as well as students and faculty.

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Systematic Treatment Planning Protocol of the Edentulous Maxilla for an Implant-Supported Fixed Prosthesis

Edmond Bedrossian, DDS; and Edmond Armand Bedrossian, DDS

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1. **A combination of tooth loss and soft- and hard-tissue loss is a:**
   A. tooth-only defect.
   B. composite defect.
   C. terminal dentition.
   D. zone 1 maxilla.

2. **A systematic treatment planning protocol would be beneficial for the evaluation of:**
   A. edentulous patients only.
   B. patients who present with terminal dentition only.
   C. both edentulous patients and those who present with terminal dentition.
   D. neither edentulous patients nor those who present with terminal dentition.

3. **Which of the following factors determined early in the examination process helps determine the surgical protocol?**
   A. the presence or absence of a composite defect
   B. visibility of the transition line
   C. available alveolar bone in the edentulous maxilla
   D. All of the above

4. **For patients who present with a tooth-only defect, what type of restoration should be planned?**
   A. a fixed ceramo-metal or all-ceramic restoration
   B. a tissue-supported overdenture
   C. a hybrid prosthesis
   D. a Marius bridge

5. **If a composite defect is present, what type of restoration should be planned?**
   A. a metal-ceramic or all-ceramic restoration
   B. a tissue-supported overdenture
   C. a hybrid prosthesis
   D. None of the above

6. **What is necessary to determine the type of implant needed to attain proper anterior-posterior implant distribution for a fixed prosthesis?**
   A. sufficient time to enable graft maturation
   B. use of a clear denture
   C. completion of an alveoplasty procedure
   D. radiographic evaluation of the edentulous maxilla

7. **Among the radiographic zones of the maxilla, the alveolar bone supporting the maxillary anterior teeth is designated as:**
   A. zone 1. B. zone 2.
   C. zone 3. D. zone 4.

8. **For patients in whom alveolar bone is present in all three zones of the edentulous maxilla:**
   A. tilted implants must be used.
   B. zygomatic implants are recommended.
   C. conventional implants may be placed.
   D. extensive sinus inlay grafting will be required.

9. **When bone is missing from all three zones, a graftless restorative approach can be used that involves the use of:**
   A. two zygomatic implants and two axial anterior implants.
   B. two tilted implants and four axial anterior implants.
   C. three zygomatic implants and one tilted implant.
   D. four zygomatic implants.

10. **A limitation of the described pretreatment screening protocol is the inability to:**
    A. measure the width of available residual alveolar bone.
    B. determine the presence of a composite defect.
    C. evaluate for an esthetic outcome.
    D. estimate the amount of soft- and hard-tissue deficiency.

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Local and Systemic Effects of Mechanico-Chemical Retraction

Mark Donaldson, Pharm D; and Jason H. Goodchild, DMD

ABSTRACT: The process of recording an acceptable fixed prosthodontic impression must include appropriate tissue management. This article reviews the effects of mechanical and chemical tissue retraction for fixed prosthodontics, specifically discussing the use of retraction cord with or without chemicals to control sulcular hemorrhage and moisture. Common astringents, hemostatics, and vasoconstrictors used in dentistry as gingival retraction agents are discussed, and recommendations for modification of patient and treatment management are provided.

LEARNING OBJECTIVES

- Discuss the use of gingival retraction cord for mechanical tissue displacement for recording a conventional fixed prosthodontic impression.
- Describe the use and various classifications of chemical agents in clinical practice for fixed prosthodontic impressioning.
- Discuss local and systemic effects of mechanical and chemical tissue retraction for fixed prosthodontics.

Appropriate tissue management is a vital part of the process of recording an acceptable fixed prosthodontic impression. In some cases, precise preparation of the tooth without iatrogenic damage to surrounding tissue is sufficient. Ideally, marginal gingiva should be healthy at the time of crown and bridge procedures.[1,2] When factors such as esthetics, existing restorations, or fracture dictate that finish lines of the prepared tooth be placed equigingival or intracrevicular, some form of tissue retraction or displacement is necessary.

Several means of tissue retraction are commonly used by dentists to create sufficient depth and width of material for crown and bridge impressions. These include mechanical, chemical, and surgical.[3-5] Often, a combination of these techniques is used. The purpose of this article is to review the local and systemic effects of mechanical and chemical tissue retraction for fixed prosthodontics. Specifically, the use of retraction cord with or without chemicals to control sulcular hemorrhage and moisture is discussed. The authors concentrate on the most common astringents, hemostatics, and vasoconstrictors used in dentistry as gingival retraction agents, and offer recommendations for modification of patient and treatment management.

Mechanical Retraction

The most common form of mechanical tissue displacement practiced by dentists to unmistakably record a conventional fixed prosthodontic impression involves the use of gingival retraction cord. Several studies have examined the use of gingival retraction techniques by dentists, and mechanical or mechanico-chemical were most commonly utilized.[6-9] Mechanical retraction using gingival cord consists simply of the use of a string, usually made of cotton, silk, or yarn wool. Products can

DISCLOSURE: Dr. Goodchild was an employee of DENTSPLY Caulk when this article was written.

be fabricated into configurations of knitted, braided, or twisted cord of varying diameters, giving the practitioner numerous choices for easier placement, manipulation, absorbency, and tissue retraction.[10] One unique product on the market offers another option that is composed of a braided cord with a thin metal filament designed to promote retention of the cord in the sulcus after placement.[11,12] The characteristics of knitted, braided, and twisted cords are summarized in Table 1. Placement of retraction cord is accomplished using cord-packing instruments, with either a smooth or serrated end, and generally requires local anesthesia.

Clinical use of retraction cord typically involves either a single-cord or double-cord technique.[1-3,5,10-14] In both cases the goal of mechanico-chemical retraction is to direct pressure into the sulcus to mitigate crevicular flow, achieve hemostasis, and create a physical space for impression material to flow and record the prepared tooth. The use of plain cord may have limited success in creating a dry, bloodless field for making impressions. Wöstman and colleagues showed that the use of nonimpregnated cotton cord caused increases in crevicular fluid flow,[15] although Kumbuloglu et al showed no recurrence of bleeding after plain, untreated cord was used.[4] Several studies have since concluded that consistently successful hemostasis and drying of the sulcus can only be achieved by a combination of mechanical and chemical means.[6,16-18] Mechanico-chemical retraction involves cord that has been impregnated or soaked in astringents, hemostatics, or vasoconstrictors to achieve the clear field necessary for successful fixed prosthodontic impressions.

Retraction cord remains in direct contact with the thin monolayer of epithelial cells of the gingival sulcus and the connective epithelium at the bottom of the sulcus until effective shrinkage and displacement of free gingiva away from tooth structures and hemostasis is obtained. It is well known that placement of cord can lead to acute tissue injury and can be associated with marginal recession. In an early study by Ruel it was demonstrated that retraction cords impregnated with 0.1% (1:1000 concentration) epinephrine resulted in an average of 0.2 mm of gingival recession after crown preparation.[19] Azzi et al showed no recession after cord placement but did emphasize that extreme care should be taken with tissue management, including the use of cord, because irreparable tissue damage could result.[20] In a more recent study by Kazemi, in agreement with Ruel, cord impregnated with aluminum chloride caused up to 0.2 mm of recession after 28 days.[21]

Mechanico-chemical gingival retraction can

TABLE 1

Characteristics of Knitted, Braided, and Twisted Cord[10]

Type of Cord	Recommended Packing Instrument	Comments
Knitted	Nonserrated (smooth)	Easy to place, expands when wet. Knitted weave minimizes unraveling after cutting and during cord placement.
Braided	Serrated or nonserrated	Tight and consistent weave, easy to place. Some brands may have a modified weave for less memory and more precise placement with less tissue damage, more absorbency.
Twisted	Serrated or nonserrated	Twisted cords can be hand-twisted before placement, allows the cord to be tighter when placed in the sulcus; as the cord untwists within the sulcus it expands to create improved access.

Chemicals have been used with gingival retraction cords to act as vasoconstrictors, hemostatics, or astringent agents capable of enhancing the effectiveness of mechanical tissue displacement.

also have some negative local effects on the gingival connective tissues directly. In fact, many authors have observed an inflammatory response or even necrosis of the sulcular epithelium and subepithelial connective tissue induced by gingival cord with or without an applied chemical agent.[4,20,22-27] Harrison examined the effect of mechanico-chemical retraction on the sulcular epithelium on dogs and found that retraction cord treated with epinephrine, alum, or zinc chloride caused tissue injuries varying from slight to severe, although most healed within 7 to 10 days.[28] More recently, Feng and colleagues studied the effect of retraction cord on healthy human gingiva and concluded that pro-inflammatory mediators were released following placement, but that acute tissue injury healed within 2 weeks.[29] This was in agreement with other studies that examined the effect of cord placement on gingival indices.[19,20,30] It is generally recommended, then, that the smallest diameter cord should be used for gingival retraction and should be in place for 3 to 5 minutes, not to exceed 10 minutes. It is further recommended that cord be placed firmly but gently and should be wet with water or other chemical agents during placement and removal from the sulcus to prevent damage.[31]

Chemical Retraction Agents

The use of chemical agents, used alone or in combination with cords, is typical in clinical practice for fixed prosthodontic impressions. The agents are supplied in the form of gingival retraction fluids, gels, or pastes (Table 2).[32,33] Cords may be preimpregnated (ie, the chemical agent is incorporated by the manufacturer) or the chemical agent may be applied to the cord by the clinician prior to placement. If chemical retraction is applied to the cord at chairside, it should be allowed to soak for approximately 20 minutes to achieve proper saturation.[34] Both Shillingburg and Kumbuloglu et al described the most desirable chemical agents to be used in gingival retraction procedures as meeting three criteria: the drug must be effective; it should not cause significant and irreversible tissue damage; and it should not produce potentially harmful systemic effects.[4,29] With respect to the pharmacologic effects of the active substance, they belong either to class 1 (vasoconstrictors) or class 2 (hemostatics, astringents).[35]

Classification of Agents

A variety of chemicals have been used with gingival retraction cords to act as vasoconstrictors, hemostatics, or astringent agents capable of enhancing the effectiveness of mechanical tissue displacement. Some techniques utilizing only gingival retraction fluids, gels, or pastes are intended to create less traumatic tissue management and hemostasis.

Vasoconstrictors do not produce coagulation of blood but act by constricting blood vessels. The most commonly used vasoconstrictor in dentistry, epinephrine, exerts its effect through stimulation of alpha-, beta 1-, and beta 2-adrenergic receptors. Epinephrine provides vasoconstriction of the small blood vessels in submucosal tissue by stimulating alpha

adrenergic receptors; this allows for delayed local anesthetic absorption and improved hemostasis in the operative field. These local effects are considered desirable by most oral healthcare providers and are the main reasons that epinephrine is employed topically as a gingival retraction fluid. Csillag et al advise the use of low-concentration epinephrine (0.01%) for gingival retraction due to its superior effect in keeping the gingival sulcus dry during the

TABLE 2

Chemical Retraction Agents Typically Used in Clinical Practice (Vasoconstrictors, Hemostatics, and Astringents)[31-33]

Agent	Concentration	Action	Comments
Racemic Epinephrine	8%	Vasoconstrictor	Possible hemodynamic changes (hypertension and tachycardia); monitor blood pressure and heart rate closely. Use with caution in patients with existing cardiac disease. A 2.5-cm piece of epinephrine-impregnated cord can release one-third of the maximum recommended dose (mrd) for a healthy patient, and twice the mrd for a cardiac patient. Consider alternatives if multiple teeth are involved or multiple impressions are needed.
Aluminum Chloride	5% to 25%	Astringent	Effective for local hemostasis and drying of the sulcus. Do not exceed 10-minute application, especially in concentrations >10%. Can be associated with a 0.1 mm loss of crestal gingiva. Has been reported to impair the setting of polyvinyl siloxane impression materials; to prevent this possible reaction rinse thoroughly with water after cord is removed.
Aluminum Sulfate	25%	Astringent	May have an irritating and even caustic effect on tissues. Aluminum chloride may be preferred. May retard the setting of polyvinyl siloxane impression materials; rinse thoroughly after use.
Alum	100%	Astringent	AKA potassium aluminum sulfate; good hemostasis but less pronounced than epinephrine. To avoid local tissue injury limit use to 10 minutes or less. May be considered a viable alternative to epinephrine if systemic effects are a concern. May retard the setting of polyvinyl siloxane impression materials; rinse thoroughly after use.
Ferric Sulfate	13.3% to 15%	Hemostatic (styptic)	Solutions greater than 15% have a higher incidence of postoperative dentin sensitivity; can cause black or bluish tissue discoloration for one to two days after application. Can be used with aluminum chloride but not with epinephrine (if combined with epinephrine a blue precipitate will form). Should be used for 1 to 3 minutes; do not exceed 10 minutes. Can impair setting of polyether and polyvinyl siloxane impression material; rinse thoroughly after use. Use during the impression stage or at delivery may cause a grayish/black discoloration under glass ceramic restoration.

impression procedure.[17] Originally, 8% racemic epinephrine was the vasoconstrictor of choice and was preferred over some of the early astringents such as zinc chloride and alum because they often caused adverse tissue reactions. Racemic epinephrine has since been the subject of many studies primarily because of the controversy regarding its possible hemodynamic effects.[6,25,36] Racemic epinephrine differs from epinephrine USP because it contains a 50:50 mixture of the d- and l-isomers; epinephrine USP contains only the l-isomer. The racemic form of epinephrine is used in retraction cord because the chemical is more stable and allows for efficacy under varying conditions of storage.[37] Racemic epinephrine is sometimes listed as dl-epinephrine on retraction cord product labels.

Astringents are chemicals that precipitate proteins to make the superficial layer of the mucosa mechanically stronger. They do not typically penetrate cells but rather toughen the mucosal surface to increase gingival resistance against infection.[38] Because these drugs have poor cell permeability, they are particularly useful in prosthodontics for the management of bleeding during gingival retraction without concern for systemic effects; they also decrease exudation and crevicular fluid flow.[38] Some examples include alum, aluminum chloride, zinc chloride (8% to 20%), and tannic acid. The term "styptic" is sometimes used to describe the concentrated form of astringents. Styptics cause superficial and local coagulation and are, therefore, often referred to as hemostatic agents. Some examples are ferric chloride and ferric sulfate.

Epinephrine

While the primary class 1 gingival retraction agent, epinephrine, exerts its effect through stimulation of alpha-, beta 1-, and beta 2-adrenergic receptors as mentioned above, it is the alpha-stimulation that is most desirable in dentistry (ie, vasoconstriction of the small blood vessels in submucosal tissue and improved hemostasis in the operative field). However, too much epinephrine, prolonged exposure, or patients with unique anatomy may present risk for some negative local effects of the vasoconstrictor (ie, tissue blanching and reduced blood flow). Given the very short half-life of epinephrine (about 2 minutes), these local effects tend to be transitory and non–life-threatening, such that many practitioners seldom consider them to be significant.

As the alpha effect causing vasoconstriction wears off, beta adrenergic stimulation dominates, resulting in relaxation of smooth muscle within the bronchial tree, cardiac stimulation (increasing myocardial oxygen consumption), and dilation of skeletal muscle vasculature; small doses can cause vasodilation via beta 2-vascular receptors; large doses may produce constriction of skeletal and vascular smooth muscle.[39] Potential systemic side effects specifically related to the hemodynamic and cardiovascular influence of epinephrine are of greatest concern primarily in the at-risk cardiovascular population (ie, hypertensive, angina, myocardial infarction, and heart failure patients). In fact, in a study by Woycheshin, it was shown that the use of 1:1000 (0.1%) epinephrine cord caused high systemic concentrations, and the authors recommended that it should not be used in large areas of tissue laceration or abrasion.[40]

The systemic effects of epinephrine-impregnated gingival retraction cord in hypertensive patients has not been reported, although several authors have studied the effect of retraction cord in normotensive patients.[36,41-44] In general, mean effects on blood pressure and heart rate were minimal.[45] Regardless, given the short elimination half-life for epinephrine, the possible systemic effects occur within minutes of absorption and will have completely subsided in 10 to 15 minutes. Perhaps the most rational suggestion in regard to modifications

Despite adequate tissue management and displacement around the prepared tooth, voids in the impression may still occur and can be the result of blood or other liquid.

of patient management should be based on patient assessment, and not on absolute amounts of epinephrine administered. For example, for patients with a diagnosed cardiac condition, a sensible protocol is to record baseline heart rate and blood pressure preoperatively and then every 5 minutes for 15 minutes following administration of a class 1 gingival retraction agent. While epinephrine is an effective vasoconstrictor both on retraction cords and in local anesthetics, practitioners should limit doses to minimize negative sequelae or consider alternate therapy. For this reason local anesthesia containing epinephrine in 1:50,000 concentrations should be administered judiciously if utilized for local hemostasis.

Aluminum Chloride, Aluminum Sulfate, Alum, Ferric Sulfate, and Others

Chemically, all the retraction agents containing astringents are characterized by a relatively high level of acidity, with their original concentrations ranging from pH 1 to pH 3 for solutions.[46] In-vivo and in-vitro observations have shown these agents to induce undesirable local side effects on gingival margin tissues in addition to their desired activity.[4,20,23-27,47-50] Studies in both human and animal models using various research methods have confirmed an inflammatory response of the surrounding soft tissues. The inflammatory response was normally transitory and its severity depended on the type and concentration of the retraction agent used. Results obtained by scanning electron microscope and energy dispersive x-ray spectroscopy (SEM-EDX techniques) reported an altered morphology of prepared human dentin surface after exposure to conventional astringents containing gingival retraction fluids.[51-53]

Of the class 2 gingival retraction agents (hemostatics, astringents), aluminum chloride, aluminum sulfate, alum, and ferric sulfate tend to be the most commonly used, with zinc chloride and potassium sulfate being used much less often.[54] Unlike epinephrine, there are no known contraindications to their use and they have minimal systemic effects due to their poor cell permeability.[24]

The use of ferric sulfate or other ferrous compounds (eg, ferric chloride) at the impression or delivery stage has been reported to cause the development of grayish black discolorations under translucent porcelain restorations.[2,55] The mechanism for this reaction is believed to be removal of the dental smear layer by the acidic ferric sulfate, causing decreased bond strengths, microleakage, and marginal discoloration.[51,52] If discoloration occurs, the restorations must be removed and remade.[2]

Chlorhexidine

Despite adequate tissue management and displacement around the prepared tooth, voids in the impression may still occur and can be the result of blood or other liquid around the teeth or blood leakage from unhealthy gingiva adjacent to the tooth being impressed.[2,3] Christensen suggested one additional method to increase gingival health and reduce bleeding, utilizing 0.12% chlorhexidine mouth rinse.

It is recommend that patients rinse twice a day for at least 2 weeks before the preparation appointment (once in the morning after eating and once in the evening immediately before retiring).[2] The rinse is used for a total of 6 weeks: 2 weeks before the procedure, 2 weeks during the provisional restoration stage, and 2 weeks after cementation of the restoration.

Chlorhexidine has activity against Gram-positive and Gram-negative organisms, facultative anaerobes, aerobes, and yeast; it is both bacteriostatic and bactericidal, depending on its concentration.[56,57] The bactericidal effect of chlorhexidine is a result of the binding of this cationic molecule to negatively charged bacterial cell walls and extramicrobial complexes. At low concentrations, this causes an alteration of bacterial cell osmotic equilibrium and leakage of potassium and phosphorous, resulting in a bacteriostatic effect. At high concentrations of chlorhexidine, the cytoplasmic contents of the bacterial cell precipitate and result in cell death. Key adverse events related to its use on dental patients include increased calculus accumulation on teeth, altered taste perception, staining of oral surfaces (mucosa, teeth, dorsum of tongue), and oral/tongue irritation. Staining may be visible as soon as 1 week after treatment begins and is more pronounced when there is a heavy accumulation of unremoved plaque and on nonpolished restorative surfaces. The stain potentially caused by chlorhexidine does not have a clinically adverse effect other than it being esthetically unpleasing; patients should be informed of the possible negative results.[58,59]

Cordless Mechanico-Chemical Retraction Agents

To overcome the challenges of traditional mechanical retention—the need for anesthesia, risk of damage to gingival and epithelial attachment, possible gingival recession, gingival inflammation, and postoperative discomfort—a new class of cordless gingival retraction materials has been introduced.[10,13,29,60-65] In addition, cordless retraction systems usually contain an astringent to aid with hemostasis and fluid control.

In 2001 a clay-based retraction paste containing aluminum chloride was introduced that relied on hygroscopic expansion of the primary ingredient, kaolin, to achieve mild tissue displacement in approximately 2 minutes.[66] Al Hamad et al studied the effects of this retraction paste product compared with conventional gingival retraction cords and found that both techniques caused gingival inflammation. Surprisingly, the clay-based retraction paste caused the highest gingival index scores after 1 and 7 days, was slowest to heal, and was associated with dentin sensitivity. The authors attributed patient sensitivity to the high concentration of aluminum chloride, the acidity of the material, and the dryness produced.[27] In a later study by Kazemi, this same product caused significantly less inflammation than cord after 7 and 14 days.[21] Gingival retraction resulting from cord and the clay-based retraction paste was also examined. It was determined that although less than cord, gingival retraction caused by the paste created enough sulcular width to allow minimum impression material thickness, as reported by previous studies.[67,68]

Recently, Bennani et al compared the pressure generated after placement of cord versus this same retraction paste.[69] It was concluded that the pressure of the paste in the sulcus was one-tenth of that of cord, and manipulation of the material after placement would further reduce the pressure. It is interesting to note that directions for other clay-based retraction systems recommend direct pressure on the material-filled sulcus by cotton compression caps or by placement of cord. According to the Bennani study, this may compromise chemical retraction in favor of direct pressure on the sulcus and pharmacologic effects of the astringent (ie, drying of crevicular fluid and hemostasis).

Conclusions

Methods of tissue management for recording fixed prosthodontic impressions include mechanical, chemical, and surgical. In many cases, a combination of techniques may be utilized. Regardless of technique used, risk of injury to the surrounding gingiva exists. The careful practitioner must understand the potential local and systemic effects of mechanico-chemical retraction. Although mechanical or mechanico-chemical retraction is often the most cost-effective means of tissue management, it can be the most traumatizing. Cordless mechanico-chemical agents may result in less tissue injury, but are usually more expensive than cord. Given today's practice overhead, it is incumbent on practitioners to be efficient and use materials to produce consistent positive outcomes. Understanding the risks and benefits of each retraction system can help dentists select the right materials for each clinical situation.

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Local and Systemic Effects of Mechanico-Chemical Retraction

Mark Donaldson, Pharm D; and Jason H. Goodchild, DMD

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1. **Wöstman and colleagues showed that the use of nonimpregnated cotton cord caused:**
   A. decreases in crevicular fluid flow.
   B. increases in crevicular fluid flow.
   C. decreases in sulcular peptidoglycan.
   D. increases in sulcular peptidoglycan.

2. **What type of retraction involves cord that has been impregnated or soaked in astringents, hemostatics, or vasoconstrictors to achieve the clear field necessary for fixed prosthodontic impressions?**
   A. mechanical
   B. chemical
   C. mechanico-chemical
   D. systemic atropine

3. **If chemical retraction is applied to the cord at chairside it should be allowed to soak for approximately how long to achieve proper saturation?**
   A. the time to dip is adequate
   B. 10 seconds
   C. 20 seconds
   D. 20 minutes

4. **Epinephrine provides vasoconstriction of the small blood vessels in submucosal tissue by stimulating:**
   A. alpha adrenergic receptors.
   B. beta 1-adrenergic receptors.
   C. beta 2-adrenergic receptors.
   D. beta 3-adrenergic receptors.

5. **Originally, what was the vasoconstrictor of choice?**
   A. zinc chloride
   B. alum
   C. 8% racemic epinephrine
   D. ferric sulfate

6. **Racemic epinephrine contains:**
   A. epinephrine USP.
   B. d-isomer only.
   C. l-isomer only.
   D. a 50:50 mixture of the d- and l-isomers.

7. **The half-life of epinephrine is:**
   A. about 2 minutes.
   B. about 2 hours.
   C. about 8 hours.
   D. about 24 hours.

8. **Chemically, all the retraction agents containing astringents are characterized by:**
   A. a relatively high level of acidity.
   B. a relatively low level of acidity.
   C. a relatively high level of vasodilation.
   D. a relatively low level of vasoconstriction.

9. **To increase gingival health and reduce bleeding, Christensen suggested utilizing 0.12% chlorhexidine mouth rinse, which is used for a total of:**
   A. 2 days.
   B. 6 days.
   C. 2 weeks.
   D. 6 weeks.

10. **A clay-based retraction paste containing aluminum chloride relies on hygroscopic expansion of what primary ingredient to achieve mild tissue displacement in approximately 2 minutes?**
    A. kaolin
    B. luvisol
    C. podzol
    D. regosol

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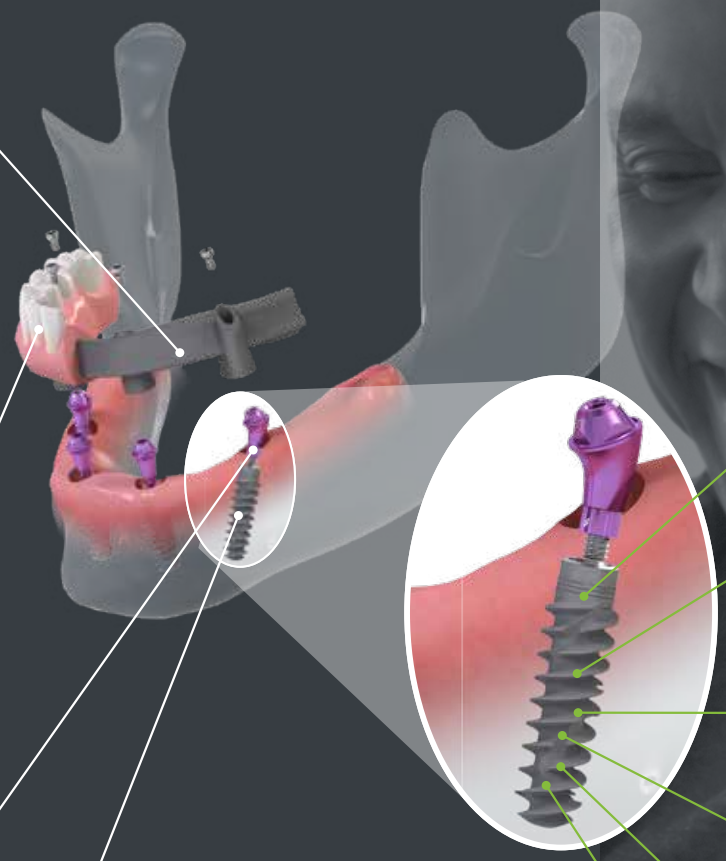

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