THERAPEUTIC BIOMECHANICS CONCEPTS AND CLINICAL PROCEDURES TO REDUCE IMPLANT LOADING. PART II: THERAPEUTIC DIFFERENTIAL LOADING

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KEY WORDS

Therapeutic biomechanics
Differential occlusal loading
Differential occlusal adjustment

Practical laboratory procedures were suggested in order to provide a modified occlusal anatomy to reduce implant loading. The concept of differential mobility caused by the flexion between a natural tooth/periodontal ligament interface with its supporting bone, compared with the stiffness of the implant/bone interface, was described. When individual tooth-supported and implant-supported prostheses coexist in the same arch, this differential mobility can shift the loading disproportionately from the natural teeth to the implants. A new concept of therapeutic differential loading is introduced and a clinical technique of differential occlusal adjustment is described to bring about a more favorable distribution of loading to all the supporting bone. Long-term natural tooth intrusion can cause implant overload. Therefore, it is suggested that periodic differential occlusal adjustment procedures be used to re-establish a long-term balance of loading between individual implant- and tooth-supported prostheses within the same arch.

INTRODUCTION

The focus of this paper is to furnish practical laboratory and clinical procedures to provide therapeutic differential loading. It is beyond the scope of this presentation to describe detailed concepts of articulator function and occlusion, which has been previously presented in depth.[1–25] The purpose here is to provide practical laboratory procedures that produce improved occlusal design,[26] as well as clinical differential occlusal adjustment procedures that decrease short- and long-term implant loading. However, the long-term prognosis of any prosthesis is directly proportional to the concept and clinical skill of the clinician to adjust the occlusion according to the biomechanical characteristics of the supporting structures.

A new concept called therapeutic differential loading will be introduced;

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this loading improves long-term prognoses when implants and natural teeth support separate prostheses in the same arch. Specific step by step occlusal adjustment procedures are required to compensate for the different loading characteristics caused by an osseointegrated implant/bone interface compared with a tooth/periodontal ligament/bone interface. The occlusal adjustment procedure is termed differential occlusal adjustment.

Occlusal Objectives of Restorative Prosthodontics

Group function vs cuspid-protected occlusion

Space does not permit a lengthy discussion of cuspid-protected occlusion.[15,16] However, it is extremely relevant when discussing articulators. Cuspid protection is controversial because other clinical research reports have indicated posterior occlusal contact in eccentric mandibular movements.[17–22] The author prefers a flexible approach (ie, in most instances with natural teeth, group function with no non–working-side contact); it is preferred in order to distribute eccentric occlusal forces to as many teeth as possible in order to maintain periodontal health. However, a canine-protected occlusion is indicated when 2 levels of occlusion are present with a deep vertical overlap.[23] On the other hand, when separate implant-supported and tooth-supported prostheses exist in the same arch, if the canine is a natural tooth, the author prefers a cuspid-protected occlusion to help limit lateral forces on the implants. To facilitate these objectives, a modified semiadjustable articulator technique will be recommended.

Semiadjustable Articulator

The purpose of the semiadjustable articulator is to provide a practical tool for the construction of a prosthesis in the laboratory that will require a minimum of occlusal adjustment when seated intraorally. In short, a labor-saving device that decreases chair time to obtain the desired occlusion.

Working-side condylar movement

Semiadjustable articulators (such as the Hanau) obtain working-side condylar rotation and lateral Bennett shift by turning the nonworking condylar postmedially (Figure 1). The Bennett angle (medial inclination) is determined by the formula $H/8 + 12$ as originally described by Hanau,[3] where H is the protrusive condylar inclination determined by protrusive check bites. (The derivation of this formula is unknown.) However, if the articulator is utilized as described for fixed prosthesis, working-side group function on the articulator will result in a posterior opening intraorally (Figure 1). This negative error cannot be corrected by occlusal adjustment.

Modification of articulator settings

Mathematical evaluation of articulators,[8] as well as over 4 decades of clinical application, indicate the elimination of the medial rotation of the nonworking condylar mechanism (0° Bennett angle). Figure 2 more accurately imitates physiologic movement. This arbitrary setting eliminates lateral Bennett shift of the working condylar mechanism,[8] which increases the posterior cusp inclines.[14] Restorations that provide group function on the working side of the articulator will produce similar working-side posterior contact intraorally (Figure 2). For example, working-side group function on the articulator is reproduced accurately intraorally (Figures 3 and 4). These examples do not necessarily imply that group function is recommended for all clinical situations. However, it does provide evidence that a simple, semiadjustable articulator can be modified to provide a more accurate practical replication of physiologic condylar movement, thus markedly simplifying prosthetic laboratory and clinical procedures.

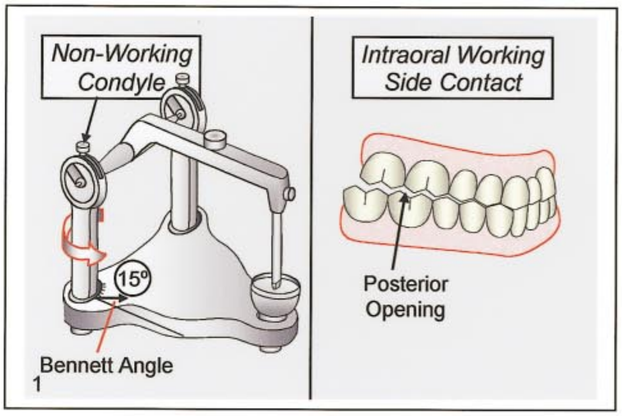
Non–working-side contact

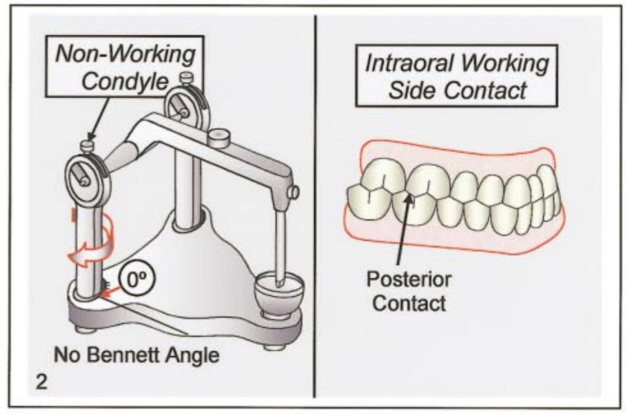
It is generally accepted that non–working-side contacts are detrimental to the periodontal support and have contributed to TMJ dysfunction pain symptoms.[24] It is important to preplan restorative procedures and to utilize preventative occlusal adjustment in order to prevent non–working-side contact from developing as a result of the procedure itself. For instance, working and nonworking guiding inclines are shown in centric occlusion (Figure 5). Bilateral contact during right lateral excursion is demonstrated (Figure 5). If the upper molar on the patient's left side is to be restored, the opposing lower buccal cusp incline should be reduced beforehand (Figure 5). In centric occlusion (Figure 5), the reduced, lower buccal, nonworking guiding incline provides good centric contact for the new upper restoration. In right lateral movement, non–working-side clearance is produced (Figure 5) as a result of the preplanned preventative occlusal adjustment of the opposing tooth.

Reduction of Occlusal Loading Using a Modified Occlusal Anatomy

Horizontal fossae

The reduction of occlusal loading using a modified centric occlusal anatomy containing a horizontal 1.5-mm fossae is not new. It was first described by Mann and Pankey[25]; however, the technique called for an intraoral functionally generated path technique that interfered with its wide acceptance. The posterior anatomy contains a 1.5-mm horizontal fossae that is extended across the occlusal of the upper molars as well (Figure 6). Sharp opposing cusps fit into the horizontal fossae, rather than line angles, which provides an *area* of centric contact that produces vertical forces (Figure 6).[26] Standard cusp to line angle occlusion can develop harmful lateral forces when the occlusion shifts to cusp to incline contact because of physiological variation.[27–30]


Non-Working
Condyle
Intraoral Working
Side Contact
15º
Posterior
Opening
Bennett Angle
1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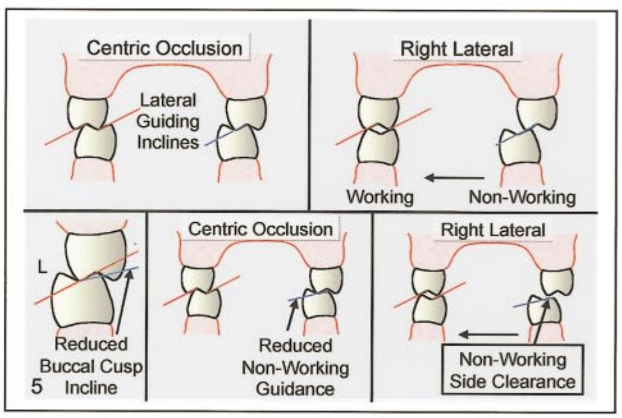
Centric Occlusion
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Non-Working
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Right Lateral
Non-Working
Side Clearance
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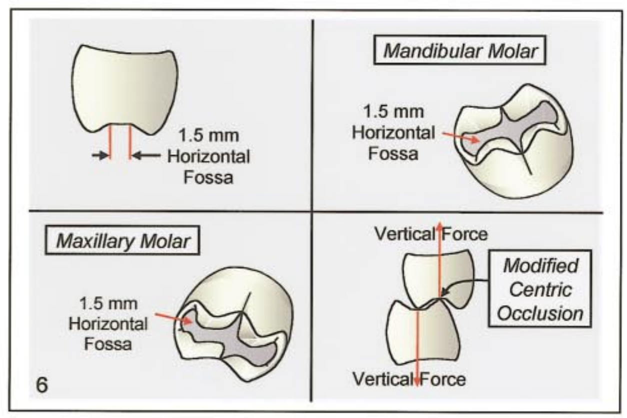
1.5 mm
Horizontal
Fossa
Mandibular Molar
1.5 mm
Horizontal
Fossa
Maxillary Molar
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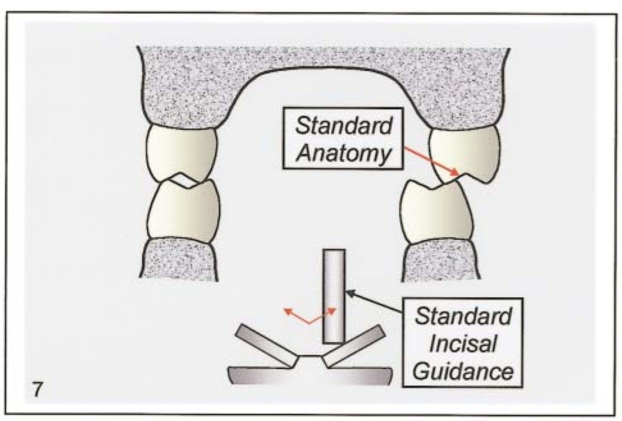
Horizontal
Fossa
Vertical Force
Modified
Centric
Occlusion
Vertical Force
6


Standard
Anatomy
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Guidance
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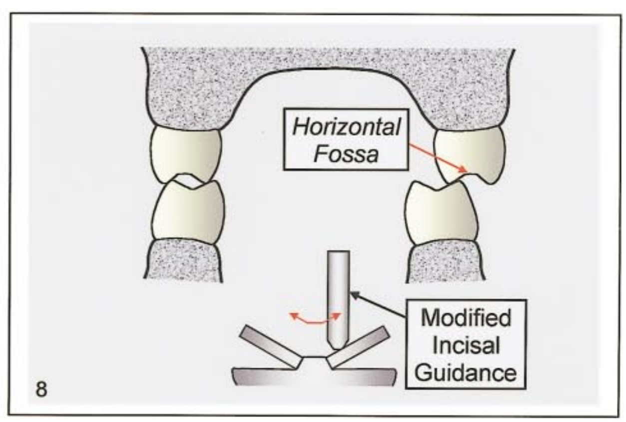
Horizontal
Fossa
Modified
Incisal
Guidance
8

Incisal Guidance Alteration for a Modified Occlusal Anatomy

Standard incisal guidance

With the standard incisal guidance, the motion of the incisal pin produces a sharp line angle as it moves from right to left lateral movement (Figure 7). As a result, the incisal guidance carves the standard anatomy in which the cusp inclines meet in a sharp line angle.[26]

Modified incisal guidance

In order to produce a posterior horizontal fossae of 1.5 mm, the incisal edges of the incisal pin are beveled approximately 1.5 mm (Figure 8). Bilateral movement of the incisal pin on the plane produces a motion that has a flat area in the middle before advancing up the inclines (Figure 8).[26] This motion produces a horizontal fossae of 1.5 mm and buccal and lingual cusp inclines (Figure 8). However, the anatomy is reversed or upside down from that of the incisal guidance. This is because the upper member of the articulator moves while the lower member remains stationary. (This ''reverse'' phenomena is the same for lateral movements on the articulator as well.[7,8,14])

Protrusive guidance

Physiologic variation in centric relation[27–30] also requires freedom of movement anteriorly. To provide this freedom, the incisal table is rotated to 0° (Figure 9). Anterior freedom of movement can be provided by the judicious use of the 2-colored marking system and occlusal adjustment (Figure 9). Once this freedom of movement is ground into the restorations, the incisal table is returned to its original inclination (Figure 10). The 2-color marking system is utilized again, and protrusive excursion (red) is adjusted without removal of centric maintaining contact (blue) (Figure 10).

Occlusal harmony with a modified occlusal anatomy

A modified occlusal anatomy containing a horizontal fossae of 1.5 mm cannot be created unilaterally.[26] The opposing occlusion must be preadjusted similar to the procedure described for Figure 5, but to contain corresponding fossae on the opposing occlusal surfaces. If this is not done, centric occlusion is lost on the affected cusps: the standard working-side inclines are shown on the left-hand side of Figure 11. Right working-side movement of the modified incisal guidance carves half of the horizontal fossae and the upper buccal cusp incline of the restoration (Figure 12). The upper lingual (slope) surface is reduced by the lower lingual cusp incline (Figure 12).

When the modified incisal guidance moves in the opposite, right, non–working-side direction, the lower buccal cusp incline reduces the upper lingual cusp incline (Figure 13). When the casts are returned to the centric occlusion position, there is a loss of the upper centric maintaining lingual cusp (Figure 14). This was one of the clinical problems associated with the functionally generated path technique previously discussed.

Modified Occlusal Anatomy With Existing Restorations

Modified occlusal anatomy will not be in harmony with adjacent natural teeth or existing traditional restorative dentistry. The 1.5-mm horizontal fossae, by definition, requires similar corrective grinding on adjacent occlusal surfaces in the entire arch (and opposing occlusion) in order to be in harmony.

Clinical examples

A 3-unit posterior implant-supported prosthesis is seated adjacent to an existing anterior tooth-supported prosthesis (Figure 15). The occlusion is adjusted on the osseo/prosthesis with the 2-color marking system to maintain centric occlusal contact. The lingual contacting areas of the existing anterior fixed prosthesis have been adjusted occlusally (with the 2-color marking system) to preserve centric contact (Figure 15). Any perforations in the metal are usually minor and can be repaired with an appropriate filling material. In another example, bilateral posterior implant-supported prostheses are adjacent to a previously existing anterior tooth-supported fixed prosthesis (Figure 16). The lingual surfaces of the anterior restoration have been corrected to be in harmony with the posterior modified centric occlusal anatomy (Figure 16).

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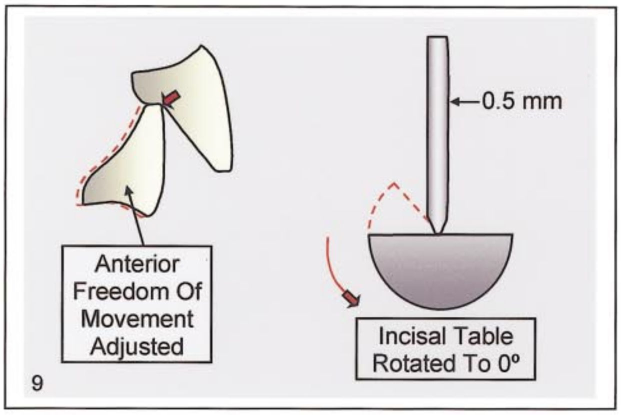
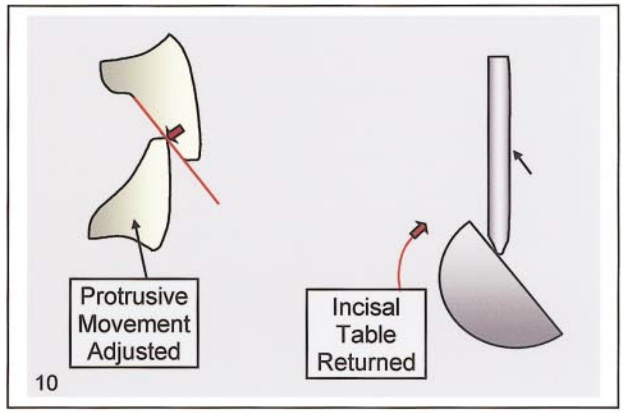
FIGURES 1–8. FIGURE 1. When a Bennett angle is used on the nonworking side (15°), the condylar post is rotated medially (left-hand side). If group function is constructed on the articulator when the completed restorations are placed intraorally, there will be a (working-side) posterior opening (right-hand side). FIGURE 2. When no Bennett angle is used on the nonworking condyle (condylar post rotated laterally to 0°; left-hand side), similar restorations placed intraorally will demonstrate posterior contact in working excursions (right-hand side). FIGURE 3. Group function is shown on the articulator. FIGURE 4. Similar working-side contact takes place intraorally when the patient moves into working-side relationship. FIGURE 5. Occlusal adjustment before restoration to provide non–working-side clearance: (a) Upper left- and right-hand side illustrates centric and right lateral guiding inclines, respectively; (b) lower left-hand side shows that lower nonworking buccal cusp guiding incline is reduced; (c) patient's upper left restoration completed to lower anatomy (lower middle); (d) during right lateral mandibular movement, non–working-side clearance is provided (lower right-hand side). FIGURE 6. The modified occlusal anatomy contains a 1.5-mm fossae (upper left- and right-hand side; lower left-hand side) so that the opposing cusps produce vertical resultant force within the range of physiologic variation (lower right-hand side). FIGURE 7. During bilateral movements, standard incisal guidance produces cuspal anatomy with buccal and lingual cusp inclines meeting in central line angles. FIGURE 8. With a modified incisal pin, bilateral movements produce horizontal fossae of approximately 1.5 mm. The width of the fossae is directly related to the length of the bevel on the incisal pin.


0.5 mm
Anterior Freedom Of Movement Adjusted
Incisal Table Rotated To 0º
9


Protrusive Movement Adjusted
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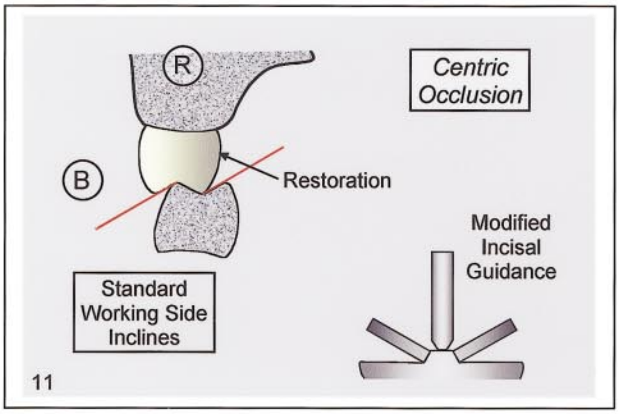
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Centric Occlusion
Restoration
Standard Working Side Inclines
Modified Incisal Guidance
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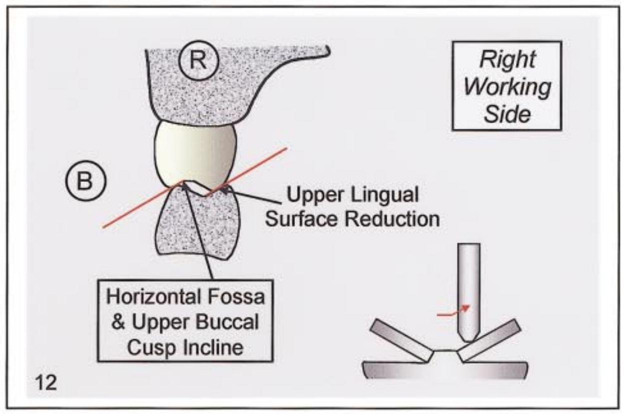
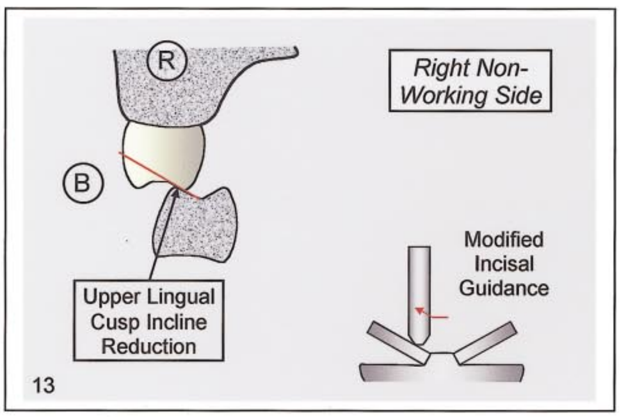

R
B
Right Working Side
Upper Lingual Surface Reduction
Horizontal Fossa & Upper Buccal Cusp Incline
12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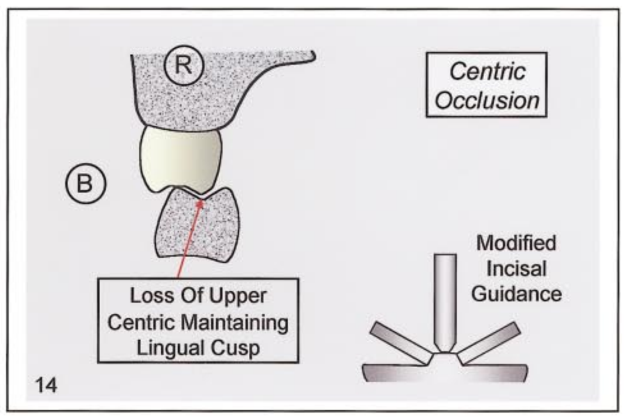
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Centric Occlusion
Loss Of Upper Centric Maintaining Lingual Cusp
Modified Incisal Guidance
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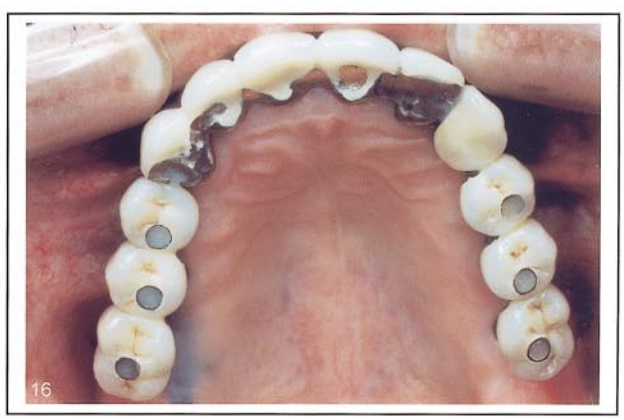
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Therapeutic Differential Loading (A New Concept)

Differential occlusal adjustment procedures are needed, in addition to the standard methods, because 2 new, dynamic biomechanical factors are introduced when separate implant-supported and tooth-supported prostheses coexist in the same arch.[31] These 2 biomechanical factors have entirely different characteristics. The first concerns the differential mobility between the natural teeth and implants, which is in effect constantly, whereas the second deals with the dynamic changes in biomechanics brought about purely by the factor of time itself. In summary, differential occlusal adjustment techniques are utilized to provide a new concept of therapeutic differential loading.

Differential mobility

The periodontal ligament provides a degree of flexion in the range of 0.1 mm, whereas the osseointegrated/implant interface is stiff.[32–34] As a result of this differential mobility, occlusal loading that is thought to be equal between the implant and tooth-supported prostheses on light occlusal contact (Figure 17), will not be equal upon forceful closure (Figure 17). The flexion of the periodontal membrane shifts the loading to the implants and their supporting bone.[32]

Long-term natural tooth intrusion

The clinical problem becomes even more complicated over a period of time. For example, regardless of the status of occlusal contact upon completion of the tooth-supported and implant-supported prostheses (Figure 18), over a long period of time individual teeth or tooth-supported prostheses can be intruded apically (Figure 18).[35] The resultant reduction of natural tooth loading can shift the burden of force distribution to the implants, causing hyperocclusion. In summary, differential occlusal adjustment procedures in addition to the standard methods are needed because 2 new, dynamic factors have been introduced (ie, differential mobility of the supporting interfaces and long-term natural tooth intrusion relative to the implants).

Differential Occlusal Adjustment

The clinical objective of differential occlusal adjustment is to provide therapeutic differential loading when individual tooth-supported and implant-supported prostheses exist in the same arch. The flexion of the periodontal ligament requires a 2-step corrective procedure. First, the standard intraoral occlusal adjustment should be carried out as usual on all the prostheses regardless of the nature of the supporting structures.[36,37] This is followed by a new procedure called differential occlusal adjustment. This 2-step procedure is further explained.

Standard occlusal adjustment

Centric occlusion is adjusted[36,37] until there is simultaneous contact on all the occlusal surfaces tested individually (arrows) as evidenced by tight occlusal contact on Mylar occlusal registration strips (Occlusal Registration Strips, Artus Corp, Englewood, NJ) of 0.0005-inch thickness held in a hemostat (Figure 19). In order to eliminate false negatives, the patient must be instructed to keep the teeth together and to try to resist lateral movement of the Mylar registration strip. To facilitate the occlusal correction process, pressure-sensitive indicating strips (Micro-O-Reg, Pulpdent Corp, Brookline, Mass) are recommended with repeated, forceful occlusal contact to mark the areas requiring occlusal adjustment.

The teeth must be completely dry in order to obtain an effective marking. Notice that the centric occlusal contact areas recorded with the pressure-indicating strips are very small and completely delineated, whereas those contacts obtained with standard articulating paper result in broad smudges (Figure 20) and are unreliable determinants for hyperocclusal contact. Preliminary standard centric occlusal adjustment is complete when all the occlusal surfaces have 1 or more discrete occlusal markings and the Mylar strips cannot pass through occlusally (Figure 20).

Differential occlusal adjustment

Differential occlusal adjustment is designed to selectively reduce occlusal loading on the implant-supported prosthesis compared with natural teeth and/or tooth-supported prostheses in the same arch. This is accomplished by a repeated process consisting of 2 steps: (1) the occlusal adjust-

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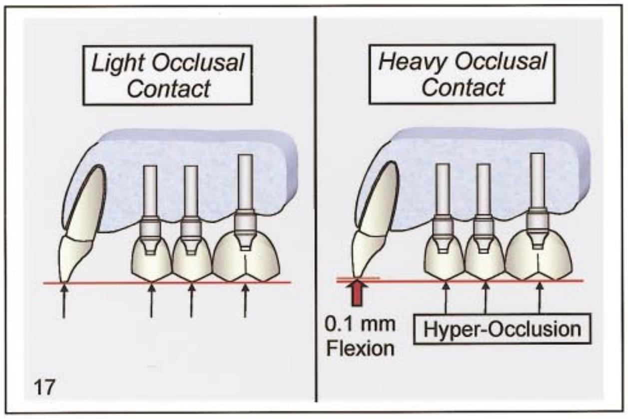
FIGURES 9–16. FIGURE 9. Freedom of anterior movement: (a) the incisal table is rotated to 0°; (b) 2-color marking system of occlusal adjustment facilitates 0.5-mm freedom of protrusive movement. FIGURE 10. Harmonious protrusive movement: (a) the incisal table is returned to its original setting; (b) using the 2-color marking system to preserve centric occlusion, harmonious protrusive excursion is provided. FIGURE 11. Consequences of no corrective grinding before opposing restoration: standard occlusal guiding cusp inclines with modified incisal guidance (in centric occlusion). FIGURE 12. During working-side movement with the modified incisal guidance, the lower uncorrected standard anatomy produces the horizontal fossa and upper buccal cusp incline (left-hand side). However, the lower lingual cusp incline reduces the upper lingual surface. FIGURE 13. During opposite non–working-side movement, the upper lingual cusp incline of the restoration is reduced by the lower uncorrected tooth. FIGURE 14. When the articulator returns to centric occlusion, a loss of upper centric maintaining lingual cusp is observed (left-hand side, arrow). FIGURE 15. An implant-supported prosthesis, containing the 1.5-mm horizontal fossae, is seated. The lingual surfaces of a previously existing fixed prosthesis have been adjusted in order to be in harmony. FIGURE 16. Bilateral implant-supported prostheses, containing 1.5-mm fossae, are adjacent to a previously existing fixed prosthesis. The lingual surfaces of the tooth-borne prosthesis are adjusted to be in harmony with the posterior modified occlusion.



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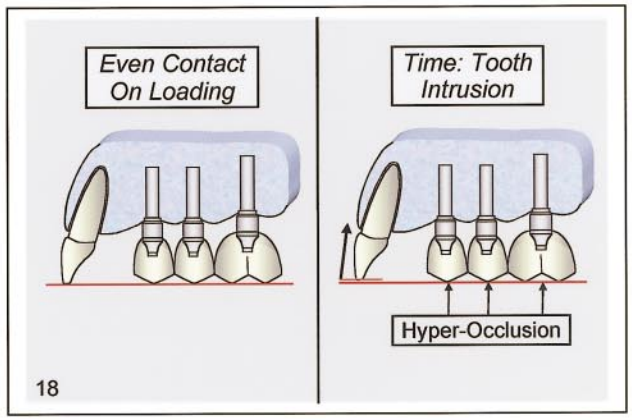

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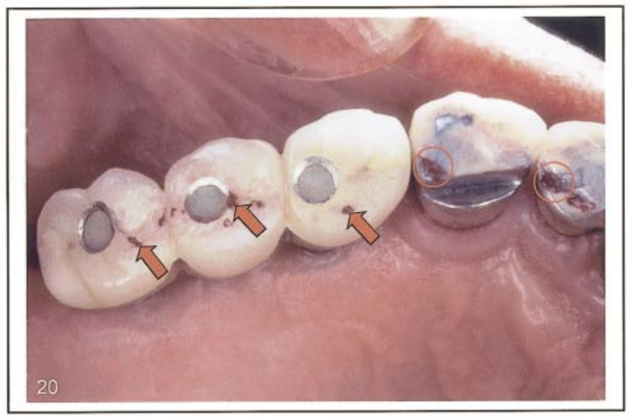
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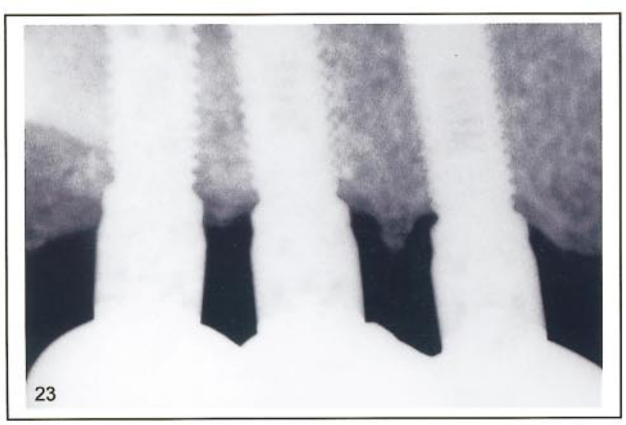
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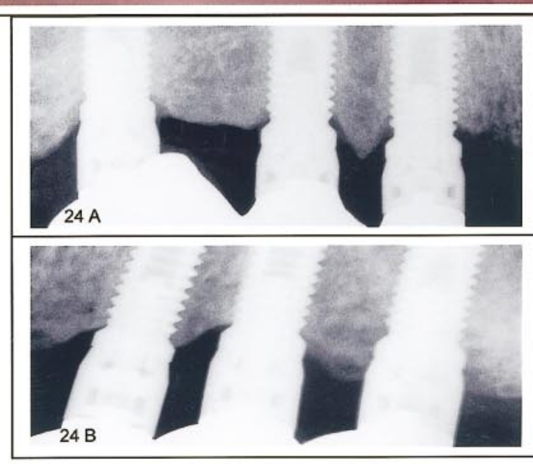
24 A
24 B

ment of 1 restoration at a time of the discrete pressure markings on the implant-supported prosthesis (Figure 20); and (2) immediate reference to the degree of pull on the Mylar strips between that corrected surface and the opposing arch (Figure 21). The author was first introduced to the concept of pulling a thin strip of tissue paper through occlusal corrected surfaces in 1952 (C. Schuyler, DDS, oral communication, 1952). If the Mylar strip cannot be pulled through, then more adjustment is necessary. On the other hand, if the Mylar strip freely passes though the occluded surfaces, then the restoration was overcorrected. The Mylar strip should pass through with a clear ''tugging'' resistance, which would indicate that the correction was less then 0.0005 inches and more in the range of 0.00025 inches. This should demonstrate a much higher degree of accuracy and control than that which was attainable with the wax penetration technique of the past. The tight occlusal contact of the Mylar strip on the adjacent tooth-supported prosthesis serves as a constant point of reference (Figure 19).

For accurate results, it is essential that the patient maintains constant pressure during the Mylar testing procedure. This procedure is designed to adjust for the difference in flexion of the periodontal ligament compared with the stiffness of the adjacent osseointegrated interface. The osseo/prosthesis is then glazed and repositioned (Figure 22).

Long-term Therapeutic Differential Loading

By definition, therapeutic differential loading should be followed by annual evaluation to accommodate for the ongoing intrusion of natural teeth compared with adjacent implant-supported prostheses.[35] The rate of natural tooth intrusion has mixed etiology and will increase with patients that have habitual or nocturnal clenching. These severe cases can be identified by exaggerated crestal bone loss around the implants. The author recommends a disocclusion night guard with anterior contact and 1 mm of posterior clearance.[38] In the author's opinion, the use of occlusal onlay night guards to decrease posterior implant loading is counterproductive and therefore contraindicated.[38] The problem of natural tooth intrusion in such patients is inescapable; therefore, in the author's opinion, long-term prognosis is dramatically improved if a program of periodic observation is utilized with the application of therapeutic differential loading as needed.

The above is not a problem when all of the prostheses in 1 arch are either natural teeth or implant-supported. Although it is correct, the time-worn admonition to keep implant-supported prostheses free-standing does not take into account the differential mobility between the periodontal ligament of natural teeth and the stiff implant/bone interface, as well as natural tooth intrusion.

Nine-year postoperative results

A 9-year postoperative radiograph of the patient shown in Figure 19 reveals minimal bone loss (Figure 23). Similarly, over the same time frame the patient illustrated in Figure 16 demonstrated minimal bone loss (Figures 23A and B, right- and left-hand sides, respectively).

Summary

Practical laboratory procedures were suggested to provide a modified occlusal anatomy to reduce implant loading. Occlusal adjustment of pre-existing restorations is usually required to be in harmony with the suggested occlusion. The concept of differential mobility caused by the difference in flexion between a natural tooth interface with its supporting bone and the stiff implant/bone interface was discussed. When individual tooth-supported and implant-supported prostheses are adjacent to each other in the same arch, this differential mobility can shift the loading disproportionately away from the natural teeth to the implants.

The new concept of therapeutic differential loading was introduced and a clinical technique of differential occlusal adjustment was described to bring about a more favorable distribution of loading to all the supporting bone. Long-term natural tooth intrusion shifts the burden to the implant-supported prosthesis. As a result of this phenomena, whenever individual tooth-supported and implant-supported prostheses exist in the same arch, it is recommended to plan periodic evaluations and differential occlusal adjustments when necessary to maintain harmonious loading.

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FIGURES 17–24. FIGURE 17. On light occlusal contact (left-hand side), all the occlusal surfaces can be adjusted to have harmonious contact. On heavy occlusal contact (right-hand side), flexion of the periodontal ligament in the range of 0.1 mm will produce hyperocclusal contact on the implant-supported prosthesis. FIGURE 18. Natural tooth intrusion: even when harmonious occlusal contact is provided on loading (left-hand side), over a period of time natural tooth intrusion can cause hyperocclusion on the implant-supported prosthesis (right-hand side). FIGURE 19. Centric occlusion is adjusted until there is tight contact with a Mylar strip on all the occlusal surfaces (arrows). FIGURE 20. Pressure-indicating strips are used with firm occlusal contact on completely dry teeth, which produces small clearly delineated markings (arrows). Standard articulating paper produces large smudges. FIGURE 21. Occlusal adjustment is continued until the occlusion strip can just be pulled through the implant-supported restorations with a slight ''drag,'' but tightly held between the natural teeth when the patient maintains firm occlusal pressure (arrow). FIGURE 22. The osseo/prosthesis is glazed and repositioned. FIGURE 23. Minimum bone loss 9 years post-operatively of patient illustrated in Figure 19. FIGURE 24. (A, B) Patient shown in Figure 16 demonstrates minimum bilateral bone loss after 9 years.

Parts I and II of this paper presented basic biomechanical phenomena and their relationship to implant and natural tooth loading. Therapeutic biomechanical corrective changes were suggested to proactively reduce the resultant forces to the supporting bone when occlusal surfaces collide in function. The concept has been called therapeutic biomechanics, and clinical techniques have been suggested to apply these principles to improve prognosis.

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