The interaction between reaction forces and stabilization systems during intrusion of the anterior teeth and its effect on the posterior unit

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SUMMARY  The aim of this research is to attain a better understanding of the initial reaction forces induced by an intrusion mechanism (acting on the anterior teeth) on the posterior unit and to examine how these forces can be neutralized.

The experiments were performed on the dentition of a dry human skull and initial tooth displacements were registered by means of two laser measuring techniques, namely holographic interferometry and the laser reflection technique. It was established that of all reaction forces induced by the intrusion arch, distal tipping of the first molars is the most pronounced. A transpalatal bar connecting the teeth does not counteract this movement. The stabilization of the posterior unit with a transpalatal bar, buccal sectionals, and high-pull headgear proved to be the most effective technique.

Introduction

The success of orthodontic treatment often depends on the control of reaction forces because the universal law of action and reaction should always be taken into account. In most cases, reaction forces are undesirable and specific measures have to be taken to intercept and neutralize their effects. This is also the case during intrusion of anterior teeth. The intrusion mechanism used is the segmented arch described by Burstone in 1977. The reaction forces, generated by the anterior unit during intrusion, have to be neutralized by the posterior unit. When only the first molars in the posterior unit are affected, the reaction forces will subject them to extrusion and distal tipping (Fig. 1). A palatal tipping movement can also be expected because the reaction forces act on the buccal side of the centre of resistance of the molars (Fig. 2). These displacements have to be avoided for two reasons: first, by losing anchorage the desired intrusion forces will partly be dissipated; and secondly, extrusion and distal tipping of the molars have a bite-opening effect which results in lengthening of the face and a posterior rotation of the mandible.

Different methods can be used to reinforce the posterior unit. A palatal bar together with sectionals and the application of high-pull headgear normally prevent these unwanted side effects.

This experiment was set up to gain an insight into the initial reaction forces induced by an activated intrusion arch and to determine the best way to neutralize their adverse effects.

Materials and methods

The tests were carried out on the dentition of a dry human skull, carefully chosen for its symmetric upper dental arch. It had 18 intact and well aligned teeth. The sutures between the maxilla and the surrounding bones had almost entirely fused. The teeth were cautiously extracted from their sockets and then fixed again with Araldite CY-208 to which a catalyst (HY-956) was added in a 1/10 proportion. This yielded an elastic modulus of 60 kg/cm² approaching the properties of the periodontal membrane (Dijkman, 1969). A thixotropic gel as a substitute for the periodontal ligament (Parfitt, 1960; Picton, 1978; Kardos, 1980) could not be used because of problems with the adhesion to the bone and after repeated loadings structural changes occurred in the gel.

The approximal contact points between the...
of the holographic fringe patterns. For the lateral registrations, markers were fixed to the buccal cusps of the teeth, perpendicular to the occlusal plane.

After this preparation, the skull was immersed in hard stone of a minimum expansion coefficient and placed on a solid support. The cranium was encased as deeply as possible for maximum immobility while all possible care was taken to ensure that the maxillofrontal and maxillozygomatic sutures were kept free. The support was arranged in such a way that the skull could still be rotated by over 90° (Fig. 4a,b), which allowed palatal as well as frontal and lateral registrations with both measuring techniques.

The intrusive arch was bent in such a way that after insertion in the molar tubes, the anterior part (in passive condition) was at the level where the labial sulcus was presumed to be (Fig. 5a). A pulley mechanism activated by deadweights of 50, 100, and 200 g, was used to apply traction on the anterior arch (Fig. 5b), thus simulating intrusion forces. Other set-ups simulated headgear forces.

This construction and the optical measuring instruments were placed on a vibration-free table. The experiment consisted of applying a given force to the intrusion arch and observing the subsequent initial effect on the teeth in the posterior unit. The initial displacements were so small that they could not be registered with conventional techniques. Two techniques based on laser light were used, namely the 'double
Figure 4 (a, b) The support allows the skull to be rotated over 90° (a and b) allowing frontal, palatal and lateral registrations, with both measuring techniques.

exposure' holographic technique and the laser technique (Burstone et al., 1978; Burstone and Pryputniewicz, 1980; Dermaut & Beerden, 1981; Dermaut et al., 1986; Duterloo, 1985; Kragt, 1981; Pavlin, 1984; Ryden et al., 1975, 1982; Wedendal and Bjelkhagen, 1974). Both techniques have their advantages and disadvantages, but complement each other in our experiment. A more detailed explanation and interpretation of the results is given in two recent papers by Van den Bulcke et al. (1986, 1987). In these papers the effects of intrusion forces on the anterior teeth and the localization of the centre of resistance of different anterior units are studied with the help of both measuring techniques.

Analysis of the results

For each different arrangement of the stabilization system of the posterior unit, holographic registrations as well as laser reflection measurements were made. The holographic exposures
Figure 5  (a) The intrusion arch in passive condition is at the presumed level of the labial sulcus. (b) The intrusion arch in activated condition.

give a visual picture of the reaction movements of the teeth and as a rule of thumb they may be interpreted as follows: the more fringes there are, the more substantial the displacement. The rotation axis is parallel to the direction of the fringes. It cannot be established whether the movement is towards or away from the observer.

The laser reflection method yields numerical data enabling the quantification and subsequent comparison of both the magnitude and direction of the reaction movements. It is also possible to distinguish mesial from distal and buccal from palatal movement; this is not the case with the holographic exposures. Palatal registrations give information about movements in the mesial–distal and palatal–buccal directions, lateral registrations about movements in the palatal–buccal direction and axial rotations.

The discussion of the results is limited to the presentation of the holographic pictures. The tables providing the laser reflection measurements are not included. When magnitude and direction of the displacements are mentioned in our analysis, this refers to the laser reflection results.

The posterior unit consists of the first molars (Fig. 6, H1–H4)

Figure 6/H1 (palatal registration): intrusive loading, 50 g. Only one fringe, perpendicular to the mesio-distal axis of the teeth, appears on the aluminium markers of the first molars. This is a very small movement. Taking into account the laser reflection results, it can without doubt be categorized as a distal tipping.

Figure 6/H2 (palatal registration): intrusive loading, 100 g. The first molars undergo a purely distal tipping, but the movement is considerably greater in comparison with the first registration.

Figure 6/H3 (palatal registration): intrusive loading, 200 g. The direction of the fringes shows almost no change. Distal tipping, however, is of an appreciably greater magnitude.

Figure 6/H4 (lateral registration): intrusive loading, 200 g. (With smaller loadings of 50 and 100 g no measurable displacement occurred.) The first molar (taking into account the laser reflection results) was subjected to slight palatal tipping and disto-buccal rotation; the buccal component is more predominant than the palatal component.

Conclusion. During intrusion of the anterior teeth, the reaction forces bring about a purely distal tipping of the first molars. The tipping is minimal with intrusion forces of approximately 50 g, but progressively increases with higher loadings, even becoming quite large with a force of about 200 g. In addition, a small palatal tipping and disto-buccal torsion can be observed.

The posterior unit consists of the first molars interlocked with a palatal bar (Fig. 6/H5–H6)

Figure 6/H5 (palatal registration): intrusive loading, 100 g. The first molars only undergo distal tipping. The holographic picture is almost the same as in Fig. 6/H2.

Figure 6/H6 (lateral registration): intrusive loading, 200 g. First a test with a loading of 100 g was carried out, but gave no fringe pattern. With the higher loading of 200 g only one fringe was observed on the markers of the first molars. In other words, there is barely any movement in the two directions (axial torque and bucco-palatal tipping) under investigation.

Conclusion. When comparing holograms H2,
Figure 6  (H1–H4) The posterior unit includes the first molars. Palatal (Fig. H1, H2, H3) and lateral (Fig. H4) holographic registrations. The intrusive loading runs up from 50 to 200 g. (H5–H6) The posterior unit includes the first molars connected with a transpalatal bar. H5: palatal registration—intrusive loading, 100 g. H6: lateral registration—intrusive loading, 200 g. (H7–H10) The posterior unit is composed of the second premolar, first and second molars connected with a sectional. H7: palatal registration—intrusive loading, 50 g. H8: palatal registration—intrusive loading, 100 g. H9: palatal registration—intrusive loading, 200 g. H10: lateral registration—intrusive loading, 200 g. (H11) The posterior unit is composed of the second premolar, first and second molars connected with a sectional. A transpalatal bar reinforces the unit. Intrusive loading, 100 g. (H12–H17) The posterior unit includes the first molars and is reinforced with a highpull headgear. H12: Palatal registration—intrusive loading, 0; headgear loading, 2 × 150 g.
H4, H5, and H6, the transpalatal bar seems to have neutralized the small palatal tipping movements and the axial torque, but does not have any effect on the distal tipping of the molars.

The posterior unit consists of the second premolar and the first and second molars connected with a sectional (Fig. 6/H7-H10).

The sectional was made of a stainless steel wire which measured 0.18 x 0.25.

Figure 6/H7 (palatal registration): intrusive loading, 50 g. Only the first molars receive the reaction forces. This hologram is quite similar to hologram H1: a small distal tipping has occurred.

Figure 6/H8 (palatal registration): intrusive loading, 100 g. The second premolars and second molars show one fringe, the first molars three fringes. The reaction forces are unevenly distributed over the six teeth; the first molars receive the larger part of the reaction forces. The distance between the fringes is somewhat larger than in hologram H2. This indicates a small decrease in distal tipping.

Figure 6/H9 (palatal registration): intrusive loading, 200 g. Distal tipping of all connected teeth is obvious, but the first molar shows the most pronounced movement.

Figure 6/H10 (lateral registration): intrusive loading, 200 g. This figure provides a lateral view of the same set-up as in hologram H9. The second premolar and the first molar undergo a very small distobuccal rotation. When loading 100 g, no fringes were observed.
REACTIONS TO INTRUSION

Conclusion. The reinforcement of the side parts of the posterior unit with sectionals results in a distribution of the reaction forces over the connected teeth. The first molars though are most affected.

When comparing holograms H3 and H9, distal tipping of the first molars seems to have decreased: there is a reduction from 8 to 5 fringes. It is noteworthy that this decrease is distributed over the second premolar and second molar. A comparison of the lateral registrations H4 and H10 shows quite clearly that palatal tipping and axial torque of the first molars have also decreased.

The posterior unit includes the second premolar and the first and second molars connected with a sectional; a transpalatal bar reinforces the unit.

Figure 6/H11 (palatal registration): intrusive loading, 100 g. In comparison with hologram H8, in which the teeth in both side parts are connected with a sectional, but not with a transpalatal bar, it is obvious that the insertion of the bar has only a small effect on the distal tipping of the teeth. Axial torsion and bucco-palatal tipping were not examined; the absence of fringes in setup H6 with a loading of 100 g, made this measurement superfluous.

The posterior unit consists of the first molars in combination with high-pull headgear (Fig. 6/H12–H17)

The type of headgear used in this experiment more or less conforms to the headgear used in clinical treatment. It has a traction direction at 60° with respect to the occlusal plane, and application points on the outer bows at the level of the interproximal space of the first and second premolars. It is obvious that changing the length of the outer bows also changes the direction of traction and has a corresponding effect on the molars. The observation of this parameter, however, was beyond the scope of this study. In order to prevent fractures or bending in the sutures the loading of the headgear never exceeded 300 g.

As shown in holograms H12 and H13 the use of high-pull headgear results in buccal tipping of the first molars because the attachments in the molar tubes are at some distance from the centre of resistance of the teeth.

Figure 6/H12 (palatal registration): headgear loading, 2 × 150 g; intrusive loading, 0. The use of headgear on the first molars (taking into account the laser reflection measurements) results in mesial and buccal tipping.

Figure 6/H13 (lateral registration): headgear loading, 2 × 150 g; intrusive loading, 0. This is a lateral view, the conditions are the same as in hologram H12. Buccal tipping of the first molar is confirmed. In addition, a mesiobuccal torsion can be observed; the buccal component is predominant over the axial rotation.

Figure 6/H14 (palatal registration): headgear loading, 2 × 100 g; intrusive loading, 100 g. The intrusion arch brings about distal tipping of the first molars which is only partly neutralized by slight mesial tipping due to the headgear force (see hologram H12). The slight palatal tipping induced by the intrusion arch is overcompensated by the buccal tipping resulting from the insertion of the headgear in the buccal tubes.

Figure 6/H15 (palatal registration): headgear loading, 2 × 150 g; intrusive loading, 100 g. This is a lateral view; the conditions are the same as in hologram H14. The only difference is that the headgear force has been increased to approximate the clinical situation. Distal tipping has somewhat decreased. This can be explained by the fact that mesial tipping due to the headgear force has slightly increased too. The net result is a decrease in the distal tipping of the molars.

However, by increasing the headgear force, buccal tipping underwent a drastic change. During clinical treatment even higher forces are applied. It can, therefore, be presumed that the effect on buccal tipping is even more pronounced.

Figure 6/H16 (lateral registration): headgear loading, 2 × 100 g; intrusive loading, 100 g. This is a lateral view of the same set-up as shown in hologram H15. Buccal tipping is confirmed. There are no axial torques.

Figure 6/H17 (palatal registration): headgear loading, 2 × 100 g; intrusive loading, 200 g. The expectation that by increasing the intrusion force, palatal tipping would also increase, is not borne out. Buccal tipping induced by the headgear is preponderant. However, strong distal tipping of the first molars can be observed. When hologram H3 (intrusion force 100 g, no headgear) is compared with hologram H17, distal tipping seems to be somewhat larger in the first
The use of headgear has, therefore, a slightly neutralizing effect in this direction.

The posterior unit includes the first molars in combination with a transpalatal bar and headgear (Fig. 6/H18–19)

Figure 6/H18 (lateral registration): headgear loading, $2 \times 150$ g; intrusive loading, 0. This set-up differs from hologram H13 in only one respect: a transpalatal bar, connecting the two first molars, has been added. Buccal tipping and axial rotation are less pronounced than in H13 (fewer fringes), but the ratio of both movements remains the same. The direction of the fringes is the same in H13 as in H18. The transpalatal bar has an intercepting effect.

Figure 6/H19 (palatal registration): headgear loading, $2 \times 100$ g; intrusive loading, 100 g. It can be observed that the fringe patterns on the right and left first molars are not symmetrical (although this was the case with the laser reflection results). When interpreting the pattern on the 26, it can be observed that in comparison with hologram H14 (same loading conditions, but no transpalatal bar), buccal tipping of the first molar has decreased.

The posterior unit consists of the second premolar and the first and second molars connected with a sectional; headgear and transpalatal bar reinforce the unit.

In these series of experiments, intrusive loading was limited to 100 g and headgear loading to $2 \times 150$ g.

Figure 6/H20 (palatal registration): headgear loading, $2 \times 150$ g; intrusive loading, 100 g. There are remarkably few fringes. This means that there are only small movements and that the reinforced posterior unit accommodates the reaction forces very effectively.

The tilted direction of the fringe patterns on the first molars still indicates slight buccal tipping. When comparing holograms H2, H5, H8, and H11 with hologram H14, it is obvious that a posterior unit arranged as in this experiment is the best way to neutralize the reaction forces generated by the intrusion arch.

The experiments show that palatal tipping of the first molars is small and less than expected, even with an intrusive loading of 200 g. The influence of the headgear is predominant and induces important buccal tipping of the first molars; it even overcompensates the palatal tipping brought about by the intrusion arch (as long as the intrusive forces are not too strong). The insertion of a transpalatal bar in the molar tubes made it possible to intercept the greater part of the reaction forces, but in our tests the headgear force did not exceed $2 \times 150$ g. Consi-
dering that in clinical treatment headgear forces of more than 400 g are applied, it can, therefore, be assumed that the buccal component of the traction force is negligible and that a transpalatal bar only partially neutralize this effect. Axial torque is on the whole unimportant.

The most important side effect of an activated intrusion arch is distal tipping of the first molars. As the direction of the axis of rotation is parallel to the transpalatal bar, it is no wonder that the introduction of the latter has very little effect on the movement. Only the mesial component of the high-pull headgear force counteracts to some extent this reaction.

As far as the mesio-distal stabilization of the posterior unit is concerned, the best result is attained by the use of sectionals, connecting the second premolar and the first and second molars.

The experiment confirmed that the best combination intercepting all reaction forces on the posterior unit is obtained by maximum anchorage, namely by means of sectionals, the insertion of a transpalatal bar between the first molars and the application of high-pull headgear. However, some distal tipping of the first molars still occurs. The shortening of the outer bows of the headgear could possibly be considered; this would mean a greater moment of force and would increase the mesial component of the headgear force, thereby counteracting the reaction forces induced by an intrusion arch.

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