A Systematic Approach to Esthetic and Functional Treatment

Editor's Note: This article was written primarily from a dentist's perspective, with contributions from a laboratory technician.

Although Dr. Hegyi is the developer and owner of the DATA Appliance discussed in this article, he does not profit from its fabrication or use. He does, however, teach courses related to the use of the appliance.

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Abstract

The achievement of ideal esthetics and function should be the goal of every dentist choosing to restore a dentition. In addition, long-term durability of our restorations is mandatory if we are to consider our treatments successful. These objectives are most predictably realized if careful attention is given to all factors affecting each part of the masticatory system, including both microbial and biomechanical issues.

Long-term durability of our restorations is mandatory if we are to consider our treatments successful.

The purpose of this article is to describe a system that manages these biomechanical factors and also assists in developing ideal esthetics. This system consists of three elements: The Integrated Classification System (ICS), the Diagnosis and Treatment Assisting (DATA) Appliance, and a Stable Biomechanical Platform. ("DATA" is a proprietary registered trademark owned by Dr. Karl E. Hegyi for dental appliances used for diagnosing and treating biomechanical issues of the masticatory system.)

This article details how the ICS, DATA Appliance, and stable biomechanical platform were utilized to guide the evaluation and treatment of a patient with complex esthetic and functional problems.[1,2] It is divided into three parts, as follows:

- Part I focuses on utilization of the DATA Appliance and ICS to evaluate the patient and guide development of a stable biomechanical platform.
- Part II demonstrates the techniques and advantages of designing an ideal esthetic and functional restorative plan on this platform. Provisional restorations are then fabricated to represent this design.

Figure 1: Retracted pretreatment smile, 1:2 view.

Figure 2: A DATA Appliance.

- Part III describes a process for creating and seating final restorations mimicking the esthetic and functional qualities developed in the provisional restorations. It then describes utilization of the DATA Appliance to perfect and protect these restorations.

Part I

Patient History and Preliminary Findings

The patient was a 53-year-old male dentist who had been experiencing a level of facial pain for the previous year that had affected his ability to eat. In addition to wanting to be more comfortable, however, he was also concerned with the health and maintainability of his teeth. He knew that he had several fractured and worn teeth and large old amalgam restorations. Because of the condition of his dentition, he was aware that he needed extensive restorative treatment. While a desire for improved esthetics was mentioned, he initially stated it was not a high priority.

Preliminary evaluation of microbial issues revealed excellent periodontal health and no active caries. Evaluation of biomechanical force issues revealed generalized moderate-to-severe excessive tooth wear, painful masticatory muscles, and damaged temporomandibular joints (TMJs). Both joints could accept firm loading with no sign of tension or tenderness, although clicking sounds that had been present for many years were noted in the left joint. Range-of-motion measurements were within normal limits.

For the appliance to give meaningful information about each biomechanical element, and to also achieve complete condylar seating, it must be worn for at least three to four weeks.

Initial esthetic evaluation revealed many potential issues, including moderate-to-severe tetracycline staining, worn and misaligned anterior teeth, occlusal plane and gingival level issues, collapsed buccal corridors, and asymmetric lip dynamics (Fig 1). While many esthetic issues existed, the patient's initial concerns clearly focused on biomechanical issues. Therefore, a more detailed evaluation of these issues was performed.

The DATA Appliance in Biomechanical Evaluation

The concept of using an anterior stop to assist in condylar seating and bite registration is well documented and has been used clinically for many years.[3] Lucia jigs and leaf gauges were among the earliest types of anterior stops used. In recent years, some clinicians, notably Dr. John Kois and Dr. John Cranham, have adapted the anterior stops to removable acrylic appliances; their appliances are known as "deprogrammers."[4,5]

These modifications not only made anterior stops more practical for longer-term use, but also expanded the clinical applications of the appliances. The DATA Appliance represents the primary author's version of an anterior stop appliance design and its application. It is a removable appliance that is used to

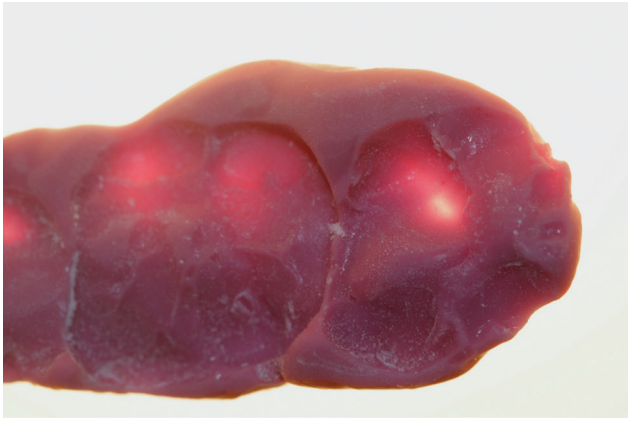


Figure 3: Perforation of Futar bite registration confirming #15 and #18 in contact with DATA Appliance seated.

assist in both evaluating and treating biomechanical force issues. It also is tooth-supported, has a different anterior stop design from other appliances, and is used to provide patient information regarding each biomechanical element of the ICS[2,6] (Fig 2). It is used to assist in both evaluating the patient and in providing appropriate treatment to develop a stable biomechanical platform.[6,7]

For this appliance to give meaningful information about each biomechanical element, and to also achieve complete condylar seating, it must be worn for at least three to four weeks. Therefore, excellent patient compliance is critical. To ensure this, a major design objective of the appliance was to make it as comfortable and esthetic as possible. As a result, the primary author has found patient compliance issues to be rare.

The patient's preliminary biomechanical evaluation and history were consistent with damaged, but well-adapted, TMJs. To confirm this, a DATA Appliance was fabricated and seated. The anterior stop was adjusted to allow contact of one lower incisor with closure, perpendicular to the arc of closure, allowing approximately 2 mm interocclusal space between the most posterior teeth.

The patient was initially reevaluated after wearing the appliance 24 hours a day for 10 days (except during eating and oral home care). Three significant responses were noted, as follows:

- There was a near-complete elimination of facial pain and joint sounds.
- There was little evidence of parafunctional activity on the appliance's acrylic anterior stop.
- The patient reported that after seven days of wearing the appliance, teeth #15 and #18 were in contact if he closed with the appliance in place.

The ICS is a classification system that individually considers the biomechanical elements of TMJ orthopedic stability, the functional occlusion, and parafunctional activity.

A bite registration using Futar D Occlusion bite registration material (Kettenbach GmbH & Co.; Eschenburg, Germany) with the DATA Appliance in place confirmed that teeth #15 and #18 were in contact (Fig 3). At that time, additional acrylic was added to the anterior stop to once again allow approximately 2 mm posterior tooth interocclusal space.

The patient was next seen 21 days later. He reported a continued near-complete absence of facial pain, with no joint sounds, and there was little evidence of parafunctional activity on the appliance's anterior stop. Another bite registration was made and revealed #15 and #18 to be nearly in contact again. Subsequent identical bite registrations were made over the next two weeks. Stabilization of interocclusal and maxillomandibular relationships is confirmed when the following criteria are met:

- Identical bite registrations are made on at least two occasions at least one week apart.
- Both condyles can accept firm loading with no sign of tension or tenderness at the condylar position of bite registration.

- The first point of occlusal contact with closure of the mounted casts on the articulator is identical to that of the patient closing with the appliance inserted with its stop reduced to first tooth contact.

A facebow registration to record the hinge axis was made and the maxillary cast mounted. The mandibular cast was then mounted using a Futar bite registration.

Union of the Data Appliance and ICS in Treatment Planning

The ICS is a classification system that individually considers the biomechanical elements of TMJ Orthopedic Stability, the Functional Occlusion, and Parafunctional Activity.[1] The ICS classifies TMJ stability as *stable, manageably adapted, transitioning, or unstable*. The functional occlusion is classified as *benign, posterior dysfunction, or anterior dysfunction*; and parafunctional activity as *benign, structural, CNS, or secondary*. (The entire ICS document is available from the primary author to any readers who request it.) Patient response to the DATA Appliance gives critical information regarding each of these elements.[2] Once each element is evaluated, the ICS guides appropriate occlusal and restorative treatment design and methodology.[1]

In this patient's case, information from appliance response, along with history and clinical examination findings, confirmed an ICS TMJ stability diagnosis of "manageably adapted." Manageably adapted joints are those that are damaged, but well adapted.[6] Response also confirmed a functional occlusion diagnosis of "posterior dysfunction" and an *initial* parafunctional activity diagnosis of "benign" or "structural parafunctional activity."[2] With posterior dysfunction, posterior teeth interfere with function. *Structural* parafunctional activity is parafunctional activity that is affected by occlusal relationships. *Benign* parafunctional activity is diagnosed when parafunctional activity is either not present or is not causing disease.

The DATA Appliance's role in platform development is to first confirm stable or manageably adapted TMJs.

This combination of TMJ stability, functional occlusion, and parafunctional activity diagnoses is common and one that can predictably benefit from occlusal correction. As in many cases, this patient not only can benefit from occlusal correction, but the occlusal correction is a fundamental requirement to developing a stable biomechanical platform. Creating this platform will not only ensure patient comfort, but will also serve as a foundation upon which ideal esthetic and functional design can be effectively developed and delivered.

The vertical dimension that allows the least invasive treatment possible, which is also consistent with all the patient's functional, restorative, and esthetic goals, should be chosen.

The Concept of a Stable Biomechanical Platform

A stable biomechanical platform is achieved when interocclusal relationships are in harmony with masticatory muscle function, together with healthy or well-adapted TMJs, *at the final treatment vertical dimension of occlusion* (VDO). It requires that maximum intercuspation occurs with equal intensity contact of all teeth with both condyles in their physiologically seated positions (centric relation [CR]). It also requires an anterior guidance that allows disclusion of the posterior teeth and one that is in harmony with the envelope of function. The DATA Appliance's role in platform development is to first confirm stable or manageably adapted TMJs. Next, it assists in achieving and confirming physiologically seated condyles. Finally, it guides appropriate treatment to create the stable biomechanical platform.[2,6,7]

The most critical decision in creating a stable biomechanical platform is choosing the appropriate VDO. The vertical dimension chosen has an impact upon three important clinical factors:

- The invasiveness of reductive reshaping or restorative treatment necessary to develop the platform.
- The horizontal, anterior-posterior relationship of upper incisor lingual contours to lower incisor edges (also referred to as the *available* envelope of function).
- The vertical interocclusal or interincisal room available for esthetic and/or restorative treatments.

The vertical dimension that allows the least invasive treatment possible, which is also consistent with all the patient's functional, restorative, and esthetic goals, should be chosen.

While a stable biomechanical platform may be achieved directly with the preparation of teeth and placement of provisional restorations, in many comprehensive restorative/esthetic treatments it is ad-

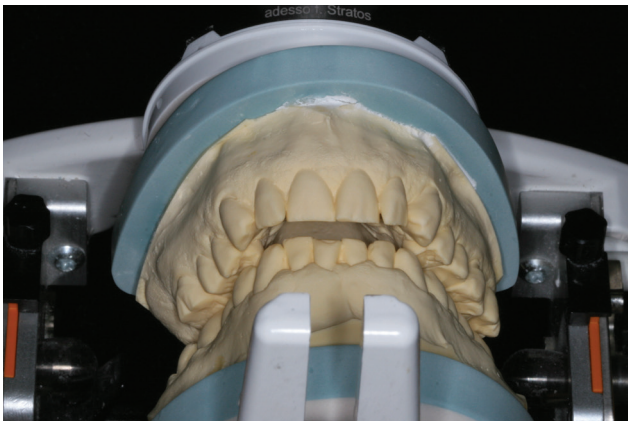


Figure 4a

Figure 4b

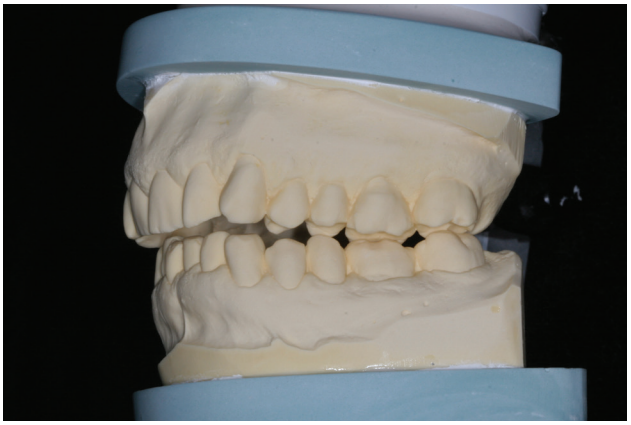


Figure 4c

Figures 4a-4c: Frontal and lateral views of pretreatment interocclusal relationships with condyles physiologically seated.

vantageous to develop this platform prior to final functional and esthetic design or tooth preparation. There are three primary benefits from doing this:

- Many patients are not concerned with ideal esthetic or restorative treatment until they experience the physical comfort that occurs with development of a stable biomechanical platform.
- It allows an easier and more predictable process of functional and esthetic design.
- Because a stable biomechanical platform establishes the final treatment vertical dimension and functional relationships, definitive tooth preparation and restoration can proceed immediately or be phased over extended periods of time.

With initial development of a stable biomechanical platform, full-mouth reconstructions can be achieved with simultaneous preparation of both arches, one arch at a time, by quadrant, or tooth by tooth. This offers a tremendous practical advantage to patients with financial limitations, as it allows extensive dental treatment to be phased over a period of time so that the patient can afford it.

Restoring biomechanical harmony is beneficial to all components of the masticatory system, including the TMJs, masticatory muscles, periodontium, and denti-

Figure 5: Anterior tooth relationships after planned reductive reshaping.

tion.[8] Therefore, development of a stable biomechanical platform is also helpful for patients without extensive restorative or esthetic needs. Many patients' treatment ends with creation of a stable biomechanical platform, with little or no restorative care. Treatment options to create this platform include orthognathic surgery, orthodontics, additive reshaping with direct or laboratory fabricated restorations, and reductive reshaping. The option(s) that most conservatively achieves the requirements of a stable biomechanical platform, and is also consistent with all other patient functional and esthetic goals, should be utilized.

Stable Biomechanical Platform Development

Stable biomechanical platform development begins on accurate mounted casts of the patient with both condyles physiologically seated (in CR). A diagnostic evaluation of the relationship of these casts is critical for both functional and esthetic design planning. When significant restorative treatment or esthetic changes are anticipated, a complete series of photographs is also needed. It is at this time that initial determination of the VDO and the treatment option(s) to develop it should be made. For most patients, a functionally acceptable stable biomechanical platform is possible at different vertical dimensions of occlusion. However, the *appropriate* vertical dimension is the one that is most consistent with *all* the patient's goals and objectives—functional, esthetic, and restorative. This should be determined before any patient treatment to develop the platform has begun.

The creation of a stable biomechanical platform prior to final esthetic and functional design is very beneficial to the laboratory technician.

In this case, the mounted casts of the patient revealed an interocclusal relationship very different from that in maximum intercuspation (Figs 4a-4c). Diagnostic evaluation of the casts began with determination of the appropriate vertical dimension. Reductive reshaping of the patient's casts revealed that when all left posterior teeth were adjusted into equal intensity, simultaneous contact, #5 and #28 just came into contact. At this vertical dimension, the remaining right posterior teeth were still slightly out of contact. However, visual assessment of the casts suggested that the remaining interincisal space seemed appropriate for an ideal esthetic and functional restoration of the anterior teeth (Fig 5). A simple wax-up of the anterior teeth on the casts supported this assessment (Figs 6a-6c). The end point of reductive reshaping and the VDO were now determined. (Note: *Final* confirmation of the appropriate vertical dimension is made in the mouth. While the vertical dimension chosen during this diagnostic cast and photograph assessment is usually correct, there is occasional need for minor modification in the mouth, usually for esthetic reasons.)

The DATA Appliance was now used to assist in achieving this relationship in the patient's mouth. With the appliance seated, a gradual reduction of the anterior stop guided reductive reshaping of the patient's dentition precisely to the point where #5 and #28 made contact. At this time, the end point of reductive reshaping had been achieved. With conservative additive

Figure 6a

Figure 6b

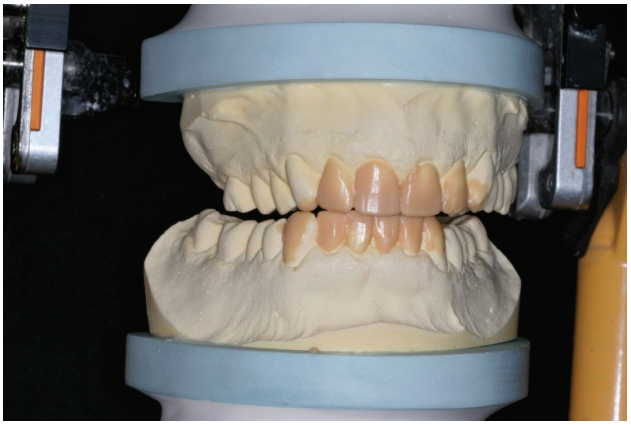


Figure 6c

Figures 6a-6c: Preliminary wax-up of anterior teeth confirming that planned vertical dimension is appropriate for ideal anterior esthetics and function.

reshaping with bonded composite to the occlusal surfaces of #29 and #30 and the lingual of upper anterior teeth, the stable biomechanical platform was created. This platform will become the foundation upon which definitive functional and esthetic restorative planning and treatment begins.

With platform development complete, the appliance was removed and set aside for use after the final restorations were seated. Definitive restorative/esthetic treatment could proceed immediately, be phased over time, or be deferred to a future date. In this case, the patient wanted to proceed immediately and as quickly as possible.

The next part of this article will illustrate the process of designing and developing esthetic and functional restorations on the newly created stable biomechanical platform. It will consider esthetic and functional planning, tooth preparation, esthetic crown lengthening, and the fabrication of provisional restorations.

PART II

INTRODUCTION

Part I of this article focused primarily on biomechanical issues in our patient's care. It described the use and advantages of the DATA Appliance, the ICS, and development of a stable biomechanical platform. It concluded with development of a stable biomechanical platform on the patient, who required extensive restorative treatment. It is important

Figure 7: Laboratory technician's pretreatment esthetic analysis.

to recall that initially, esthetic improvement was not a high priority for this patient. However, once development of a stable biomechanical platform made him comfortable, he indicated that improved esthetics were very important. The patient now indicated that there were no restrictions on treatment options he would accept to achieve ideal function *and* esthetics—except that he did not want treatment of any type for his remaining second molars.

This second part of the article will first explore the laboratory technician's perspective of the techniques and advantages of designing ideal functional and esthetic restorations on a stable biomechanical platform. This will include the importance of clinician/laboratory technician interaction and the responsibilities of each in case design. Because the success of this case also depends on clinical techniques not involved with the ICS, DATA Appliance, or stable biomechanical platform, some of the most important of these will also be described. This part will conclude with the creation of provisional restorations designed for ideal function and esthetics, intended to serve as a template for final restorations.

Esthetic and Functional Design

The creation of a stable biomechanical platform prior to final esthetic and functional design is very beneficial to the laboratory technician. In addition to knowing that the patient is comfortable, we know that a functionally acceptable VDO has already been determined and confirmed by the dentist. If the dentist has also done an esthetic assessment of this vertical dimension (as it was in this case), we also know it is a vertical dimension that is appropriate for ideal esthetic design. Often, as laboratory technicians, we are asked by the clinician to decide treatment vertical dimension. While input from the laboratory technician to the clinician is helpful, choosing treatment vertical dimension ultimately should be the responsibility of the dentist.

A stable biomechanical platform also provides information about other functional considerations, including the anterior guidance and envelope of function. Combined with an already determined final vertical dimension, these elements give guidance to the laboratory technician in both functional and esthetic design. Having this information makes the process of restoration design easier and more predictable. It is also makes efficient use of our time, with little need for remakes or modifications.

In every large or esthetically critical case it is extremely important for the clinician and the technician to work as a team. Their combined experiences and perspectives, along with input from the patient, offer the best opportunity for an ideal outcome. This process should begin as soon as initial records have been acquired. In this particular case, the clinician provided us the required 12 AACD photographic views and the mounted casts of the case after the stable biomechanical platform had been developed.

The patient's pretreatment photographs show a gummy smile, deficient buccal corridor, and a lack of symmetry and golden proportions (Fig 7). Our "educated guess" indicated that these could be corrected with a combination of:

Figure 8a

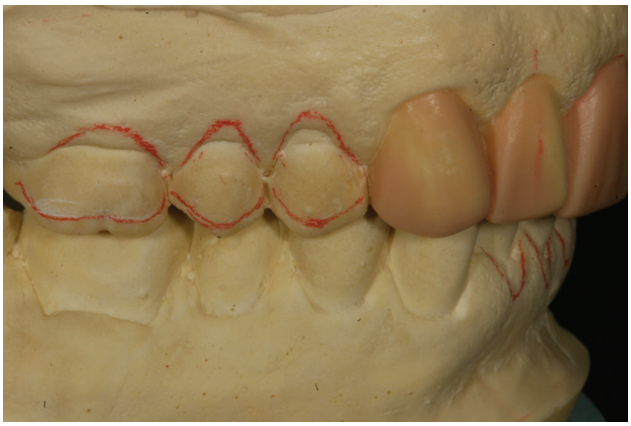


Figure 8b

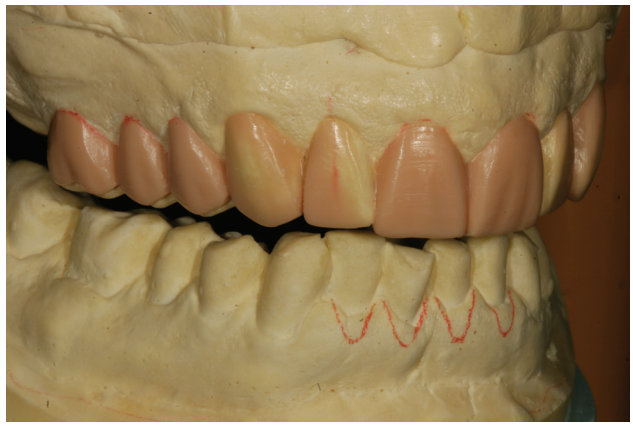


Figure 8c

Figures 8a-8c: Planning ideal gingival levels, incisal edge and buccal cusp tip positions, and buccal corridor development.

- incisal edge lengthening and shortening
- esthetic crown lengthening
- adding to the buccal contours
- reducing lingual contours.

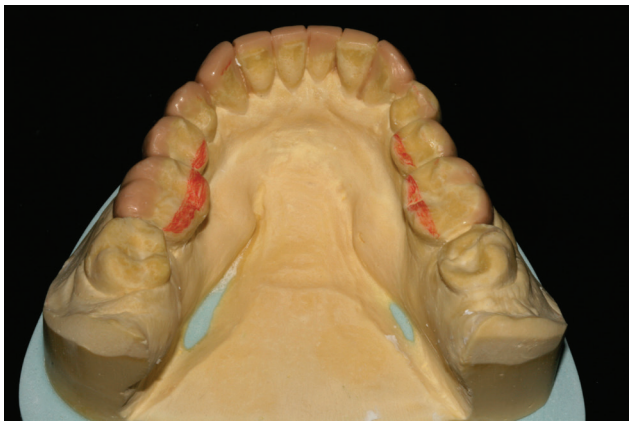
These corrections were discussed with and agreed to by the clinician. They were then presented to the patient, and a decision was made to move forward.

Verified mounted master casts of the stable biomechanical platform, along with upper and lower duplication impressions of these casts and a facebow transfer, were sent to the laboratory. The impressions were poured up and mounted on a semi-adjustable Stratos articulator (Ivoclar Vivadent; Amherst, NY). The mounting of casts is verified when the first point of occlusal contact with closure of the mounted casts on the articulator is *identical* to that of the patient closing with the DATA Appliance inserted with its stop reduced to first tooth contact (in this case, the buccal incline of the mesiolingual cusp of #15 and the lingual incline of the mesio-buccal cusp of #18).

Measurements were made and steps were taken to balance the teeth, lips, and gingivae, and a semi-full contour additive-only wax-up was completed (Figs 8a-8c). (Please note the accuracy of the clinician's impressions. This is critical for diagnostic accuracy. Diagnostic impressions should be as good as final impressions for restorations.) A Sil-Tech stent (Ivoclar Vivadent) of the additive wax-up was laboratory-fabricated and the case was sent back to the clinician's office for try in.

Transfer of this wax-up design directly to the patient's dentition using the laboratory-fabricated Sil-Tech stent and Luxatemp temporary material (Zenith/DMG; Englewood, NJ) allowed for a careful assessment and refinement of each characteris-

Figure 9: Additive wax-up intraoral transfer.



Figures 10a & 10b: Proposed lingual arch form reduction.

tic (Fig 9). This esthetic preview is beneficial to both the dentist and laboratory technician. In addition, the preview is a powerful motivator for patient case acceptance. With incisal edge position, buccal corridor, and gingival levels determined, an accurate full contour wax-up of both esthetic and functional details can be made. With planned changes confirmed, the full contour wax-up now represents a refined design rather than an educated guess.

A full contour wax-up allows a better understanding of required tooth preparation, including margin placement and reduction needs. During this process, every step is meticulously and methodically planned for chairside conservation of time and to ensure that the most minimally invasive procedures are used. The following steps describe the process used by the laboratory technician in this case to ensure predictable functional and esthetic results and help the clinician during patient treatment.

Step 1: Additive wax-up stent fabrication

1) Fabricate esthetic additive wax-ups on mounted casts of the stable biomechanical platform.
2) Duplicate additive wax-ups and pour in die stone.
3) Fabricate a Sil-Tech stent of each additive wax-up. (These stents will be filled with Luxatemp and transferred to the patient's mouth to confirm planned esthetic changes [as described previously] and then assist initial tooth preparation by the clinician [described in the "Initial Tooth Preparation and Provisionalization" section to follow]).

Step 2: Arch form and occlusal plane correction

1) Fabricate green reduction guides over duplicated additive wax-up casts.

Figure 11a

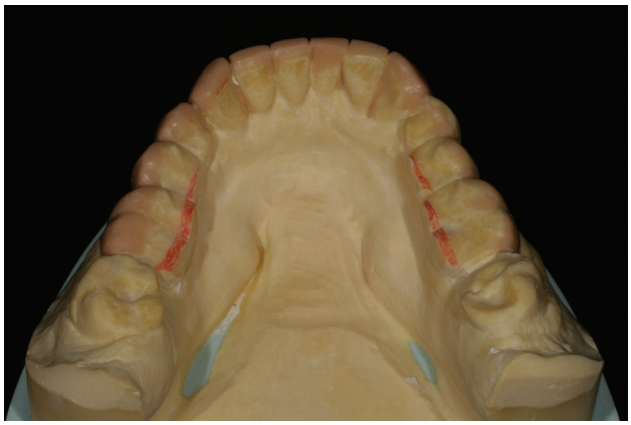


Figure 11b

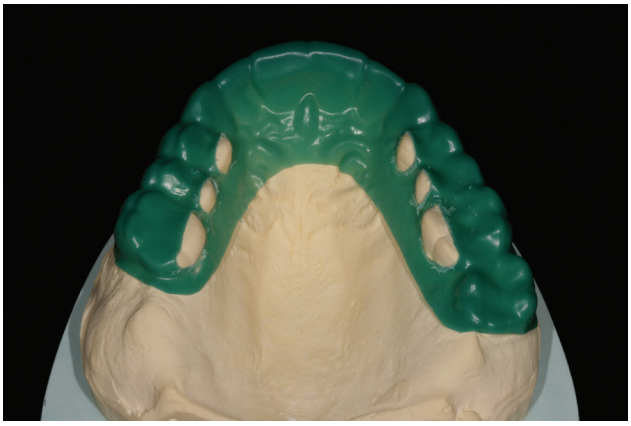


Figure 11c

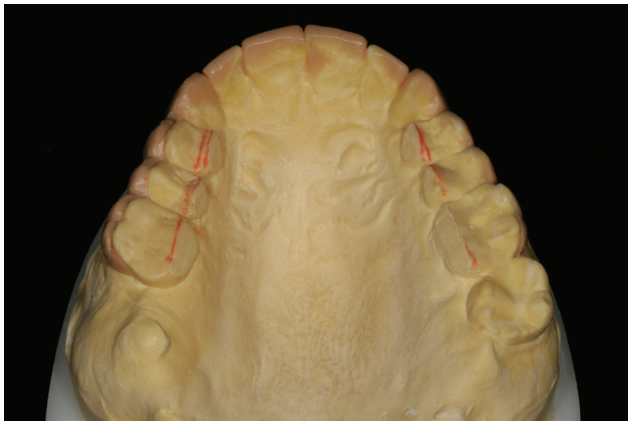


Figure 11d

Figures 11a-11d: Green reduction guide adjusted to correct arch form.

Figures 12a & 12b: Green reduction guide adjusted to correct occlusal plane.

2) On original mounted additive wax-up casts, outline lingual tooth contours needing reduction to correct arch form in red pencil (Figs 10a & 10b).
3) Place green reduction guides over original additive wax-up casts and reduce guides to the red lines to indicate the new lingual contours (Figs 11a-11d).
4) Reduce the occlusal surfaces of the green guides to be continuous with the upper and lower incisal planes to indicate the new occlusal plane (Figs 12a & 12b). (These green reduction guides will be used by the clinician during initial tooth preparation [described in the "Initial Tooth Preparation and Provisionalization" section to follow]).
5) Fabricate a new Sil-Tech stent of these modified additive wax-up casts (to be used in Step 4 below).

Step 3: Full-contour wax-up cast preparation

1) Make pilot depth cuts into modified mounted additive wax-up casts (Figs 13a-13c).
2) Continue preparing teeth on casts to depths meeting the ceramic manufacturer's specifications (in this case, pressed Swiss SNF Metals [Toronto, Ontario, Canada]).
3) Refine tooth preparations and margins on casts.
4) Duplicate each prepared cast in die stone and review reduction needs with clinician.

Step 4: Full-contour wax-up, clinician's reduction guide, and provisional restoration; matrix fabrication

1) Place new Sil-Tech stents (from Step 2 above) over mounted prepared casts.
2) Inject wax into stents over prepared teeth on casts.
3) Refine anatomy, contour, and function of new full-contour wax-ups (Figs 14a-14c).
4) Duplicate upper and lower full-contour wax-ups in die stone.
5) Fabricate provisional restoration and tooth reduction matrixes for clinician (described in the "Initial Tooth Preparation and Provisionalization" section).

Because gingival levels were to be changed, esthetic crown lengthening needed to be performed.

These steps will help to ensure success and predictability in final preparation by the clinician and will be repeatable intraorally with the combined use of the additive wax-up stents, the green reductive stents, and the final temporary stents.

The case was then packaged and sent to the clinician's office for review and preparation.

Initial Tooth Prepa ration and Provisionalization

Because gingival levels were to be changed, esthetic crown lengthening needed to be performed. In this case, this was done in two phases. While this is a novel approach to esthetic crown lengthening, it is based on sound biological principles with advantages to both the patient and clinician.

At the tooth preparation appointment, the first (soft tissue) phase was completed. Measurements from the midfacial gingival margin to the crestal bone of each tooth to be crown-lengthened were made and recorded. The gingival margins were then surgically trimmed to match the contours and levels determined previously in the esthetic additive-only process. The osseous phase of surgery was performed only after the patient accepted the new gingival levels, and will be described in the next section of this article. Although the initial trimming of soft tissue may invade the biologic width, it is virtually nontraumatic for the patient, and the second (osseous) phase is performed within six weeks—before any adverse biological response occurs. This "two-stage" method requires adequate amounts of attached tissue, but offers the benefit of allowing the patient to live with and approve their new gingival levels before osseous recontouring commits them to these levels.

During tooth preparation, proper tooth reduction and contour are critical for both restoration esthetics and strength. When significant change in tooth contour or dimension is required, it is easy to "get lost" during tooth preparation, resulting in either over- or under-reduction. A simple, yet effective three-step process to ensure proper reduction begins with a guide to gross reduction.

The first step begins with an overlay representing final planned restoration contours and dimensions that will be outside those of the existing teeth. To do this, a small area of enamel on each tooth is etched and bonded to aid in retention of the overlay. A Sil-Tech index of the additive wax-up (from Step 1 of the previous section) is then filled with a provisional-type composite resin, inserted and *completely* seated. To approximate final restoration dimensions, it is also important that there is no tooth structure lying outside these dimensions. To accom-

Figure 13a

Figure 13b

Figure 13c

Figures 13a-13c: Initial depth cuts into additive wax-up.

plish this, the green reduction index (from Step 2 of the previous section) is used to guide the removal of this tooth structure (Fig 15). Tooth preparation now proceeds through both the composite overlay and remaining tooth structure to depths appropriate for restoration type and shade—in the same manner in which preparation is done on teeth when no change is made in contour or dimension.

In the second step, once gross reduction is completed, each preparation is checked and refined with a putty silicon index of the full-contour wax-up sectioned through each tooth (from Step 4 of the previous section) (Fig 16). In the final step, after all functional and esthetic adjustments are made to the provisional restorations, the thickness of each provisional restoration is checked with a crown gauge (Fig 17).

Combined, these three steps ensure that reduction of every part of each preparation meets restoration esthetic and strength requirements. (Note: In this patient, because tooth preparations were to be finalized after osseous esthetic crown lengthening, only the first two steps of this process were done at this time. The third step of checking provisional restorations with a crown gauge will be done at the time of final tooth preparation and impressions.)

All restorations in this case were to be bonded pressed ceramic, including full-coverage and three-quarter crowns. Because of this, following preparation, all teeth received immediate dentin sealing. The benefits of immediate dentin sealing have been well described by Pascal Magne and include:[9]

Figure 14a

Figure 14b

Figure 14c

Figure 14d

Figure 14e

Figures 14a-14e: Completed full-contour, fully functional diagnostic wax-up.

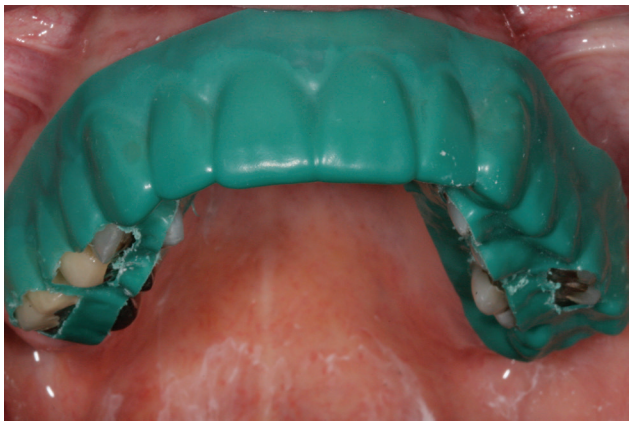


Figure 15: Intraoral view of green reduction guide for initial arch form and occlusal plane correction during tooth preparation.

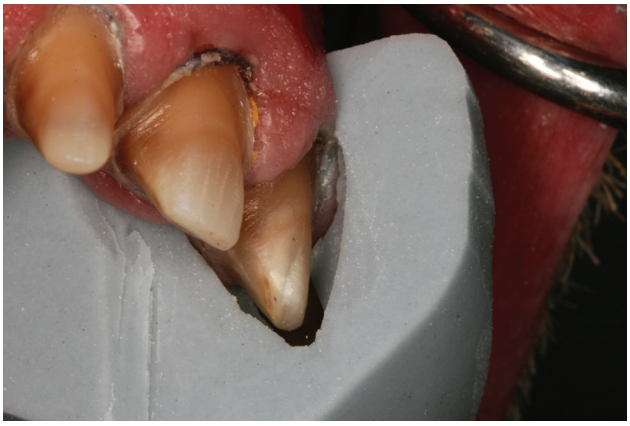


Figure 16: Sil-Tech index in second step of tooth preparation guidance process.

Figure 17: Crown gauge for final confirmation of tooth preparation reduction.

Figure 18: Use of occlusal indicator wax to confirm anterior tooth relationships in harmony with envelope of function.

Figure 19: Initial provisional restoration occlusion prior to adjustment. (Note occlusal contact #15 confirming maintenance of planned vertical dimension.)

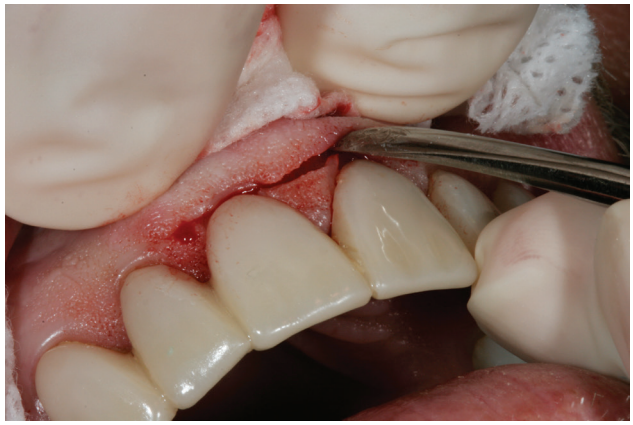


Figure 20a

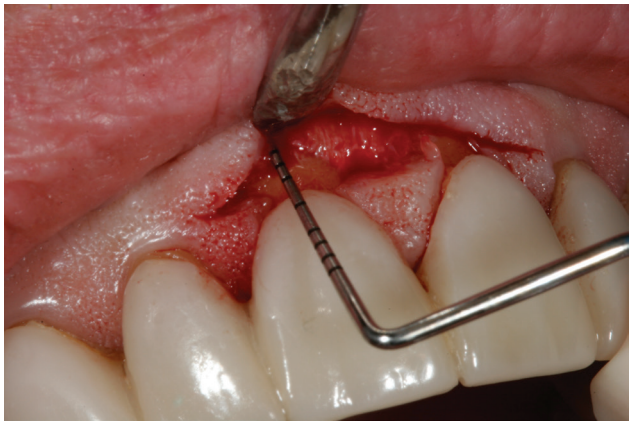


Figure 20b

Figure 20c

Figures 20a-20c: Biologically guided esthetic crown lengthening.

- increased bond strength of the resin dentin bonding agent to the dentin
- protection of the dentin and pulp from bacteria
- decreased tooth sensitivity during the provisionalization phase.

Immediate dentin sealing may be done with either total-etch (wet) or self-etching methods. In this case, a self-etching protocol was followed using Clearfil Protect Bond (Kuraray America; New York, NY). With immediate dentin sealing complete, direct, splinted provisional restorations were made using another putty silicon index of the full-contour wax-up filled with Luxatemp Fluorescent provisional material. (Note: If composite or bis-acryl provisional restorations are made directly over sealed preparations, it is important to lightly coat the preparations with a lubricant, such as petroleum jelly, prior to fabrication. This is necessary to prevent the provisional restorations from bonding to the preparations.)

One of the most critical functional elements requiring confirmation in the provisional restorations is the lingual contour of the upper anterior teeth. This is the contour of the lingual aspect of upper anterior teeth between the incisal edge and the occlusal stop. It is crucial that these contours allow disclusion of the posterior teeth with all excursive movements, yet be in harmony with the envelope of function. While many functional and esthetic elements can be determined on the workbench with accurately mounted casts and photographs, even the most carefully created wax-up represents only an educated guess of these contours. They are determined by the envelope of function and

Figure 21: Final stump shades.

must be confirmed directly in the mouth, with the patient in function.

The research of Lundeen and Gibbs made clear that with chewing, if the upper incisor lingual contour is properly shaped, lower incisal edges should contact upper incisors only at the beginning and end point of the chewing cycle—the point of maximum intercuspation.[10] Only the lingual surfaces of upper canines, and not the upper incisors, guide the mandible into maximum intercuspation during the chewing cycle.[10]

Clinically, a proper lingual contour can be confirmed with the application of Kerr (Orange, CA) occlusal indicator wax to the lingual surface of the upper anterior teeth (or provisional restorations). With the patient chewing something firm (peanuts or carrot pieces work well), it is proper for the wax to be perforated along the lingual contour of the upper canines. However, on central and lateral incisors, the wax should be perforated only at the point of maximum intercuspation (Fig 18). Occasionally, it is even necessary to change upper or lower incisal edge positions to accommodate the envelope of function. This is one reason why incisal edge positions represent both a key esthetic *and* functional element. In this case, no occlusal adjustment of the provisional restorations was required on the day of preparation, and only minimal adjustment at the one-week follow-up visit (Fig 19).

Osseous Esthetic Crown Lengthening

A key biologic principle in periodontics is that the relationship of the gingival margin to crestal bone is genetically determined and variable from patient to patient.[11] As a result, if crestal bone height is surgically reduced, the gingival margin can be expected to mature at the same relationship to the new osseous crest as it had before osseous reduction—as long as a normal epithelial attachment exists and gingival tissues are healthy.

If osseous surgery is performed, the final gingival margin levels after healing can be predicted at the time of surgery. Knowing this, the gingival flaps may be immediately positioned at these levels at the surgical appointment. This allows finalization of tooth preparations and impressions as soon as early healing is complete—approximately four to six weeks after surgery. Without applying this biological principle, final gingival levels cannot be predicted at the time of surgery, and final tooth preparation and impressions must wait until full gingival maturation has occurred—a minimum of 12 weeks after osseous reduction. These concepts were the basis for our patient's esthetic crown-lengthening technique.

Once he accepted gingival levels and contours developed at the tooth preparation appointment, the patient was referred to a periodontal surgeon, Dr. Michael Morgan (Independence, OH), for the osseous phase of esthetic crown lengthening. Pretreatment distances of gingival margins to the osseous crest (measured and recorded earlier, prior to initial soft tissue recontouring), combined with final approved provisional margin position, guided crestal bone reduction and flap positioning (Figs 20a-20c).

Final Tooth Preparation and Impressions

Six weeks after osseous crown lengthening was complete, the func-

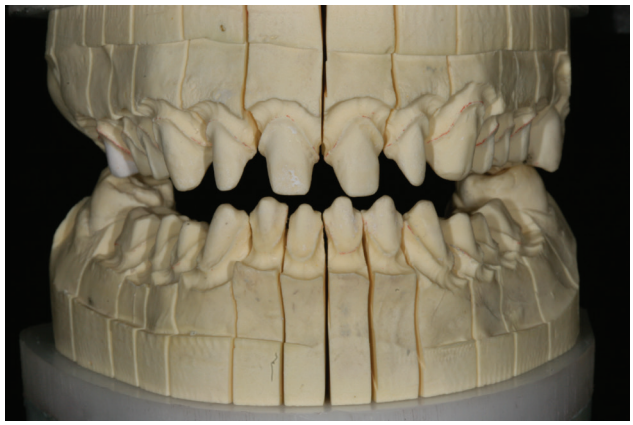


Figure 22a

Figure 22b

Figure 22c

Figures 22a-22c: Cross-mounted working dies and provisional restoration casts.

tionally and esthetically approved lower provisional restorations were removed. At this time, the final step to ensure proper tooth reduction was done by checking the thickness of each provisional restoration with a crown gauge (Fig 17). Necessary adjustments to tooth preparations were made to allow adequate and uniform restorative material thickness for optimum strength and esthetics. A single Ultrapak retraction cord (Ultradent Products; South Jordan, UT) was placed, and the immediate dentin sealing process described previously was performed again in those areas where teeth were re-prepared. After dentin sealing was complete, the retraction cord was pushed deep enough into each sulcus to expose approximately .5 mm of tooth structure apical to preparation margins. Expasyl (Kerr) gingival retraction paste was then injected into each sulcus. Although Expasyl does not seem to create much gingival retraction on its own, it does a good job of maintaining gingival retraction already developed by other means, and it provides excellent hemostasis. Sixty seconds after the last increment of Expasyl was injected, all was rinsed off with an air/water spray. Final impressions were immediately taken with custom trays filled with Aquasil LV and Aquasil XLV (Dentsply Caulk; Milford, DE) injected into each sulcus.

Prior to removing the upper provisional restorations, a bite registration between the final lower tooth preparations and these provisionals was made and set aside to be used later for cross-mounting procedures.

The upper provisional restorations were then removed, preparations refined, retraction cord placed, and final impressions made in the same manner they were for the lower teeth. A facebow registration to re-

cord the hinge axis was made. Next, the critical final bite registration between upper and lower final preparations was made. Even with a facebow registration made, it is a good idea to make this bite registration at, or as close as possible to, the final vertical dimension of occlusion. This can usually be accomplished with an acrylic or composite Lucia jig made chairside to fit over the upper incisor preparations and adjusted to the final VDO. (Remember to lubricate the teeth first if you have done immediate dentin sealing and are making a composite jig directly in the mouth.) As with the DATA Appliance, the Lucia jig should allow contact of one lower incisor, perpendicular to the path of closure. With the Lucia Jig made, a Futar bite registration was made. Stump shade photographs were taken and upper and lower provisional restorations re-cemented with a polycarboxylate temporary cement (Fig 21).

The last part of this article will describe the process of communicating esthetic and functional elements with the laboratory technician. This communication will guide fabrication of the final restorations. The restorations will then be seated and the appliance reintroduced to refine the functional occlusion. After refinement of the functional occlusion, the appliance will be used to confirm a final parafunctional activity diagnosis and protect the final restorations from potential nocturnal bruxing and clenching.

Part III

Introduction

Completion of the treatment described in Parts I and II of this article left the patient ready for final restoration fabrication and seating.

The following have been accomplished for the patient thus far:

1) A DATA Appliance has been utilized to create a stable biomechanical platform.
2) Ideal functional and esthetic restorative treatment objectives have been determined and designed on this platform.
3) Tooth preparations and crown-lengthening procedures consistent with this design have been performed.
4) Provisional restorations matching this design have been fabricated and seated.

The final part of this article will illustrate a process for creating and seating final restorations mimicking the esthetic and functional qualities developed in these provisional restorations. Key functional and esthetic qualities requiring communication will be listed and methods of communicating them detailed. In conclusion, techniques for utilizing the appliance to perfect and protect these restorations will be described.

Laboratory Communication

Communication of both the functional and esthetic qualities developed in the provisional restorations is critical if each is to be realized in the final restorations. Key esthetic elements to be communicated include:

- upper and lower incisal edge positions
- upper and lower incisal embrasure forms
- upper posterior buccal cusp tip positions
- upper and lower labial and upper buccal contours
- the most gingival point of anterior tooth interproximal contacts.

Key functional elements to be communicated include:

- upper and lower incisal edge positions
- anterior tooth stop presence and locations
- upper anterior tooth lingual contours
- lower posterior tooth buccal and lingual contours
- posterior tooth fossa and incline forms.

These elements can be effectively communicated by cross mounting accurate casts of the provisional restorations against casts of the master dies. This involves first mounting the casts of the upper and lower working dies using the facebow and final bite registration. Next, the cast of the upper provisional restorations is mounted opposing the lower working die cast. Finally, the cast of the lower provisional restorations is mounted to the upper provisional cast. With this completed, all provisional and working die casts are cross mounted (Figs 22a-22c). Fabrication of putty silicon indexes of the mounted provisional casts then allows precise duplication of functional and esthetic elements. Processes to communicate one functional element will be described in greater detail.

As detailed in the previous part of this article, one of the most important functional elements is the lingual contour of the upper anterior teeth. Once perfected in the patient's mouth on the provisional restora-

Figure 23a

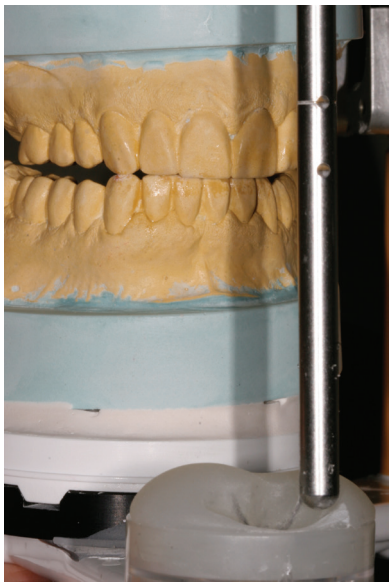


Figure 23b

Figure 23c

Figures 23a-23c: Custom incisal guide table recording lingual contour of approved upper anterior provisional restorations in lateral and straight excursive movements.

tions, it is critical that they be duplicated in the final restorations. This is most effectively done with use of a custom incisal guide table (Figs 23a-23c). The custom incisal guide table is made using the cross-mounted casts of the upper and lower provisional restorations and records the lingual contours of the upper provisional restorations. Once fabricated, it is used to confirm duplication of these contours on the final restorations. Duplication of contours is confirmed when the articulator's incisal pin maintains contact with the custom guide table while the upper and lower final restorations maintain contact with each other through all excursive movements on the articulator. If a restoration causes the incisal pin to separate from the guide table, this would indicate that the lingual contour of that restoration is more restrictive to the envelope of function than the provisional restoration. More restrictive lingual contours create potential problems with both functional occlusion and parafunctional activity movements and should be avoided.

RESTORATION FABRICATION

Sil-Tech indexes are made from the cross-mounted provisional casts to record incisal edge and buccal cusp tip positions. These will be used to confirm the final wax-ups and to guide porcelain cutback and layering techniques (Figs 24a-24d).

Full-arch Sil-Tech matrixes are made from the upper and lower provisional casts. The die casts are then checked for any areas that may interfere with complete seating of the matrixes over these casts. Once complete seating is confirmed, the matrixes are injected with wax onto the die casts.

The wax injections are then checked against the index of the cross-mounted provisional casts for accuracy. They are then individually separated and the anatomy, contours, and function are refined. Each individual wax crown is then sprued.

The sprued wax-ups were invested, burned out, pressed, broken out of the investment, and fit and contoured to match the provisional casts. The restorations were cut back utilizing the wax-up stents and layered. Each restoration was carefully checked to make sure there was only point contact on cusp tips and in fossae or on marginal ridges. Upper anterior tooth lingual contours were confirmed utilizing the custom incisal guide table.

The restorations were then checked for shade, glazed, pol-

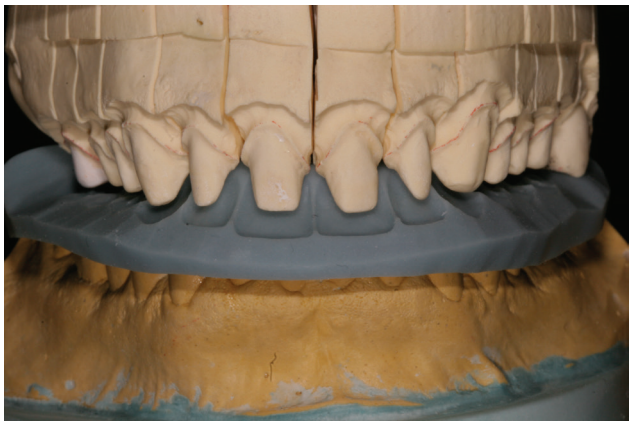


Figure 24a

Figure 24b

Figure 24c

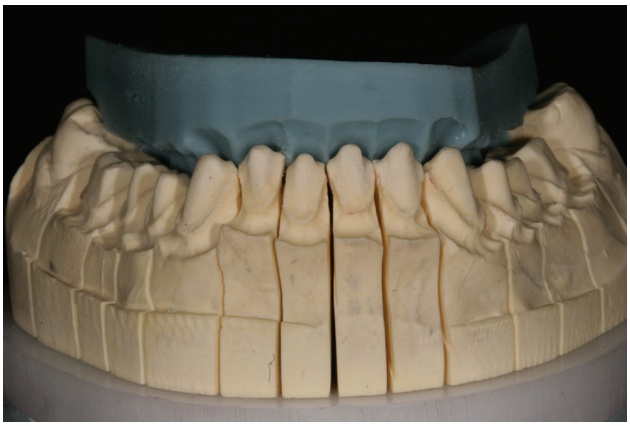


Figure 24d

Figures 24a-24d: Sil-Tech guides for incisal edge and buccal cusp tip communication. These will also be used to assist in porcelain cutback and layering procedures.

ished, etched, and ready for delivery (Figs 25a-25c).

Restoration Seating

There are a number of protocols for seating final restorations. Protocols include the choice of cementing/luting media and restorations being seated in either one or multiple visits. Cementing/luting protocols should be based upon the type of restorations and the manner in which the teeth were treated at the time of preparation (e.g., was immediate dentin sealing utilized?). The decision to seat all restorations in one or multiple visits is affected by several factors, including patient availability, comfort, and operator preference. Either option is acceptable and should be chosen to meet the specific needs of each case. In this case, limited patient availability made it more practical to seat all restorations in one visit.

The facts that the final restorations were pressed ceramic and that immediate dentin sealing was used at the time of tooth preparation determined the cementation technique. Pressed ceramic restorations rely on a strong bond between the restoration and prepared tooth structure (dentin and enamel) for their strength. With immediate dentin sealing, the bond to enamel and dentin are created at the time of preparation, leaving both exposed enamel and dentin covered with a thin layer of bonded resin. Therefore, the critical bond at the time of seating is that between the restoration and this layer of resin. In this case, because immediate dentin sealing was performed with Kuraray Protect Bond, Kuraray DC Bond and Esthetic cement were chosen for final bonding and cementation. Kuraray DC Bond is a dual-cure, self-etching adhesive. Esthetic cement is a dual-cure resin cement. After removal of

Figure 25a

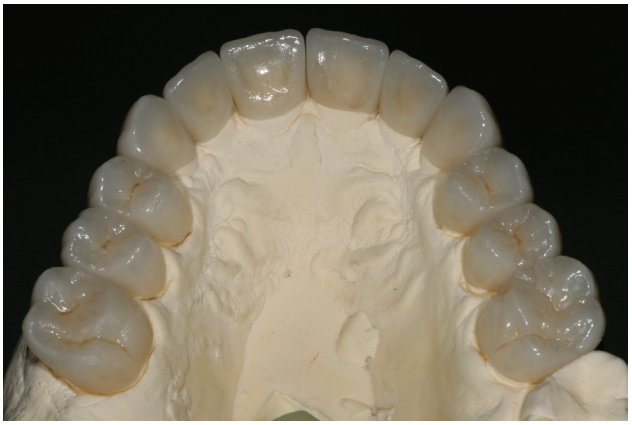


Figure 25b

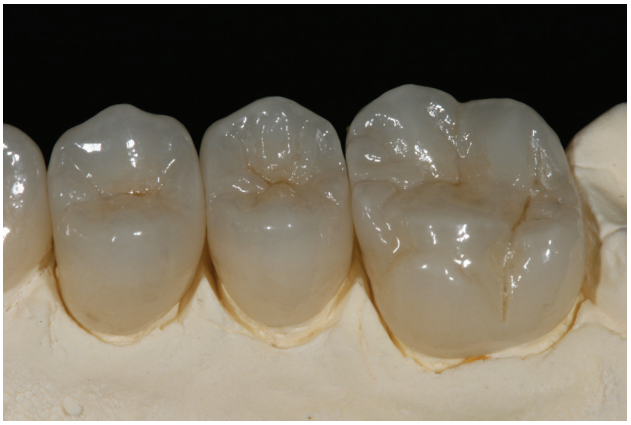


Figure 25c

Figures 25a-25c: Final restorations on casts.

the provisionals, the preparations were cleaned with micro abrasion. The DC Bond was then applied to the already sealed preparations to ensure bonding to the existing resin layer and any tooth structure that may have become exposed during cleaning. The inside of the restorations were primed with Kuraray ceramic primer. The restorations were filled with Esthetic cement, seated, and cured.

FUNCTIONAL OCCLUSION REFINEMENT AND MANAGEMENT OF PARAFUNCTIONAL ACTIVITY

With careful attention to all case details, from tooth preparation and bite registration techniques to final restoration seating protocols, there should not be much need for occlusal adjustment. However, subtle refinement is required in nearly all cases. If necessary, initial occlusal adjustments can be made at the seating appointment. Conversely, final refinement of the functional occlusion is best completed at a later visit, when the patient's masticatory muscles are rested and deprogrammed, and mandibular movements are not influenced by local anesthetic. If many restorations are involved, it is helpful to make these refinements with use of the DATA Appliance.

A brief time of wearing the appliance after restorations are seated once again allows complete relaxation and deprogramming of masticatory muscles. Then, the appliance can guide final adjustment of the restorations in the same manner it guided reductive reshaping of the original dentition (although this should involve only very slight adjustment of the restorations) (Fig 26). While use of the appliance is not mandatory, it is a simple technique to finalize the functional occlusion with tremendous precision.

If the appliance is to be used after restorations are seated, the existing

Figure 26: Occlusal stops after final occlusal adjustment with the DATA Appliance. (Again, note occlusal stop on #15 confirming achievement of planned vertical dimension.)

appliance may be refit chairside, or refit or refabricated in the laboratory on casts of the final restorations. The practicality of re-using the previous appliance, or fabricating a new one, depends primarily upon the amount of change in upper tooth contours. In this case, because major changes were made in the lingual contours of upper teeth, a new appliance was made and seated to finalize the functional occlusion.

Even with the functional occlusion perfected, unmanaged parafunctional activity can damage natural teeth or any type of restorations. Therefore, once refinement of the functional occlusion is complete, attention should turn to management of parafunctional activity. During the evaluation phase, this patient's response to the appliance determined a *preliminary* parafunctional activity diagnosis of benign or structural parafunctional activity. This was based on the fact that there was little evidence of parafunctional activity on the appliance stop for the six weeks it was worn. However, a *final* diagnosis of parafunctional activity requires at least six *months* of monitoring. For this reason, if there is suspicion of nocturnal bruxing or clenching, it is recommended that the appliance be used as a nightguard following placement of final restorations. This is for two important reasons:

- It will allow monitoring of parafunctional activity to determine if there is need for long-term nightguard utilization.
- It will protect the new restorations from any nocturnal bruxing or clenching activity, if any is present.

To perform these functions, after occlusal finalization, the DATA Appliance is modified by adding additional acrylic to the anterior stop. However, the stop is now designed differently than it was during initial patient evaluation. At initial placement, only a single lower incisor made contact with the anterior stop. Now, acrylic is added to allow both lower central incisors to contact the anterior stop with equal intensity. The anterior stop is also vertically opened enough to clear canine tooth interference in lateral excursive movements.

Conclusion

Many systems exist today for dentists to help their patients achieve ideal esthetics and function. To be most useful, a system should fulfill five basic requirements. It should:

- provide highly predictable esthetic *and* functional results
- be simple enough to be understood and used by most dentists
- be usable in a broad range of clinical situations
- make efficient use of operator and patient time
- allow flexibility in phasing treatment.

It has been the goal of this article to illustrate how utilization of the DATA Appliance, the Integrated Classification System, and development of a stable biomechanical platform fulfill these requirements.

Although the case illustrated in this article involved significant functional and esthetic challenges,

Figures 27a & 27b: The patient, free of pain, with a new smile and a new attitude.

the principles utilized apply to all patients who desire an improvement in masticatory system comfort, function, or esthetics. These fundamental principles include first using the DATA Appliance and ICS to determine if the patient can benefit from definitive restorative or occlusal treatment. Second, the appliance is used to facilitate development of a stable biomechanical platform. If no other restorative or esthetic needs exist, development of this platform represents the end of treatment—leaving the patient comfortable and in a biomechanically maintainable state of dental health. If, on the other hand, the patient needs or desires additional restorative or esthetic treatment, the stable biomechanical platform provides the foundation upon which this treatment can be predictably planned and delivered. In addition, because the platform is developed at a vertical dimension of occlusion that is appropriate for planned restorative and esthetic treatment, many phasing options for final treatment are possible. Final restorations may be completed simultaneously, as they were in this case, or phased over time, without compromise to esthetics or function.

While this article has highlighted the benefits of utilizing the ICS, the DATA Appliance, and developing a stable biomechanical platform, achieving long-lasting esthetics and function requires techniques and skills beyond those needed just to utilize these tools. Proper tooth preparation and laboratory communication are among those most essential. For this reason, a description of some of these additional techniques has also been detailed in this article to acknowledge their importance. In the end, consideration and management of all factors affecting each part of the masticatory system are critical if predictable outcomes are to be realized.

By accepting treatment, our patients demonstrate a high level of confidence in our clinical skills and judgment. By agreeing to provide treatment, we in turn should assume responsibility to provide the finest care possible. However, while clinical excellence is important, if we are to truly consider our treatments successful, patients should benefit from our efforts. We should in some way make our patients' lives better for what we have done for them (Figs 27a & 27b).

Acknowledgments

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