The refinement of adhesive technology and contemporary restorative systems has enabled restorative teams to deliver significantly improved aesthetic restorations. These technological advances have enhanced the clinician’s ability to optimize the aesthetic display of discolored, maligned, or deficient tooth structure in an otherwise harmonious and intact periodontium. In the presence of anterior hard and soft tissue deformities, however, the selection of even the most advanced restorative materials often proves inadequate in solving aesthetic dilemmas commonly associated with trauma, periodontally compromised teeth, multiple tooth loss, or deformed edentulous spans within the aesthetic zone (Figure 1). The development of aesthetically successful treatment plans for patients in this category is consequently more complex and requires a broader perspective that must be explored in greater detail.

Since various modalities can be utilized to perform anterior tooth replacement in each patient, the determination of a single strategy to effectively direct aesthetic restorative treatment has proven elusive. Clinicians generally agree that successful restoration requires a thorough understanding of the varied components responsible
for an aesthetic smile and, ultimately, access to interdisciplinary clinical solutions capable of enhancing soft tissue deformities. While numerous surgical techniques exist for the effective augmentation of mucogingival and ridge defects through the utilization of soft tissue and osseous grafts,\(^1\) the regeneration of interproximal papillae has not achieved a similar degree of success. In order to improve the understanding of this disparity, recent emphasis has been placed on the primary role of the underlying osseous architecture in predicting and guiding interproximal soft tissue contours.

In one clinical study of the natural dentition, Tarnow et al determined that the presence or absence of interproximal papillae fill was inversely related to the distance from the base of the contact area to the underlying crest of bone.\(^6\) At a distance of 5 mm or less, the papilla fill was present virtually 100% of the time. When the distance measured 6 mm, papilla fill was present 56% of the time, and at a distance of 7 mm or more, papilla fill was present in only 27% of the sites examined; bone sounding and radiographs were predominantly utilized to ascertain these measurements (Figure 2). Salama et al have suggested that a similar relationship exists in implant therapy, and that the height, width, and depth of peri-implant papillae contours may be affected by this same correlation.\(^7\) The authors emphasized that the most successful and predictable aesthetic results can be accomplished only when underlying labial and interproximal osseous support is therapeutically provided for the desired soft tissue contours.

Clinical observation further suggests the existence of a predictable papilla length (PPL), which is the achievable and maintainable papilla length in the maxillary anterior sextant as measured from the most coronal interproximal height of bone (IHB) immediately adjacent to a tooth or an implant fixture following surgical or restorative intervention. This distance is approximately 4.5 mm between adjacent implants, 5 mm for the natural dentition, and 5.5 mm for interproximal implant surfaces not immediately adjacent to a second implant.\(^8\) This discrepancy in
interproximal soft tissue depth is believed to occur predominantly due to the dynamics that are in effect when an implant is adjacent to a periodontally optimal natural tooth. When this relationship occurs, the more coronal IHB immediately adjacent to the tooth appears to supersede that of the implant in its influence over the final papilla height (Figure 3). The achievement of interproximal soft tissue dimensions that are greater than the PPL, while possible, is not predictable. Aesthetic strategies in anterior tooth replacement must, therefore, utilize surgical and restorative modalities that conform to the parameters of the PPL.

The objective of this paper is to present diagnostic and prognostic criteria that emphasize the osseous-gingival relationship, particularly on the identification of the relative position of the IHB to adjacent structures. Based on this diagnostic classification and established therapeutic objectives, a treatment planning algorithm for the achievement of predictable aesthetic results is presented.

Diagnostic Procedure

Successful tooth replacement strategies and the consistent achievement of aesthetic results in the presence of anterior soft tissue deficiencies must be initiated with a rigorous diagnostic protocol. The primary phase in the diagnostic procedure has been termed the “what phase” in reference to the various concerns that must be addressed preoperatively.9 At this time, patient expectations and dental history are evaluated in order to select the proper restorative modality.

The restorative team must first identify potential obstacles to the achievement of an aesthetic result. A lack of balance, harmony, and continuity of form between the shape of the dentition, the gingival contour, and the lips may compromise the postoperative result. Consequently, improper interdental/interocclusal space or malocclusion should be evaluated. The presence of vertical osseous and soft tissue deformities, particularly in the interproximal region, may contribute to disharmonious soft tissue contour in the

Diagram 1

Figure 5. Preoperative view of a patient with agenesis of the maxillary left lateral incisor and premolars. The position of the canine effects an anterior edentulous span large enough for two teeth.

Figure 6. A combination onlay-interpositional soft tissue graft procedure was utilized to augment the anterior edentulous span and establish ideal ovate pontic receptor sites.

Figure 7. Postoperative view exhibits the efficacy of the soft tissue approach to ridge augmentation. Note the integration of the soft tissue contour and the definitive ceramometal restoration.
...aesthetic zone. Of these factors, deficiencies in the interproximal vertical component are the least predictable and require the greatest technical proficiency to remedy. In order to facilitate the formulation of strategies, a classification scheme for the IHB has been developed (Figure 4).

The fundamental cause of tooth loss must similarly be investigated in this preoperative phase. Since a variety of causal factors may result in the need for anterior tooth replacement, a diagnostic understanding of the etiology of tooth loss permits the restorative team to anticipate the obstacles that may be encountered during the therapeutic phase. Agenesis, endodontic failures, and root fractures, while capable of causing defects in the labial plate, do not generally affect IHB. In contrast, loss of multiple adjacent teeth— as well as periodontal defects— have the greatest propensity to cause interproximal bone loss that will compromise the foundation of future papillae.

Based on the ability of the restorative team and the health status, dental knowledge, availability, resources, and motivation of the patient, a treatment that addresses the aforementioned clinical obstacles can be selected. A miscalculation in any of the considerations embodied within the diagnostic phase, by the clinician or the patient, may lead to poor decisions and undesirable results. In particular, if the available restorative options fail to satisfy the expectations of the patient, then the clinician must...

*Table*

**Diagnostic and Prognostic Evaluation in Aesthetic Restorative Therapy**

<table>
<thead>
<tr>
<th>Predictable</th>
<th>Possible</th>
<th>Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gingival-restorative interface outside the aesthetic zone.</td>
<td>Gingival-restorative interface within the aesthetic zone.</td>
<td>An inability to find a balance between what the patient expects and what is possible for the team. Patient should be referred.</td>
</tr>
<tr>
<td>Thick/flat periodontium.</td>
<td>Pronounced scalloped periodontium.</td>
<td></td>
</tr>
<tr>
<td>Minimal vertical hard and soft tissue defects.</td>
<td>Significant vertical hard and soft tissue defects.</td>
<td></td>
</tr>
<tr>
<td>IHB intact (ie, Class 1).</td>
<td>IHB deficient (ie, Class 2 or 3).</td>
<td></td>
</tr>
<tr>
<td>Single-tooth replacement.</td>
<td>Multiple adjacent tooth replacement.</td>
<td></td>
</tr>
<tr>
<td>No space deficiencies.</td>
<td>Inadequate interdental or interocclusal space.</td>
<td></td>
</tr>
</tbody>
</table>

*This chart is modified from the theme presented by Professor Peter Schäfer at the 1997 Annual Meeting of the Academy of Osseointegration in San Francisco, CA. These factors are acknowledged to have considerable influence over a result and can suggest a predictable, guarded, or poor prognosis. The factors in the middle column in particular are cumulative as the table progresses. The clinician should consider aborting the treatment if a multitude of negative factors are present or accumulate in a patient.*
modify those expectations, improve the team’s ability to deliver the desired result, or refer the patient for specialized treatment (Table).

**Treatment Planning**

When gingival deformities exist in the anterior region, decisions to restore missing teeth should focus on the restoration of natural contour and harmony in the surrounding soft tissue profile. Seibert presented a classification scheme that described three-dimensional soft tissue ridge defects based on the degree of buccopalatal and/or vertical components of the deficiency.\(^{10,11}\) Seibert and Salama demonstrated soft tissue ridge augmentation procedures in conventional and implant therapy as a means to restore natural contour and harmony.\(^{12}\) Although Bahat et al established the need for three-dimensional hard tissue augmentation prior to implant therapy to improve the biomechanical loading conditions as well as the aesthetic profile of implant-supported restorations, a surgical technique that predictably enhances deficient interproximal bone and papillae has not yet been developed.\(^{13}\)

In order to improve the reconstructive zones prior to conventional restorative therapy, Ingber forcibly erupted periodontally and restoratively compromised teeth.\(^{14-16}\) Salama et al suggested the nonsurgical orthodontic enhancement of the hard and soft tissues surrounding selected hopeless teeth prior to extraction and implant placement.\(^{7,17}\) The authors maintain that, outside of an infrabony defect, this orthodontic intervention is the only predictable approach to enhance the relative position of the IHB along tooth surfaces in the vertical plane.

Alone or in combinations, the aforementioned techniques are routinely utilized to correct anterior tissue deformities and achieve aesthetic results. The case presentations that follow exhibit a variety of anterior soft tissue dilemmas related to compromised or missing teeth. The treatment plans demonstrate the application of the IHB classification scheme in the selection of effective surgical, orthodontic, and restorative therapeutic strategies for various clinical circumstances.
Case Presentations

Case 1
Treatment Strategy for Class 2 IHB Utilizing a Soft Tissue Graft Solution
A 20-year-old female patient presented with agenesis of the maxillary left lateral incisor and premolar teeth (Figure 5). The topography of the osseous and soft tissue components of the edentulous ridge was noted to be flat to concave. Upon diagnostic evaluation, which included a fully contoured waxup, it was evident that the position of the canine at the site of the first premolar had caused a space discrepancy that formed an anterior edentulous span with a width sufficient for two teeth. Since the underlying bone was determined to be 6 mm to 7 mm from the apical extent of the contact point of an ideally contoured restoration, the restorative team classified the site of the future papilla at the midpoint of the ridge to be a deficient Class 2 IHB. Due to time and financial constraints, orthodontic therapy was refused by the patient; extensive osseous augmentation of the knife-like ridge that would have predisposed the patient for an implant-supported restoration was similarly rejected.

Due to the presence of an adequate number of well-distributed and stable natural abutments in the indicated region, the reconstructive team elected to utilize a combination onlay-interpositional soft tissue graft harvested from the palate, as described by Seibert and Louis, to augment the anterior edentulous span and establish ideal ovate pontics (Figure 6). This soft tissue approach to ridge augmentation is an efficient and efficacious technique for optimizing the emergence profile of pontics in conventional restorative therapy where a deficient ridge is present. Following 10 weeks of healing and soft tissue contouring under a provisional restoration, a porcelain-fused-to-gold restoration was fabricated to restore natural harmony within the aesthetic zone (Figure 7).

Case 2
Treatment Strategy for Class 2 IHB Utilizing an Orthodontic Solution
During orthodontic therapy for an implant consultation, a 16-year-old female patient presented with agenesis...
of the mandibular central incisors (Figure 8). In a diagnostic phase, a Class 2 IHB at the midline of a slightly concave ridge was identified and classified. The challenge presented in this clinical dilemma was the reconstruction of an optimal central papilla between two adjacent implants.

Understanding the limitations and lack of predictability associated with an attempt to achieve a midline papilla between two adjacent implants with a Class 2 IHB, the therapeutic team elected to establish a more predictable environment by orthodontically shifting the lateral incisors into the position of the central incisors (Figure 9). This approach established two separate and more manageable single-tooth replacement scenarios where reduced-diameter implants (MicroMiniplant, 3i, Palm Beach Gardens, FL) were utilized with UCLA-type custom abutments (Figure 10). The orthodontic treatment was preceded by an initial surgical phase that used a guided bone regenerative procedure to increase the buccolingual dimensions of the ridge prior to tooth movement.

The orthodontic treatment modality utilized shifted the Class 1 IHB on the mesial aspect of the lateral incisors horizontally to the midline where they were able to support an ideal papilla. In addition, the Class 1 IHB on the distal aspect of the lateral incisors would have dominance over those of the implants to effectively support the coronal positions of the peri-implant papilla (Figure 11). The definitive porcelain-fused-to-gold restorations were integrated with the papilla and achieved the aesthetic objectives of the patient.

**Case 3**

**Treatment Strategy for Class 3 IHB Utilizing an Osseous Graft Solution**

A 62-year-old female patient presented for comprehensive rehabilitation of function and aesthetics. Due to extensive decay, the patient's right central and lateral incisors had been extracted prior to presentation (Figure 12). While identifying the potential obstacles to treatment during the preoperative diagnosis, vertical and horizontal ridge defects were observed in the right premaxilla.

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**Figure 16.** Facial view of the seated abutments demonstrates soft tissue harmony between the implants and the natural dentition.

**Figure 17.** Magnified facial view exhibits the favorable status of soft tissue harmony at the midline due to the surgical coronal repositioning of the IHB around the implant.

**Figure 18.** Postoperative radiographic appearance of central incisors demonstrates the new position of the IHB.
Although the mesial aspect of the left central incisor exhibited a Class 2 IHB relationship, a Class 3 IHB was diagnosed for the region between the anticipated restorations for sites #7 and #8 (Figure 13). In order to prepare the sites for optimal implant placement, it was necessary to augment the existing edentulous spans in the horizontal and vertical dimensions.

Augmentation of the ridge was performed utilizing an autogenous osseous graft from the mandibular symphysis. Using a simultaneous placement protocol, implants (Ø3.75 mm Mark II, Nobel Biocare, Westmont, IL) were placed into the fixated osseous grafts in the position of #8 and #10 (Figure 14). In order to avoid the complications associated with the restoration of adjacent implants within the aesthetic zone, no implant was placed in the area of #7. Vertical osseous augmentation not only facilitated optimal placement of the implant fixtures (Figures 15 through 17), it also increased the IHB on the distal aspect of the right central incisor implant to a more coronal position (Figure 18) that allowed for enhanced support of aesthetic soft tissue contours (Figure 19). In any instance where three or more consecutive teeth are being replaced and sufficient bone is available to place implants of adequate length, it is preferable to alternate implants and pontics in order to optimize soft tissue aesthetics. The combination of the improved soft tissue contour and the definitive porcelain-fused-to-gold restoration allowed the pretreatment objectives of the restorative team and the patient to be achieved.

**Case 4**

**Treatment Strategies to Alter Deficient IHB Utilizing an Orthodontic Solution**

A 50-year-old female patient presented with advanced periodontal disease that required multiple tooth replacement (Figures 20 through 22). Upon clinical examination, it was determined that a Class II malocclusion was exacerbated by migration of the teeth and a parafunctional habit (ie, tongue thrust). Severe defects in the anterior...
soft tissue were secondary to the periodontal breakdown. In addition, the presence of a Class 3 IHB was evident at hopeless teeth #7 through #11. A combination periodontal/orthodontic/implant therapy was selected to restore the patient to proper function and aesthetics.

The initial phase of treatment focused on meticulous inflammatory control and oral hygiene instruction as well as strategic extractions of the hopeless mandibular molars. The second (or site development) phase of therapy required the orthodontic leveling and aligning of the mandibular arch as well as retraction of the mandibular incisors. In the maxilla, the hopeless teeth (#8 through #11) were orthodontically retracted and extruded to enhance the underlying osseous and soft tissue profile prior to extraction and implant placement (Figure 23). Orthodontic extrusion shifted the previously deficient Class 3 IHBs into a more coronal Class 1 position, which was closer to the future restorative contact point and more capable of supporting an optimal peri-implant papilla (Figure 24). In contrast to the surgical augmentation utilized in the previous case presentation, the advantage of the orthodontic approach was the provision of nonsurgical vertical enhancement and soft tissue enhancement.

Once the hopeless teeth had been extracted, the implant fixtures were placed into the maxillary arch (Figure 25). A hollow cylinder implant (ITI 15-degree Esthetic Plus, Straumann, Waltham, MA) was placed in position #8, a tapered implant (Osseotite, 3i, Palm Beach Gardens, FL) was placed in the area of #10, and a tapered, stepped-screw implant fixture (Frialit-2, Friatec, Irvine, CA) was placed in position #11. The left incisor was initially retained to aid in the stabilization of a provisional fixed restoration.

Prior to the loading of the anterior implants, the endodontically treated tooth (#9) was cut to the osseous level and submerged. The use of this technique, while previously utilized to maintain bone level beneath complete denture restorations, allowed the authors to
vertically support hard and soft tissue levels in the critical anterior region. Maintenance of the root tip was integral for the long-term stable preservation of the IHB at the most coronal position and the stability of the midline papilla. The site was treated as an ovate pontic and avoided the obstacles of restoring adjacent implants at the midline (Figure 26). The definitive porcelain-fused-to-gold restorations were then placed and connected to the prepared abutments (Figures 27 through 29). The implant-supported restorations were determined to be well integrated with the soft tissue architecture developed during the restorative phase of the treatment, and satisfied the aesthetic expectations of the patient and the restorative team (Figure 30).

Conclusion
An accurate prognosis for successful aesthetic results in anterior tooth replacement cannot be obtained without a thorough understanding of the interdependence of the osseous and soft tissue profiles, particularly as they relate to the interproximal papilla. The abstraction of the interproximal height of bone and predictable papilla length are two extremely useful diagnostic and prognostic determinants that are effective at guiding aesthetic strategies in conventional restorative and implant therapy. In the presence of Class 1 IHB, more predictable and routine restorations are possible. In contrast, for potential abutments exhibiting Class 2 IHB, even the size of the retraction cord in impression taking has to be carefully selected as these areas are extremely susceptible to recession or blunting of the papilla subsequent to restorative or surgical manipulation. The authors have demonstrated the direct relationship that exists between the dimensions and coronal position of the IHB and the predictable development of a stable, aesthetic soft tissue profiles.

This article has outlined various surgical and orthodontic strategies utilized to enhance deficient anterior soft tissue contours prior to conventional and implant restorative therapy. Surgical and orthodontic enhancement are the therapeutic tools capable of coronally positioning the
IHB, while restorative intervention to reshape the crown forms is an effective method to apically position the base of the contact point to conform with the PPL.

Acknowledgment
The authors acknowledge their gratitude to co-therapists Dr. Farshid Sanavi, Dr. Yongkun Kim, and Dr. Yu-Min Cheng for their contributions to the cases presented in this article.

References
CONTINUING EDUCATION
(CE) EXERCISE NO. 34

To submit your CE Exercise answers, please use the answer sheet found within the CE Editorial Section of this issue and complete as follows: 1) Identify the article; 2) Place an X in the appropriate box for each question of each exercise; 3) Clip answer sheet from the page and mail it to the CE Department at Montage Media Corporation. For further instructions, please refer to the CE Editorial Section.

The 10 multiple-choice questions for this Continuing Education (CE) exercise are based on the article “The interproximal height of bone: A guidepost to predictable aesthetic strategies and soft tissue contours in anterior tooth replacement” by Henry Salama, DMD, Maurice A. Salama, DMD, David Garber, DMD, and Pinhas Adar, MDT. This article is on Pages 1131-1141.

Learning Objectives:
This article presents information on the primary role of the underlying architecture in predicting and guiding interproximal soft tissue contours. Upon reading the article and completion of this CE exercise, the reader will have:

• A key to understanding the direct relationship between the dimensions and coronal position of the IHB and the predictable development of a stable, aesthetic soft tissue profile.
• A description of the surgical and orthodontic strategies utilized to enhance deficient anterior soft tissue contours prior to conventional and implant restorative therapy.

1. With regard to the distance from the base of the contact area to the underlying crest of bone:
   a. The papilla is present virtually all the time at a distance of 6 mm.
   b. The papilla is present in only 56% of the sites at a distance of 7 mm.
   c. It is inversely related to the presence or absence of interproximal papillae fill.
   d. All of the above.

2. The predictable papilla length in implant therapy:
   a. Is the same as it is for natural dentition.
   b. Is approximately 4.5 mm between adjacent implants.
   c. Is approximately 5.5 mm for natural dentition.
   d. b and c.

3. The primary phase in the diagnostic procedure for anterior soft tissue deficiencies includes all of the following except:
   a. Treatment planning.
   b. Identification of potential obstacles.
   c. Etiology of tooth loss.
   d. Evaluation of patient expectations.

4. Which of the following factors affect IHB?
   a. Agenesis.
   b. Endodontic failures.
   c. Periodontal defects.
   d. None of the above.

5. Which of the following factors require the greatest technical proficiency to remedy?
   a. Improper interdental/interocclusal space.
   b. Lack of harmony among tooth shape, gingival contour, and lips.
   c. Deficiencies in the interproximal vertical component.
   d. a and c.

6. According to the authors, what is the most predictable approach to enhance the position of the IHB?
   a. Forced eruption.
   b. Orthodontic intervention.
   c. Surgical enhancement.
   d. Ridge augmentation.

7. A soft tissue graft is best utilized for:
   a. Reconstruction of a central papilla between 2 adjacent implants.
   b. Increasing the IHB of an implant for enhanced support.
   c. Optimizing the emergence profile of pontics in ridge-deficient patients.
   d. Vertical support of hard and soft tissue levels in the anterior region.

8. Orthodontic treatment is best utilized for:
   a. Reconstruction of a central papilla between 2 adjacent implants.
   b. Increasing the IHB of an implant for enhanced support.
   c. Optimizing the emergence profile of pontics in ridge-deficient patients.
   d. Vertical support of hard and soft tissue levels in the anterior region.

9. A hard tissue graft is best utilized for:
   a. Reconstruction of a central papilla between 2 adjacent implants.
   b. Increasing the IHB of an implant for enhanced support.
   c. Optimizing the emergence profile of pontics in ridge-deficient patients.
   d. Vertical support of hard and soft tissue levels in the anterior region.

10. A combination periodontal/orthodontic/implant therapy is best utilized for:
    a. Reconstruction of a central papilla between 2 adjacent implants.
    b. Increasing the IHB of an implant for enhanced support.
    c. Optimizing the emergence profile of pontics in ridge-deficient patients.
    d. Vertical support of hard and soft tissue levels in the anterior region.