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Movement evaluation of overerupted upper molars with absolute anchorage: An *in-vitro* study

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Abstract

Introduction: The overeruption of upper molars due to the premature loss of antagonist teeth can be treated with the help of miniscrews. The aim of this study was to evaluate the movement of a typodont molar according to the biomechanical approach used with miniscrews. Study design: The study was conducted with four plaster models filled with typodont wax. In each model we used one absolute anchorage on the palatal side and another on the buccal side in different positions, thus generating four different biomechanical systems. A force of 150 g was applied to each side of the resin tooth. Periapical radiographs were taken preintrusion and immediately after completion of the intrusion. Photographs were taken in both the sagittal and occlusal planes every 3 min. The radiographic films and photographs were measured and compared.
Results: A vertical movement of the molar was observed in all the models, with system 4 showing the greatest movement. Rotation in the occlusal plane only occurred in system 2, while in system 1 there was a change in the axial axis of 37 degrees.
Conclusions: The anchorage site and the combination of forces applied may determine the resulting tooth movement.

Key words: *Anchorage, miniscrews, overerupted molars, intrusion, force.*

Introduction and Literature Review

In everyday clinical practice it is common to come across upper molars that are extruded due to the premature loss of antagonist teeth. One possible solution to this would be endodontic treatment followed by the insertion of a fixed prosthesis. From the orthodontic point of view there are more conservative options which may help to solve the problem (1).The orthodontic aim would be to move the tooth to the desired position, with intrusion being the main outcome to be achieved. Various types of apparatus and ways of achieving this movement have been designed. For example, palatal bars with a spring mechanism and elastomeric chains, modified palatal bars, removable resin plates with bands, or corticotomy combined with the use of magnets (2-7). However, one of the potential undesirable effects of using conventional apparatus to obtain molar intrusion is the extrusion of adjacent teeth that act as an anchorage unit.

In this context the introduction of implants in the orofacial region has ushered in new strategies for resolving the problem of dental anchorage and undesired movements. Indeed, the use of miniscrews and miniplates has become the treatment of choice for molar intrusion (8). However, controversy remains as regards the best anatomical site for the implant and the force vector to be used. It should be taken into account that the position, number of anchorages and force units will result in different moments and forces in the three spatial planes. The need to identify a simple and effective biomechanical approach thus justifies the present research.

The specific aim of the study was to compare the movement of the resin upper molar fixed in typodont wax according to different combinations of force vectors applied with a system of absolute anchorage.

Material and Methods

Measurements were taken in four identical plaster models obtained from a patient with a complete set of definitive teeth. The plaster teeth from the first quadrant of the model were then eroded away and this area was filled with a class II-1 typodont wax (Rocky Mountain Morita Corporation®, Denver, USA). A resin, upper-left first molar (Rocky Mountain Morita Corporation®, Denver, USA) was then placed in the wax. The axial axis of this first molar formed an angle of 90º with respect to the occlusal plane that was considered as the plane of reference. The system of absolute anchorage used screws that were fixed at one of their ends. The metal bar was cemented to the model according to the forces which we proposed to apply. Traction was achieved by means of an elastic chain (Lancer,Per®dental Spain). The design of the models is shown in Figure 1.

A dynamometer was used to calculate a total force of 300 g for each system. In these models we defined a standard space for the precise location of radiographic plates.

Four biomechanical systems were included in this study, each one using a different location for absolute anchorage (representing different vectors) (Fig. 2). For each combination a molar was positioned 2 mm on the occlusal side of the reference plane. For combinations 1 and 2 we used a button at the centre of the crown on both the buccal and palatal sides. In combination 3, two buttons were cemented on each face, while in combination 4 no button was used.

On the buccal and palatal sides of combination 1 the fixed anchorage of the metal bar was positioned 2 mm mesial and 10 mm apically from the tooth, as measured from the mesial amelo-cemental junction. An elastic chain was placed on each side between the anchorage and the button, with a force of 150 g. In combination 2 the fixed anchorage was positioned 2 mm distally and 10 mm apically from the tooth on the buccal side. In contrast, on the palatal side the fixed anchorage was positioned 2 mm mesial and 10 mm apically. The chains were applied with the same force used in the previous typodont. For combination 3 the fixed anchorage was positioned 2 mm mesial and 10 mm apically on both the buccal and palatal sides. A bilateral force of 150 g was applied from the fixed anchorages. In combination 4 the hooks were positioned as in combination 2. However, here a single chain was used from the buccal to the palatal button, passing along the occlusal face of the molar and fixed to it with a drop of composite. Here the total force applied was 300 g.

The models were placed in a transparent recipient containing water at a constant temperature of 55º C throughout the experiment. In order to obtain a series of sequential images of molar movement we set up two cameras (Nikon® 4500, Tokyo, Japan), fixed on tripods, on the buccal and occlusal sides and took photographs every 3 min. Radiographs were also obtained via X-ray apparatus (Castellini® type x range 50/l, Bologna, Italy). We used X-ray film (Kodak® Ultra-speed D) with radiolucent material, over which was placed a 1-mm square metal mesh. For each system we took one initial and one final radiograph. The distance from the focus to the X-ray apparatus was 20 cm, and we used a peak kilovoltage of 65 at 10 mA and an exposure time of 0.4 s

The occlusal recordings were used to evaluate the rotation of the tooth crown, while the sagittal recordings enabled us to analyse the mesial and vertical movement of the crown and the inclination of the tooth's axial axis.

Results

The radiographic examination revealed important differences in the various types of movement of each of the systems.

Combination 1 showed the greatest mesial movement of the crown (6.5 mm) and the largest shift in the tooth's axis (37º). The greatest vertical movement was ob-

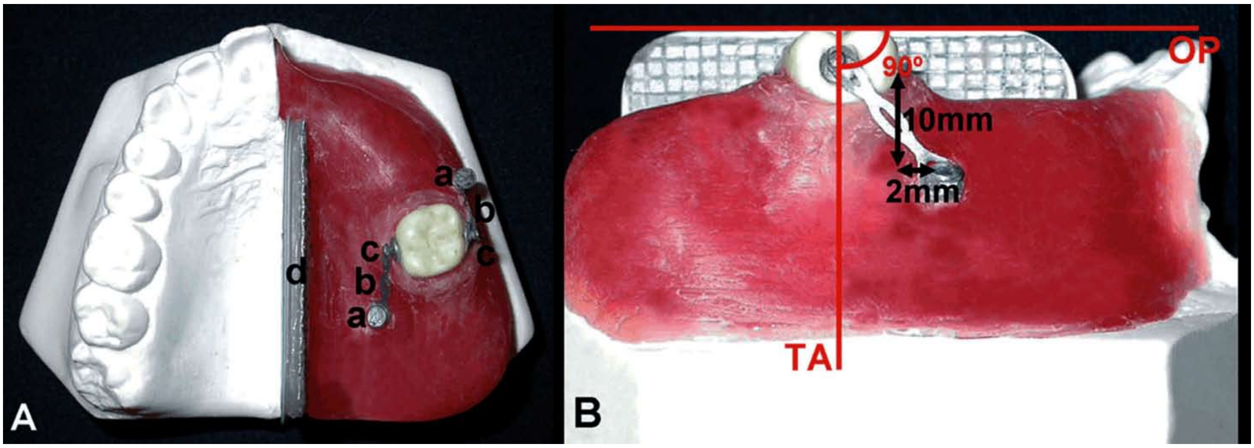


Fig. 1. Digital photographs of the models used. A, Occlusal view. Hook of the metal bar (a); Elastic chain (b); Metal button (c); Radiolucent material with metal mesh for X-ray films (d). B, Sagittal view. Inclination of the tooth's axial axis (TA) with respect to the occlusal plane (OP).

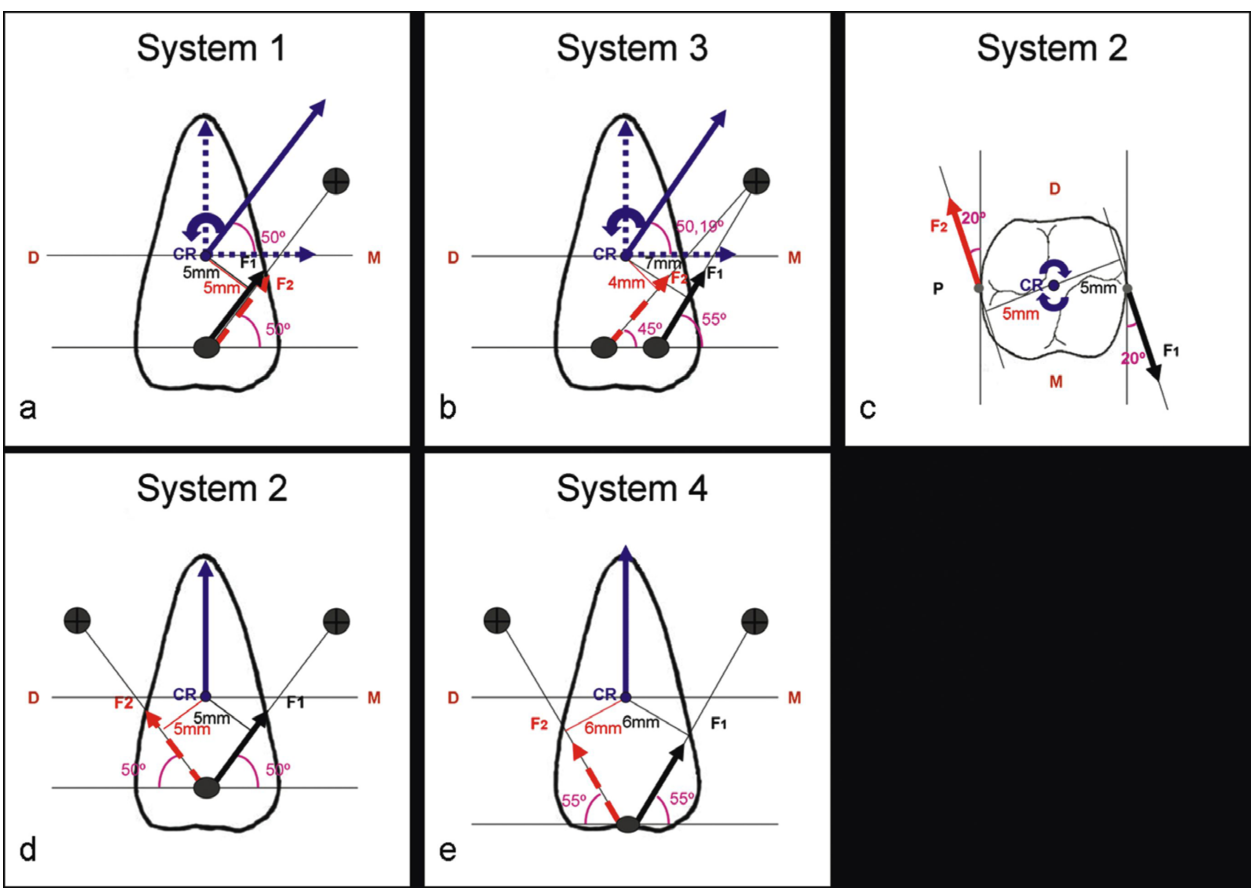


Fig. 2. A two-dimensional schematic representation of orthodontic point-forces applied away from the centre of resistance of an upper molar. The figure shows five different combinations of force systems (a), (b), (c), (d), (e), and the respective analysis of vectors. (a), (b), (d), (e), Sagittal view. (c), Occlusal view. The equivalent force system in each one of the combinations can be seen. (F1) Force of 150 g applied to the buccal side; (F2) Force of 150 g applied to the palatal side. Mesial (M); Distal (D).

served in combination 4, with a value of 5.5 mm. Rotation was only produced in combination 2, this being 32º (Table 1). Analysis of the sagittal photographs revealed a sequence of gradual molar movement (Table 1). The moment/force (M/F) relationship at the centre of resistance was evaluated in each of the systems (Table 2). All the systems were evaluated at the sagittal level with the corresponding force vectors. It should be noted that in system 2 the vectors were evaluated at the occlusal level (Table 2).

Discussion

Several authors have discussed the force applied to molars. Melsen and Fiorelli used 50 g buccolingually for intrusion movements in young adults (9), while Park et al. recommend an initial force of 200-300 g for this intrusion (1). In the present study a total force of 300 g was used to observe the continuous movement with a single application. In this way the position of the model was not altered and measurement errors were avoided.

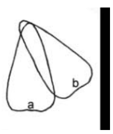
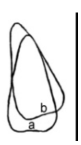
One way of treating molar extrusion due to the loss of antagonist teeth is through the use of miniscrews. Clinical studies have shown this to be a stable anchorage system for orthodontic movement (10). Several factors determine the ideal number of miniscrews. Melsen and Fiorelli suggest applying buccolingual biomechanical force to avoid the undesired inclination. One determining factor when intruding molars is the point at which the force is applied (9). This should be applied simultaneously to both buccal and palatal sides in order to direct it through the centre of resistance (11). In line with previous research the present study used two miniscrews as anchorage, one on the buccal and another on the palatal side (12).

In certain circumstances the patient's anatomy, such as in the case of a reduced interradicular space, may hinder the placement of a miniscrew, and this would require having a single area in which to insert two screws. Poggio et al., in a study using computed tomography, report that the largest space available in the maxilla is between the first molar and the second premolar. The next largest area is that between the first premolar and canine, followed by the area between the first premolar and the second premolar. The space on the palatal side is greater than that on the buccal side. For this reason most clinicians opt for a biomechanical approach in which the implants are placed on both the buccal and palatal sides between the first molar and the second premolar (13). Other factors that may determine the use of two rather than three or more miniscrews are the intraoperative time, the clinician's criterion and financial considerations (5).

In combination 1, in which both miniscrews were implanted on the mesial side of the molar, we observed mesialization of the crown, vertical movement and a shift in the axial axis (Table 1). No rotations were produced. With respect to the centre of resistance (CR) there was a mesial horizontal movement and a vertical movement. The movement expected from the analysis of this system's vectors corresponds to the results obtained. This biomechanical approach is commonly used by clinicians as the screw implantation site is a safe and easily-accessible area (13). Whether for anatomical reasons or in order to compensate excessive mesialization of the crown, some authors place one miniscrew distally on the buccal side and another mesially on the palatal side (12). The biomechanical approach used in combination 2 prevented the mesial movement of the crown and the desired vertical movement was achieved. However, the axial shift in the tooth's axis was less than in the previous combination, and there was also rotation of the crown. The rotation and vertical movement are consistent with the analysis of the system's vectors. The anatomy only enables the two miniscrews to be implanted on the same side (mesial or distal). The biomechanical approach used in combination 3 avoided undesired effects. Here, vertical movement was obtained, but this was accompanied by mesialization of the crown and a shift in the tooth's axial axis. With respect to the centre of resistance (CR) there was a mesial horizontal movement and a vertical movement. In this case there was no rotation. The movement produced was consistent with the analysis of the system's vectors. The biomechanical approach used in combination 4 achieved the greatest vertical movement, and this system also showed the least inclination. The vertical movement coincides with the analysis of the system's vectors. This may be because the force passes through the centre of resistance, as indicated in the studies by Chang et al. (11) In contrast to the other systems, in which two point-forces that did not pass through the centre of resistance were applied, system 4 consisted of a single vertical point-force passing through the tooth's longitudinal axis. Kravitz et al. argue that in this case a nickel-titanium coil can be used instead of a chain (14).

The results obtained show that undesirable effects were produced in some of the combinations. For instance, a shift in the axial axis was observed in combinations 1 and 3. In order to control the moment produced the miniscrew could be implanted in the most apical position possible. Thus, the higher the anchorage point is, the closer the passage of the force is to the centre of resistance, and more vertical movement is consequently achieved. However, this high position faces an anatomical limitation, namely the maxillary sinuses, and thus the implant must be placed as vertically as possible with respect to the cortical bone. Moreover, insertion in non-keratinized mucosa may favour periimplantitis and these factors should be taken into account when choosing the most suitable site (15).

Table I. Comparison of displacement (mm), change in direction (º) and rotation (º), measured at different planes for each combination.

	Vertical movement of RC (mm)	Horizontal movement of RC (mm)	Mesial movement of crown (mm)	Vertical movement of crown (mm)	Tooth axis change (º)	Rotation (º)
Combination 1 	4,5	2	6,5	0	37	0
Combination 2 	4	0	0	4	8	32
Combination 3 	3,5	1	4,5	3,5	26	0
Combination 4 	5	0	0	5,5	1	0

(a) Inicial position of the tooth in the systems 1,2,3 y 4.
(b) Final position of the tooth in the systems 1,2,3 y 4.

Table 2. Quantitative analysis of force (g) and moment (g.mm) values generated in the four systems shown in Fig. 1.

	Labial			Palatal			Resultants				
	F_V (g)	F_{M-D} (g)	M_L (g.mm)	F_V (g)	F_{M-D} (g)	M_P (g.mm)	F_V (g)	F_{M-D} (g)	M_S (g.mm)	M_O (g.mm)	$(M/F)_{CR}$ (mm)
System 1 (Sagital)	114,9	96,4	-750	114,9	96,4	-750	229,8	192,8	-1500	0	-5
System 2 (Sagital)	114,9	96,4	-750	114,9	-96,4	750	229,8	0	0	0	0
System 2 (Oclusal)	0	96,4	-482	0	-96,4	-482	0	0	0	-964	∞
System 3 (Sagital)	122,9	86	-950	106	106	-600	228,9	192	-1450	0	-5.2
System 4 (Sagital)	122,9	96,4	-900	122,9	-96,4	900	246	0	0	0	0

FV, Vertical force; FM-D, Mesial-distal force; ML, Labial moment; MP, Palatal moment; MS, Sagital moment; MO, Oclusal moment; (M/F)CR, Moment/force ratio in the center of resistance. Negative sagital moment indicates mesial inclination of the crown. Negative oclusal moment indicates mesial-palatal rotation of the crown. Negative mesial-distal force indicates distal direction. Only System 2 displayed oclusal actions.

The comparison of clinical and laboratory measures revealed differences between them (16). Since the present *in vitro* study analysed force vectors the results are more reliable and can be extrapolated to clinical practice. Further research is needed to provide a biological basis for this study.

Conclusions

The site in which miniscrews are placed may determine the resulting movement of the tooth. A biomechanical approach in which the force vector passes close to the centre of resistance will produce a purer translation movement. The greatest amount of vertical movement was produced with the biomechanical approach used in system 4. Rotation in the occlusal plane was only produced in system 2.

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