Different approaches to anchorage: A survey and an evaluation

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Traditional methods for anchorage and different types of extradental-intramaxillary types of anchorage have been widely discussed. The present paper focuses primarily on the interaction between the sagittal and the vertical components of anchorage. In addition, anchorage will be discussed from the aspect of the tissue reaction generated by the orthodontic force system and the interaction between the orthodontic force system and the forces generated by occlusion.

Craniofacial development

In the postnatal growth pattern of the facial skeleton the interaction between vertical and sagittal development is reflected in variations in the mandibular growth pattern.[1] During growth, the mandible is displaced by a combination of translation and rotation. The rotational component is determined by the relationship between the vertical development of the maxillary complex and that of the condyle. In cases where condylar growth in the vertical plane exceeds vertical development in the molar region, including sutural growth of the maxillary complex and development of the alveolar process, an anterior or forward rotation of the mandible will occur. In cases where the vertical component of condylar growth is small compared with the vertical development of the maxilla, the mandible will tend to rotate posteriorly toward the development of a long face.[2]

The impact of maxillary and especially mandibular rotation on the sagittal jaw relationship has been demonstrated clearly by Isaacson et al.[3,4] who expressed the effect of mandibular rotation

Abstract

Orthodontic treatment outcome is often compromised by the loss of anchorage. The forces acting on the anchorage unit have, however received surprisingly little attention, and the loss of anchorage is most frequently expressed in the sagittal occlusal relationship. The present paper discusses the interaction between vertical and sagittal components of dentofacial development, and the importance of taking vertical forces into consideration is stressed. The biological background for anchorage is reviewed, i.e., the impact on the cellular reaction of the periodontal ligament around the teeth of the anchorage unit from the orthodontic force system and from occlusion. A new rigid appliance consisting of two occlusal splints connected with transpalatal arches is introduced. The advantage of using the patient's sense of occlusion as part of anchorage by means of this appliance is demonstrated in a number of case presentations.

Key Words

Anchorage • Posterior stability • Extrusion • Reactive unit • Active unit • Biological anchorage • Posterior rotation • Biomechanics

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Figure 1A

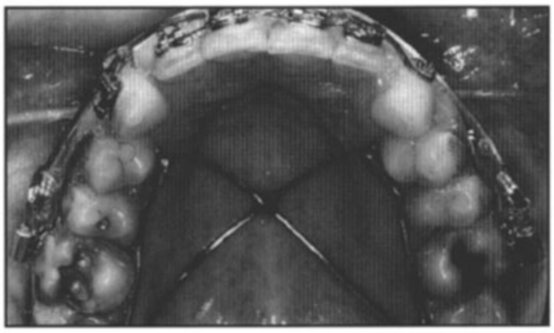
Figure 1B

Figure 1A-B
A: Example of a rigid anchorage system in a patient who needed intrusion and retraction of an upper front section. The lateral part of the appliance consists of baseplates (small nets) that are welded to the wire system, and the total appliance is passively bonded to the anchorage unit of the upper jaw.
B: Occlusal view of the appliance. An iron cross of .036 stainless steel wires soldered together is bonded to the lingual surfaces of the side segments.

on the occlusion. The relationship between the sagittal and the vertical components of growth was also thoroughly analyzed by Woodside et al.[5] They explained the effect of a change from an oral breathing pattern to a nasal pattern and described how vertical (posterior) rotation influences the position of the chin point from a direct forward movement to a downward backward positioning.

Interaction between sagittal and vertical components of anchorage

In spite of the tight relationship between sagittal and vertical development, most concepts of anchorage focus only on the sagittal relationship anchorage. Vertical changes occurring in the molar region during treatment do, however, influence the skeletal relationship significantly. Furthermore, sagittal anchorage loss hardly ever occurs without an extrusional component.

Extraoral traction is often used at the start of treatment for the purpose of displacing the molars distally in order to obtain a normal molar relationship. In case of distal movement of a molar without an intrusive component, the impact on the vertical jaw relationship is dependent on the original angle between the palatal plane and the mandibular plane. The steeper the mandibular plane the more posterior rotation will be generated as a result of distal molar displacement accompanied by extrusion.

Melsen[6] described how cervical traction, although resulting in a correction of a distal molar relationship, had a detrimental effect on the sagittal jaw relationship due to molar extrusion. Following treatment, posterior rotation of the mandible reversed in most patients and a certain catch-up of the forward growth of the chin was observed.[7] The catch-up, however, is dependent on sufficient vertical growth of the condyle following treatment. This point has also been discussed by Wieslander[8] in a paper with the very significant title "Physiological recovery following orthodontic treatment."

Even minor extrusion of posterior teeth results in a posterior rotation of the mandible.[9,10] Stöckli and Teuscher[10] demonstrated that an eruption of 1 mm of the first molars will result in an increase of the sagittal jaw relationship of 2.5 degrees. However, vertical growth of the condyle often compensates for this undesirable side effect in growing individuals. Vertical control is of crucial importance. It is a particular problem in slow-growing or nongrowing patients, where extrusion will not be compensated for by condylar growth. In these individuals even small amounts of extrusion will result in posterior rotation of the mandible. Taking this point into consideration, Teuscher[9] developed a treatment concept based on the hypothesis that mandibular growth would contribute the maximum to correction of Class II malocclusions if sagittal and vertical development of the maxillary complex was reduced through the use of high-pull traction. This principle is applied to functional appliances when the line of action of the extraoral force passes between the center of resistance of the dentition and the center of resistance of the maxillary complex.

Vertical forces cause problems not only when a Class II relationship is being corrected, but also during differential space closure. The application of different moment to force ratios with respect to the two active and reactive units may result in an extrusive force component to the anchorage unit.

Burstone suggested the addition of a high-pull headgear with a short extraoral bow[12] to control the large distal tipping moment and extrusion forces produced by a retraction T-loop. This solution, however, is not ideal as the extraoral pull is only used intermittently and with a different force magnitude than the space closing mechanics, i.e., the T-loop. However, the anchorage unit is not only under the influence of forces exerted by the orthodontic appliance, but is also influenced by occlusal forces.

The effect of the vertical force component generated by the orthodontic appliance interacts with occlusal forces, and therefore depends on

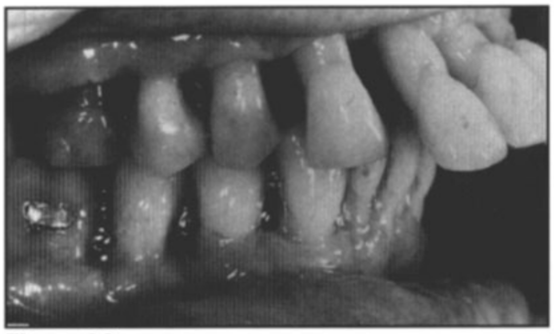

Figure 2A

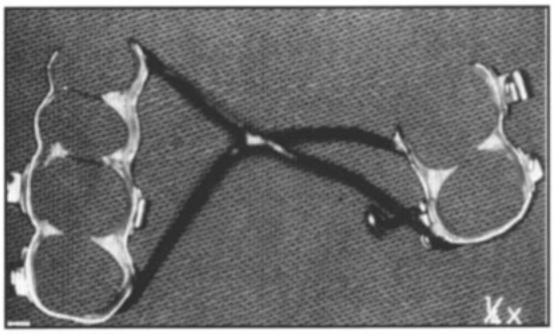

Figure 2B

Figure 2C

Figure 2A-C
A: Patient with severe marginal bone loss in need of canine and incisor retraction without anchorage loss.
B: Stiff appliance used for anchorage, consisting of an .036 stainless steel cross welded to metal semicircular band material that was adapted closely to the teeth on a model by means of a metal alloy with a low melting temperature.
C: Lateral view of the appliance in the mouth. Anchorage was further reinforced by the addition of light cured acrylic giving a better distribution of the occlusal forces. The canine has been retracted without any change in the anchorage unit.

the muscular matrix of the patient. Occlusal forces may neutralize extrusive forces produced by the orthodontic appliance.

The anchorage problems related to differential space closure have previously been discussed by Melsen et al.[13] Evaluation of anchorage loss should include an estimation of both the mandibular inclination and the cant of the occlusal plane, since a posterior rotation of the mandible or a steepening of the occlusal plane may be reflected in anchorage loss sagittally.

Anchorage from a biological point of view

The periodontal ligament and surrounding alveolar bone are characterized by turnover that is determined by general and local factors. A relative equilibrium exists between forces acting on the tooth and the resistance of the periodontium maintaining the position of the teeth. In case of ideal anchorage this equilibrium in the anchorage unit is maintained.

When an orthodontic force is applied to a tooth, the cells of the periodontal ligament (PDL) are differentiated into active osteogenic and osteoclastic cells, and new cells are retrieved from the blood vessels. As a result, both the PDL and the adjacent bone exhibit increased cellular activity,[14] which facilitates tooth movement.

Quinn and Yoshikawa,[15] in a survey paper on tooth movement and force magnitude in orthodontics, concluded that the most likely hypothesis supported by the literature was that a linear relationship between force and the rate of tooth movement exists up to a certain force level, whereupon tooth movement continues at a constant rate. The biological background was, however, not discussed in detail.

The magnitude of the threshold, i.e. the lower limit of the force that will produce tooth movement, is not fully known but is most likely dependent on the interaction with forces already acting on the tooth. Therefore, the general hypothesis, that more teeth automatically offer more resistance to tooth movement, cannot be supported.

Kvam[16] has shown that even the seating of a band is enough to produce an activation of the cells of the PDL. This confirms the observation that even a mechanical stimulus of a short duration can produce long term changes in bone turnover.[17]

The best anchorage from a biological point of view is the periodontal ligament, where no change in the turnover occurred, i.e., where the force acting on the PDL and the surrounding bone is below the threshold that leads to tooth movement. Reitan[18] and, lately, Brudvik and Rygh[19,20] have, however, shown that even low forces can generate hyalinization around the active unit. It is therefore likely that the force level acting on the reactive unit may correspond to the necessary force for the displacement leading to loss of anchorage.

The idea of a well-defined threshold value can thus not be used as a baseline for building up reliable anchorage. An optimal force level for anchorage cannot be established, because the interaction between the surrounding tissues and the orthodontic force is subject to considerable individual variation.

Although the cellular reaction starts immediately after force application, the first measurable tooth displacement is only an expression of the compression of the periodontal ligament, and to a limited degree, the elasticity of the surrounding bone.[21] After a certain lag time, resorption starts, most frequently from the marrow spaces, with indirect resorption followed by direct resorption

Figure 3A-G
A-B: Patient with severe marginal bone loss and need for intrusion and retraction without anchorage loss.
C-D: Frontal and lateral view of the appliance used. The deep bite was opened by intrusion, delivered from an .018 TMA base arch extending from the molar region and with a point of force application to the incisor segment close to the lateral incisors. In the lateral view the anchorage unit, which included an occlusal splint, can be seen.
E: Occlusal view of the iron cross connecting the two lateral splints that are in maximum occlusion, stimulating the occlusal forces. Occlusal onlays are adapted for maximal occlusal contact.
F: Frontal view of the treatment result.
G: Tracing demonstrating that no anchorage loss, either sagittal or vertical, has taken place during the notable retraction and intrusion of the anterior unit.

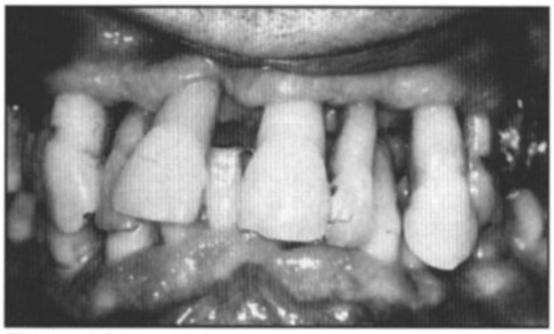
Figure 3A

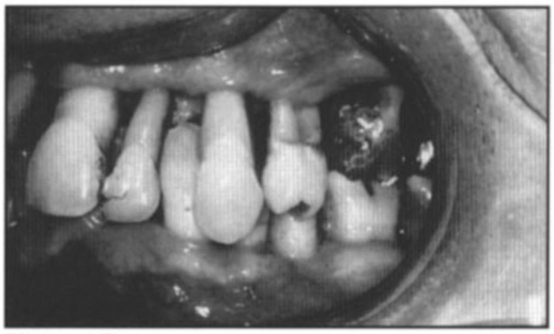
Figure 3B


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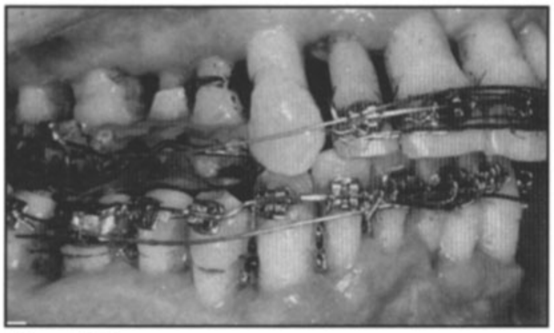


Figure 3D

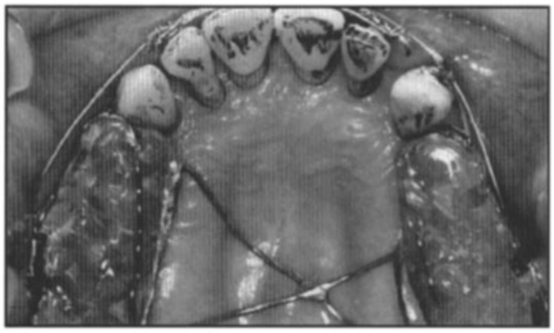


Figure 3E


Figure 3F

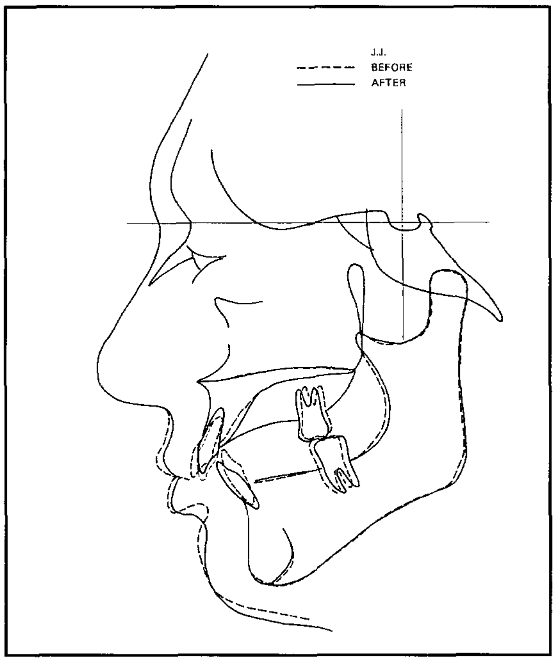


Figure 3G

of the wall of the alveolus in the direction of the force.[19,20] The lag time is greater in adults and is longer for cortical bone than for trabecular bone, due to the fact that fewer cells are available for the resorption process.[22,23]

If maximal anchorage is necessary during space closure, leveling of the anchorage unit should be postponed in order to avoid intra-arch movement that would facilitate the forward displacement of the teeth of the posterior unit.

Through the use of extraoral anchorage the periodontal tissues around the anchorage teeth are intermittently stimulated before retraction is initiated, actually just preparing for anchorage loss from a biological point of view.

When treatment is initiated with what has been described in the literature as "anchorage preparation," either by means of intraoral mechanics or by the distal movement of molars with headgear before progressing to the retraction mechanics, cellular activity is stimulated first

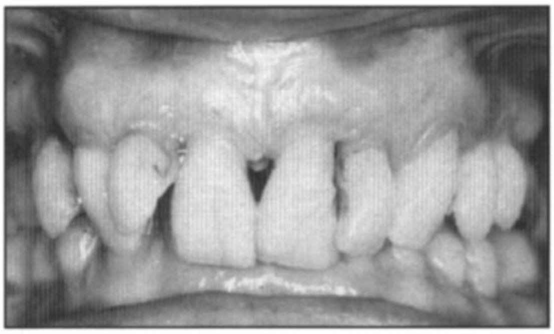


Figure 4A

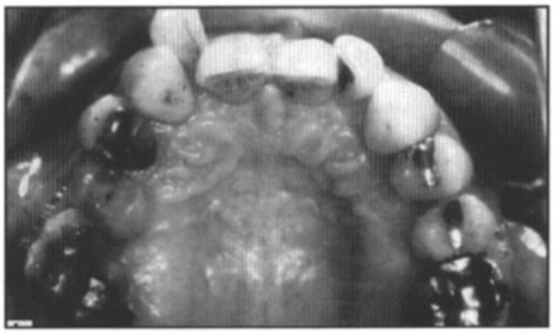
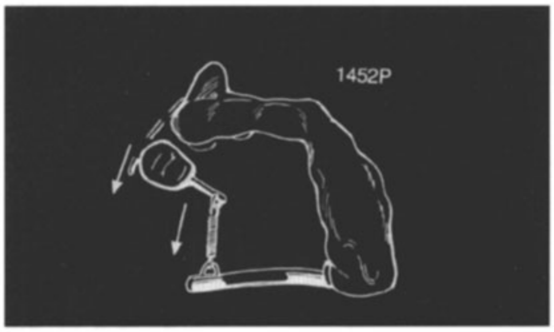


Figure 4B



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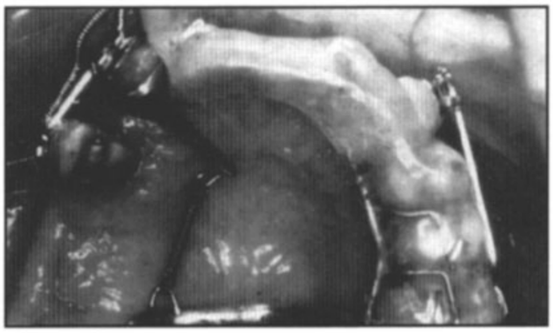
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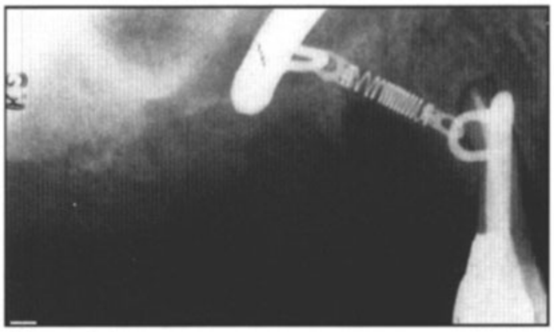
Figure 4E


Figure 4F


Figure 4G

Figure 4A-G
A: A 43-year-old patient with deep bite and severe incisor crowding.
B: Occlusal view. Right molar and second premolar were compromised periodontally and extracted. The only way to resolve crowding was to move the first premolar and canine distally.
C: Anchorage provided by an occlusal coverage splint with cast extension crossing the palate. Force system was lingual because there was no possibility of bypassing the proclined incisor.
D: Premolar displaced and force application moved to the canine. Premolar stabilized with a stiff stainless steel wire to the splint, bypassing the canine.
E: X-ray showing line of action of the force above the center of resistance.
F: Space opened and rotation of lateral incisor performed with a TMA .017x .025 wire with bypass corresponding to the lateral and a welded L-loop (.018 TMA).
G: After treatment, the premolar and canine had been moved distally to allow for alignment of the lateral incisor.

around the anchorage unit. This approach is in complete contradiction to the idea of keeping cellular activity as low as possible around the reactive unit in order to achieve maximum anchorage.

Once the force threshold has been passed, cellular activity of the periodontium is increased and tooth movement is facilitated. When retraction is initiated after anchorage preparation, the teeth of the active unit will be surrounded by a passive PDL with low cellular activity in the surrounding bone. The result is delayed tooth movement with the teeth of the anchorage unit surrounded by a highly active PDL. From a biological point of view it is advisable to enhance cellular activity around the teeth to be moved but not around the anchorage unit, which should be kept passive.

One approach to enhance anchorage is to increase the rigidity of the arches inserted in the reactive unit. Transpalatal and lingual arches have been recommended[24,25] for this purpose. The insertion of a rigid arch can be the final step following leveling, gradually replacing elastic wires with larger and more rigid wires. This approach would be undesirable if maximum anchorage is required. However, it is impossible to bend a rigid wire completely passively, and even minor activations may stimulate the PDL and facilitate anchorage loss. There are two ways to avoid this: Either adapt the wire on the study

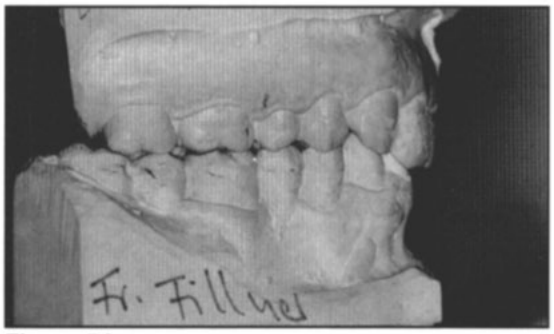

Figure 5A

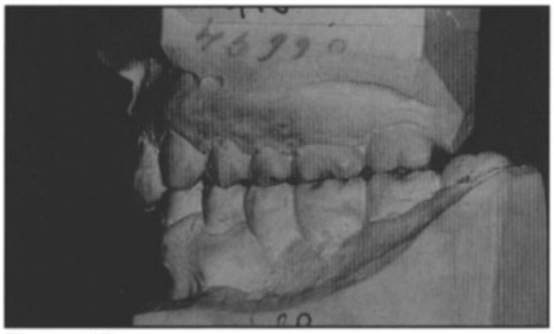

Figure 5B

Figure 5C

Figure 5D

Figure 5E

Figure 5F

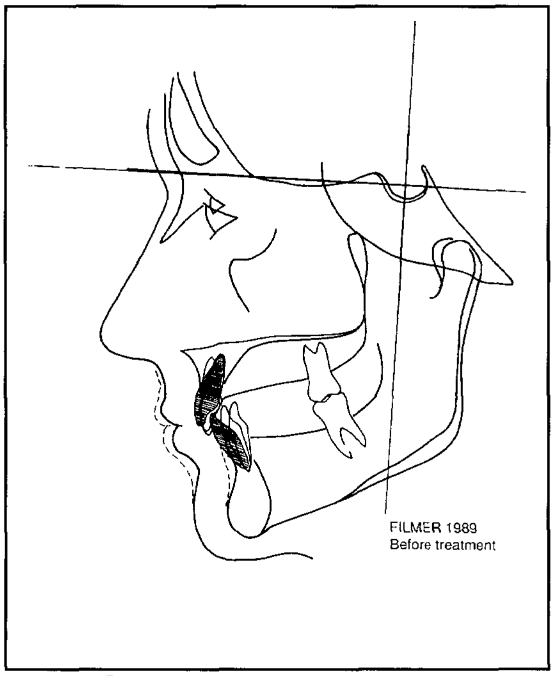

Figure 5G

Figure 5A-G
A: Mounted study casts of patient with severe deep bite and gingival impingement. The patient is bruxing.
B: Rigid anchorage system in a patient with deep bite and bridges in the mandibular molar and premolar regions.
C: Mandibular anchorage system consisting of two splint segments connected by a lingual bar, adapted for maximum occlusion. The active unit comprised four incisors consolidated with a wire bonded to the lingual surface. Intrusion could be initiated in the mandible before it was possible to place brackets. The other active unit included two canines that had to be intruded and tipped mesially. The appliance comprised a base arch generating intrusion and proclination of the anterior teeth and two cantilevers acting on the canines. In the maxilla, incisors were connected with a wire bonded to the lingual and a base arch for intrusion.
D: Occlusal view showing two lateral units connected by a rigid semicircular bar.
E-F: Posttreatment occlusion.
G: Tracing showing the changes that occurred during treatment. No anchorage loss could be verified.

cast and tie the brackets directly to the wire before bonding them as a unit, or weld the wire directly to baseplates for brackets (Figures 1 and 2). The latter procedure can be recommended if no later leveling or intra-arch movement is desirable.

Occlusion as part of anchorage

Increased rigidity of the anchorage unit might be obtained if the transpalatal arch is replaced by a so-called "iron cross," which ensures total control of the transverse dimension and maximum anchorage in the maxilla. This very efficient appliance is often used in adult patients and consists of bilateral occlusal splints connected transpalatally with an iron cross with imbedded molar tubes to provide rigid anchorage. The splints can be used with or without occlusal coverage and can be cast in metal[26] or produced in thermo-formable[27] or light-cured acrylic (Figures 3 to 5). One advantage of this type of anchorage is that it can be adapted for maximal

Figure 6A

Figure 6B

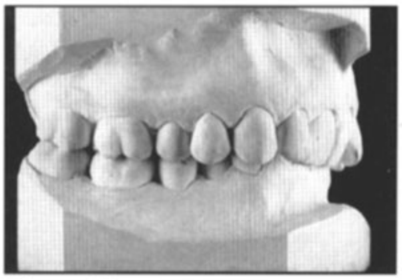

Figure 6C

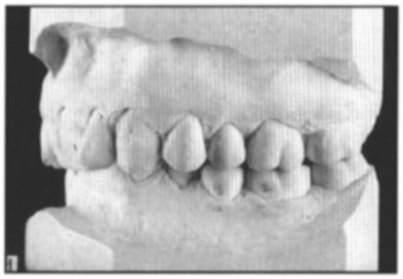

Figure 6D

Figure 6E

Figure 6F

Figure 6G

Figure 6H

intercuspidation and thereby stimulate occlusion. An additional advantage of the splints is that they can include edentulous areas and therefore allow for the occlusion of teeth that have no opponent to be included as anchorage. The efficiency of this type of anchorage is demonstrated in the cases shown (Figures 3, 5, and 6).

The impact of occlusion on anchorage has received limited attention. The sense of occlusion might be lost during orthodontic treatment. When the teeth start drifting or even tipping distally, the sense of occlusion is disturbed and occlusal forces are subsequently reduced. When the inclination of the occlusal plane is increased, occlusal forces are reduced and the loss of anchorage occurs more easily due to the posterior rotation of the mandible. Even a slight shift in occlusion does not occur without a change in the sense of occlusion and, the sensation of premature contact reduces the occlusal force level.

The first to perceive whether the occlusion is disturbed is the patient who can sense minor occlusal changes. If this is the case, it is time to change the force system or lower the force level. By building up the occlusion before treatment either with onlays or splints, occlusal forces are also stimulated and patients should be encouraged to chew and, if necessary, exercise to simulate chewing. The use of chewing gum has previously been recommended in the treatment of open bite and could play a role in vertical anchorage control.

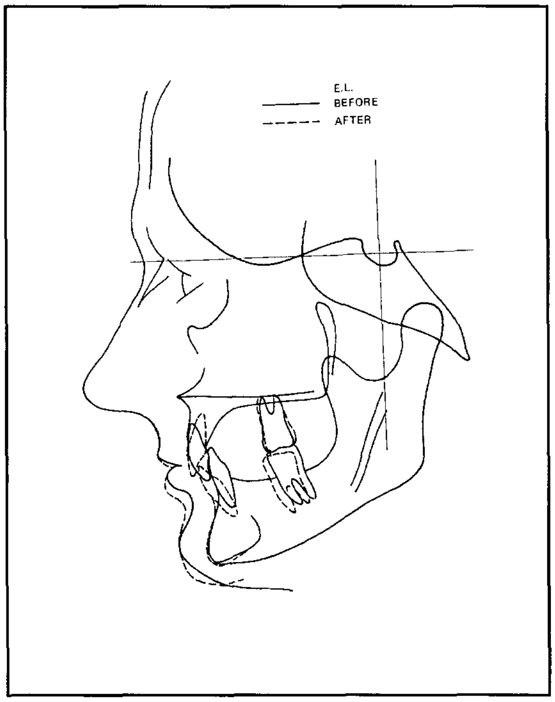

Figure 6I

Figure 6A-I
A-B: Extraoral view of a patient with a severe deep bite and a gummy smile.
C-D: Study casts revealing 1/2 cusp width distal molar and 1 cusp width distal canine relationship. Treatment consisted of intrusion and proclination of upper incisors and protraction of lower incisors. The segmented arch approach was applied.
E-F: Extraoral view after treatment.
G-H: Treatment result intraorally.
I: Tracing demonstrating that the treatment did not result in any extrusion. The mandible was displaced forward 1 mm when the bite was opened. This contributed to the correction of the Class II relationship.

Conclusions

In patients whose treatment results depend on maximum anchorage, mobility of the posterior unit before space closure should be avoided. The present paper focuses on the biological basis for anchorage and shows how an appliance with maximum rigidity combined with self-monitoring the sense of occlusion can ensure the maintenance of anchorage.

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