VRIJE UNIVERSITEIT

INTRUSION OF THE MAXILLARY INCISORS

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door

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geboren te Assen

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voor Caroline, Bas en Tom

The study described in this thesis was performed in the orthodontic practice of orthodontist Edsard van Steenbergen in Apeldoorn, The Netherlands.

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CHAPTER 1

GENERAL INTRODUCTION

This chapter contains modifications of the following publications:
van Steenbergen E, Burstone CJ, Prahl-Andersen B, Aartman IHA. The role of a high pull headgear in counteracting side effects from intrusion of the maxillary anterior segment. Angle Orthod 2004;74(4):480-486.

van Steenbergen E, Burstone CJ, Prahl-Andersen B, Aartman IHA. The influence of size of a buccal segment on prevention of side effects from incisor intrusion. In press Am J Orthod Dentofacial Orthop.

van Steenbergen E, Burstone CJ, Prahl-Andersen B, Aartman IHA. The influence of force magnitude on intrusion of the maxillary anterior segment. Angle Orthod 2005;75(5):723-729.

van Steenbergen E, Burstone CJ, Prahl-Andersen B, Aartman IHA. The relation between the point of force application and flaring of the anterior segment. Angle Orthod 2005;75(5):730-735.
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Correction of a deep overbite is often one of the major steps in orthodontic treatment. Depending on diagnosis and treatment objectives, deep overbites can be treated orthodontically by intrusion of maxillary and/or mandibular incisors, extrusion or passive eruption of buccal segments or a combination of these[1,2,3]. Flaring of incisors also decreases the vertical overbite. Intrusion of maxillary incisors is indicated in patients with excessive incisor display. In patients with an Angle Class II malocclusion hinging open of the mandible, caused by extrusion of the buccal segments, creates a more convex facial profile and increases the lower face height. Since Class II patients often have an increased facial convexity a further increase in these cases is not esthetically pleasing.

Until recently very few clinical studies have focused on intrusion[2,4,5]. Some investigations were performed in order to retrospectively compare different methods of deep overbite correction[4] with little consideration for proper randomized allocation of treatment modality[2,4]. Other reports on intrusion were based on observational studies[1], in vitro or laboratory studies[6,7] and animal studies[8,9]. Because intrusion is often the preferred way of deep overbite correction a prospective randomized clinical trial focusing on all aspects related to intrusion is needed as a scientific basis for evaluation of treatment outcome and to increase treatment efficiency. A recently published review of studies on intrusion also emphasized the need for prospective randomized clinical trials with the least number of confounding variables on adolescent samples[10]. The previously carried out studies however, give an insight into the commonly encountered side effects from incisor intrusion. To improve the application of intrusion into clinical practice it is important to critically evaluate the side effects, which have been addressed in these studies. In the next paragraphs the most common side effects and the options to reduce these will be discussed.

1. Steepening of the buccal segment is caused by the moment $M = F \times D$, in which F is the intrusive force and D is the distance from the point of force application to the center of resistance of the buccal segment. The line along which distance D is measured is perpendicular to the line of action of the intrusive force [1,2,3,11-15]. (figure 1).

Several methods have been suggested to decrease this side effect such as increasing the number of teeth included in the buccal segment, high pull headgear wear, and/or decreasing the amount of intrusive force[1,2,3,11,12,13]. Including the canine in the buccal segment does not only increase the size of the buccal segment, but also moves the center of resistance anteriorly, thereby decreasing the moment on the buccal segment[1,2,3,6,15]. A high pull headgear with a force anterior to the center of resistance counteracts the moment from the intrusion arch that causes steepening of the buccal segment[1,2,3,7,17] (figure 2). The lower the amount of intrusive force on the anterior segment, the smaller the counterclockwise moment on the buccal segment[1,2,3,4,5,7,12,13].

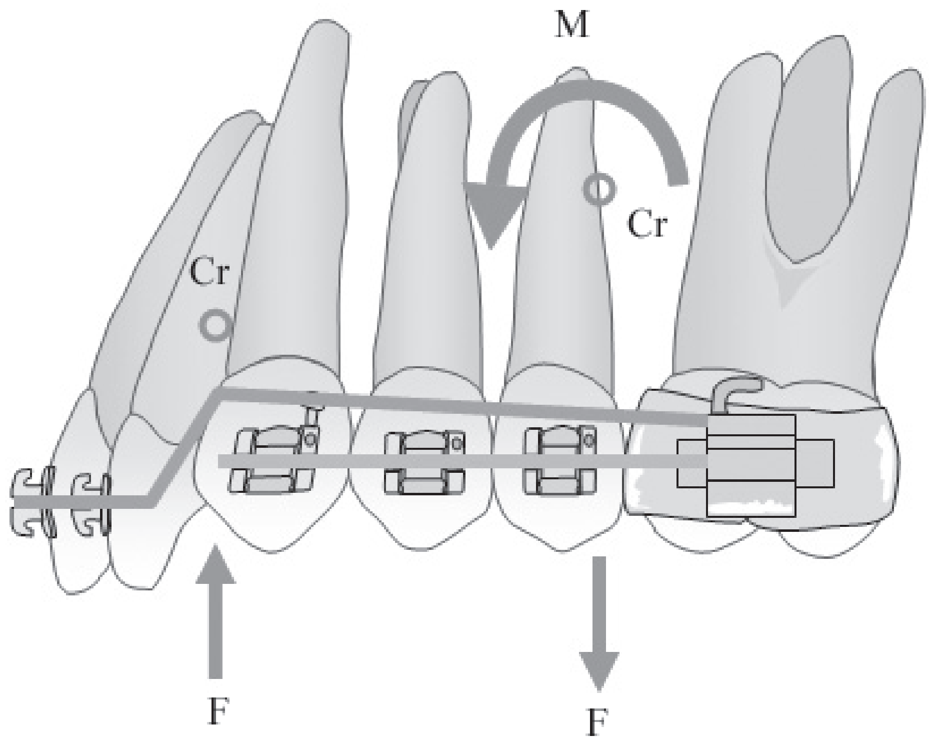

Figure 1
Force system delivered by the intrusion arch; an intrusive force on the anterior segment and an extrusive force and a counterclockwise moment on the buccal segments.

2. Extrusion of the buccal segment is caused by force F (figure 1), which is equal in magnitude, but opposite in direction to the intrusive force[1,2,3,4,7,12,13]. Extrusion of the buccal segments will hinge the mandible open. Occlusal forces in part counteract extrusion[1,2,3,12,13]. To further decrease the possibility of extrusion the clinician has the following options: keeping the intrusive force on the anterior segment as low as possible, increasing the size of the buccal segment, and counteracting the extrusive force on the buccal segment by an intrusive force delivered by a high pull headgear[1,2,3,12,13,17,18]. There are however no studies on how each option to prevent extrusion works clinically.

3. A decrease of the maxillary arch width can be caused by constricting moments in the transverse plane, which act on the buccal segments[1,2,3,12]. These moments are created by the extrusive forces on both sides, which are delivered buccal to the center of resistance of the buccal segments. Besides keeping the forces as low as possible (just enough to intrude the anterior segment), increasing the num-

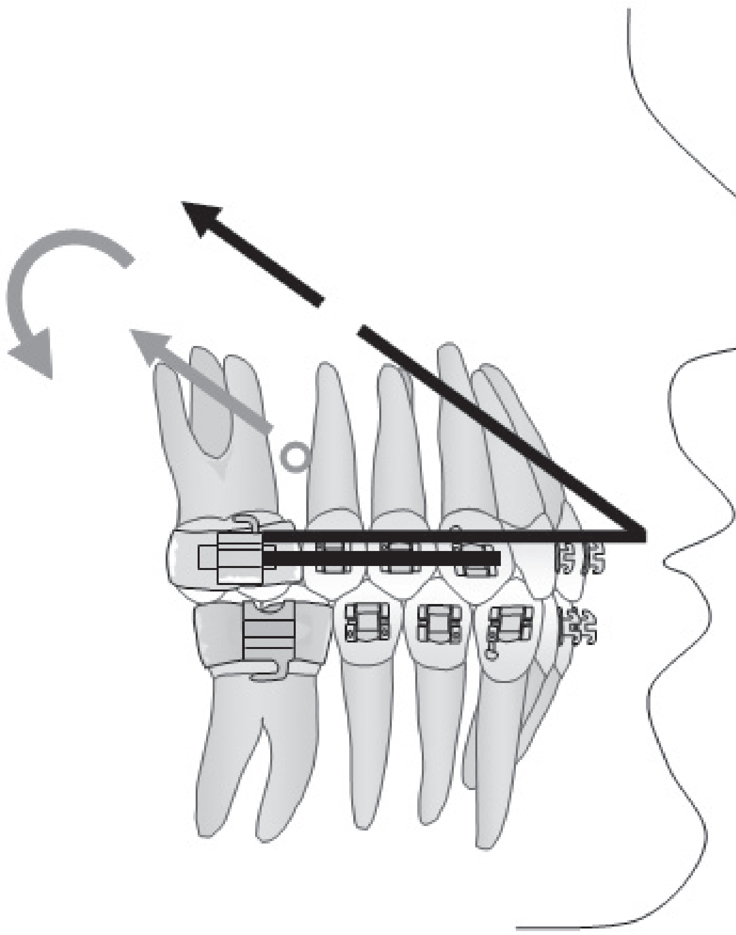

Figure 2
Force system delivered by a high pull headgear with a force above the center of resistance of the buccal segment.

ber of teeth in the buccal segment and using a high pull headgear to counteract the vertical force, the clinician can use a passive transpalatal arch to maintain the inter molar distance[19]. Besides a counteracting force and moment, a high pull headgear also provides a rigid arch of constant width. The extent to which the constricting moments influence the transverse width has not been reported in clinical studies.

4. The axial inclination of the anterior segment in the sagittal plane can be altered by selecting the location of the point of intrusive force application on the anterior segment[1,2,3,5,6,7,20]. A more anterior location of the point of force application causes flaring, whereas a more posterior location will cause uprighting of the

anterior teeth[1,2,3,5,6,7,13]. Studies on dry skulls have determined that the center of resistance for a segment of 4 maxillary incisors lies apical of a point between the distal half of the canine[6] and the distal side of the lateral incisor[7]. Therefore if an intrusion arch is attached at that point and the line of force goes through the center of resistance, the anterior segment will move bodily in apical direction.

A large fluctuation in force level increases the likelihood of side effects on the buccal segments (as described under 1,2, and 3) when the forces are too high. No movement takes place when the forces are too low, thereby decreasing efficiency. The force should be delivered at a constant and optimal level[1,3,5,21]. This requires a spring with a low load-deflection ratio, meaning a small amount of force per millimeter of activation. A low load deflection spring can be created by bending helices in a stainless steel wire or by using a material like TMA[22,23,24], which has a lower stiffness and therefore doesn't need helices. A low load-deflection rate also makes the amount of activation by the clinician less critical and decreases the need for frequent reactivations. The recommended force level has been reported as low as 5 grams per tooth in patients with decreased periodontal attachment[5]. Commonly 10-20 grams of force is advocated for maxillary incisor intrusion[1,2,3,4]. This recommendation is based on clinical experience. A comparison of the effects of different force levels would be meaningful in creating a more efficient approach toward intrusion. It is important to investigate which amount of force intrudes incisors most efficiently, meaning as fast as possible with the least amount of side effects.

The segments should be as rigid as possible to minimize side effects from wire deformation and to evenly distribute the moment and forces over the buccal segment as an unit[1,2,3,12,14].

In order to be able to calculate the magnitude of the moments and forces delivered, the force system should be determinate[1,3,12,13,25]. Therefore the intrusive force has to be delivered through a point contact to the anterior segment. This can be achieved by tying the intrusion arch in a piggyback fashion onto the anterior segment[1,2,3]. When the axial inclination of the anterior segment is normal, the intrusion arch is tied to a point as far distal as possible on the anterior segment in order to have the line of force as close to the center of resistance of the anterior segment as possible (as described under 4). The distal wings of the lateral incisor brackets are the most distal points of the anterior segment.

This study focussed on correction of deep overbite by intrusion of maxillary central and lateral incisors and evaluated various options to decrease side effects and thereby increase treatment efficiency.

The purpose of the present study is to determine if:

1. High pull headgear wear has an effect on steepening, extrusion, and narrowing of the buccal segments and the rate of incisor intrusion.
2. The size of the buccal segment influences the amount of steepening, extrusion and narrowing of the buccal segments and the rate of intrusion.

3. The intrusive force level influences the amount of steepening, extrusion and narrowing of the buccal segments and the rate of intrusion.
4. In patients with a normal axial inclination (within two standard deviations) of the anterior segment, application of an intrusive force at the distal wings of the lateral incisor brackets causes a change in axial inclination of that segment.

In this study only side effects from a biomechanical point of view will be addressed. The design of the study is as follows: 40 patients needing maxillary incisor intrusion were recruited. All patients were randomly assigned to one of 4 groups. In group 1 incisors were intruded with 10 grams of force per tooth, the buccal segment extended from canine to first molar and patients wore a high pull headgear at night. In group 2 the intrusive force and buccal segments were the same as in group 1, but no headgear was used. In group 3 the intrusive force was the same as in groups 1 and 2, but the buccal segment consisted only of the maxillary first molar. In group 4 the intrusive force was 20 grams per tooth, the buccal segment was the same as in groups 1 and 2. Records were taken before the start of intrusion and after intrusion was performed. No other form of treatment was performed in the mean time.

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CHAPTER 2

THE ROLE OF A HIGH PULL HEADGEAR IN COUNTERACTING SIDE EFFECTS FROM INTRUSION OF THE MAXILLARY ANTERIOR SEGMENT

This chapter is a modification of the following publication:
van Steenbergen E, Burstone CJ, Prahl-Andersen B, Aartman IHA. The role of a high pull headgear in counteracting side effects from intrusion of the maxillary anterior segment. Angle Orthod 2004;74(4):480-486.
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Introduction

This part of the study focused on correction of deep overbite by intrusion of maxillary central and lateral incisors with a one-piece intrusion arch[1-6] and evaluated if a high pull headgear can decrease side effects and thereby increase efficiency[7-9].

The purpose of the present study was to determine if high pull headgear wear had an effect on steepening, extrusion, and narrowing of the buccal segments and the rate of incisor intrusion.

In order to make orthodontic treatment more efficient, intrusion is often combined with alignment[1,4,5]. In this study, however, the primary focus was on side effects caused by intrusion. Therefore it was decided to perform intrusion after alignment of buccal as well as anterior segments.

Null hypothesis:

High pull headgear has no effect on steepening, extrusion and narrowing of the buccal segments nor on the rate of incisor intrusion.

Materials and methods

To evaluate the effect of the use of a high pull headgear on steepening, extrusion, and narrowing of the buccal segments and on the rate of incisor intrusion, two treatment groups were compared: one group of 10 patients in which no headgear is worn (group 1) and another group of 10 patients in which a high pull headgear with a force anterior to the center of resistance was worn at night (for 8 hours per day) (group 2).

<u>Size of the clinical trial</u>

The main purpose of this study was to determine the importance of a high pull headgear in counteracting side effects from the intrusion arch. The chance of success of preventing side effects using the high pull headgear was estimated to be 90% and the chance of success not using it 10%.

Using the formula

$$n= \frac{p_1 \times (100- p_1) + p_2 \times (100 - p_2)}{p_1 - p_2} f(\alpha,\beta)^{10}$$

the number of patients per group was calculated to be 10. The significance level a was set at 0,05. The power, 1-b, was set at 0,90. According to these assumptions 10 patients were required in each group, adding to a total of 20 patients.

<u>Sample</u>

Twenty orthodontic patients between the ages of 10 and 15 years and needing maxillary central and lateral incisor intrusion of at least two millimeters were recruited for this study from all patients referred to the principal investigator's practice. Treatment was performed by this orthodontist only. Patients included in the sample had at least maxillary first molars, first and second premolars, canines and all maxillary incisors present and fully erupted and were adolescents. Patients with extremely flared or upright (such as in Class II division 2 patients) incisors were excluded as well as patients with periodontal disease. Patients with crowding to the extent that they need extractions in order to perform alignment were also excluded. No other forms of orthodontic treatment were performed in these patients during the period of maxillary incisor intrusion. All patients willing to participate in this study were included in the sample if they met the above mentioned requirements. The group was subdivided into two subgroups. Assignment of patients to each of the 2 subgroups was performed by simple randomization[10].

Records

One lateral cephalometric x-ray and one set of impressions with a wax bite in centric occlusion was taken of each patient at the start of intrusion and when intrusion of the maxillary 4 incisors was completed. The lateral cephs were taken with the aid of a cephalostat by the principal investigator. The patient's head position in the cephalostat was documented, so that pre- and post intrusion cephs were taken with the patient's head in the same location. In order to distinguish the patients right and left side a ligature wire was tied around the right canine bracket in such a way that it was clearly visible on the lateral ceph. Impressions were poured in plaster and trimmed in centric occlusion.

Measurements

Lateral cephs were traced on a computer screen[11-14]. From each set of lateral cephs a maxillary superimposition (structural) was made[13]. The tracings were digitized and analyses performed by computer[14]. The following measurements were performed:

1. Vertical movement of the center of resistance of the maxillary central incisor (indicating the amount of intrusion); vertical means perpendicular to the palatal plane (the line connecting the anterior (ANS) and posterior nasal spine (PNS)
2. Change in axial inclination of the buccal segment
3. Vertical movement of the buccal segment
4. Change in inter molar width, measured on the models
5. Rate of intrusion, expressed in millimeters per week

Treatment protocol

Patients were recruited after explanation of the treatment plan by orthodontist. First bands and brackets (0.022" x 0.028" slot) were placed and segments aligned. Alignment was performed in segments, the anterior segment extending from right to left lateral incisor and the buccal segment from canine to first molar, while controlling vertical forces as much as possible[1,9,10]. When the wire segments were 0.018" x 0.025" stainless steel and passive, one lateral ceph, 5 intra-oral photographs (one frontal, two buccal, and 2 occlusal photographs), and one set of impressions with a wax bite in centric occlusion were taken. In order to be certain that the segments were passive, they were left in place for 5 weeks after insertion, before records were taken and intrusion was started. At the same visit the intrusion arch was placed with a force level of 40 grams measured in the midline (20 grams per side). The clockwise moment produced by the extrusive force on the buccal segment was approximately 600 gram millimeter (gmm) per side, when the distance from the point of force application in the anterior segment to the center of resistance of the buccal segment was 30 mm and the intrusive force 20 grams per side. This moment acts 24 hours per day adding to 14400 gram millimeter hours (gmmh).

The extrusive force on the buccal segment produced by an intrusion arch that delivers 40 grams of force in the midline was 20 grams per buccal segment. This force was delivered 24 hours per day, adding to 480 gramhours (gh). It was most important to prevent steepening of the buccal segment by using a high pull headgear at night with a force anterior to the center of resistance of the buccal segment. To fully counteract the clockwise moment delivered by the intrusion arch a counterclockwise moment of 1800 gmm. was needed during 8 hours[15] (8 h times 1800 gmm = 14400 gmmh).

In this study the moment delivered to the buccal segment in each patient was calculated from the original headplate by multiplying the intrusive force by the distance from the point of force application at the anterior segment to the center of resistance of the buccal segment perpendicular to the line of force[1,4,8,15]. A mark was made on the headgear so it delivered 200 grams of force per side and could easily be checked and when necessary adjusted by the patient or parent. The force was assumed to be delivered at 45 degrees to the occlusal plane. In each patient the outer bow was bent in such a way that the moment delivered by the headgear was three times the moment delivered by the intrusion arch and in opposite direction. The amount of gramhours on the buccal segment would therefore be zero.

The distance from the buccal cusp tips to the center of resistance of the buccal segment was measured on the original ceph. The distance from the cusp tips to the buccal tube was measured in directly in the mouth. Utilizing these measurements the facebow was bent upwards to the extent, that the line of force (with a magnitude of 200 g) was 9 mm above the center of resistance in order to deliver the desired moment of 1800 gmm. The outer bow extended as far distally as the inner bow.

If it was assumed that the line of force was at 45 degrees to the occlusal plane, an intrusive force of 141 g. (200 times the sine of 45 degrees) acted on the buccal segment while the headgear was worn, adding to 1131 gh (8h times 141.42 g).

This results in a net intrusive force on the buccal segment (480 gh extrusive force minus 1131 gh intrusive force). In this clinical trial the decision was made that it was important to fully counteract the clockwise moment delivered to the buccal segment by the intrusion arch.

Visits were scheduled every 5 weeks. During each visit the intrusive force and headgear force were measured, recorded, and, when necessary, adjusted to the proper level. When the incisors were intruded to the proper level, the intrusion arch was removed and a lateral ceph, impressions, and wax bite were taken. The same actions were undertaken when side effects were clearly present. Loose bands and brackets were recorded and replaced in a manner that the segment remained passive.

Results

To test the null hypothesis an ANOVA for repeated measures was used (General Linear Models ; GLM procedure in SPSS 10). GLM's are Analyses of Variance for repeated measures. In the following paragraphs the results of the different analyses are presented.

Vertical movement of the center of resistance of the maxillary central incisor (indicating the amount of intrusion) is shown in Table 1.

Table 1

Group	Start (SD)	Finish (SD)	Difference (SD)
No headgear	10.44 (1.45)	8.20 (1.75)	2.24 (0.53)
Headgear	10.49 (3.04)	8.12 (2.68)	2.37 (0.86)

The mean vertical distance in millimeters of the center of resistance of the maxillary central incisor to the palatal plane is shown in the start and finish columns. The difference indicates the amount of intrusion (vertical movement of the center of resistance). The standard deviations are in parentheses.

The intrusion was statistically significant in both groups, $F_{1,18}$ = 179,007 and p = 0,000, but the difference in intrusion between the headgear and no headgear groups was not statistically significant, $F_{1,18}$ = 0,142 and p = 0,71.

Change in axial inclination of the buccal segment is shown in Table 2.

The overall change in axial inclination of the buccal segments of both groups combined was small and not statistically significant, $F_{1,18}$ = 4,41, p = 0,05. The difference in axial inclination change between both groups is not statistically significant, $F_{1,18}$ = 0,89, p = 0,36.

Vertical movement of the buccal segment is shown in Table 3.

Group	Start (SD)	Finish (SD)	Difference (SD)
No headgear	8.84 (3.61)	9.47 (3.92)	0.63 (1.15)
Headgear	7.62 (3.36)	7.86 (3.66)	0.24 (0.64)

Table 2
The start and finish columns show the mean angle between the maxillary left buccal segment and the palatal plane in degrees. The difference indicates the change in axial inclination of the buccal segment.

Group	Start (SD)	Finish (SD)	Difference (SD)
No headgear	9.38 (1.64)	9.51 (1.30)	0.13 (0.60)
Headgear	9.43 (2.24)	9.30 (1.99)	-0.13 (0.53)

Table 3
The start and finish columns show the mean distance in millimeters between the center of resistance of the buccal segment and the palatal plane. The difference means the vertical movement, which is an extrusive movement in the no headgear group and an intrusive movement in the headgear group.

The difference in vertical movement of the buccal segment between start and finish of both groups was not statistically significant, $F_{1,18}$ = 0,00 and p = 1,00. The difference in vertical movement between both groups was also not statistically significant, $F_{1,18}$ = 1,06 and p = 0,32.

The change in inter molar width, measured on the models, is shown in Table 4.

Group	Start (SD)	Finish (SD)	Difference (SD)
No headgear	50.88 (3.80)	50.61 (3.33)	0.27 (0.53)
Headgear	50.13 (3.37)	50.66 (2.65)	0.53 (0.89)

Table 4
The mean arch widths in millimeters are shown in the start and finish columns. The difference indicates the change in inter molar width.

The change in inter molar width of both groups combined between start and finish was not statistically significant $F_{1,18}$ = 0,63 and p = 0,44. The difference in change in intermolar width between both groups, however, was statistically significant $F_{1,18} = 6,00$ and $p = 0,025$.

The rate of intrusion, expressed in millimeters per week, is shown in Table 5.

Group	Rate (SD)	Minimum	Maximum
No headgear	0.15 (0.05)	0.08	0.26
Headgear	0.14 (0.07)	0.03	0.27

Table 5
The mean amount of vertical movement per week is shown in this table with the maximum and minimum amount of movement in each group.

A one-way ANOVA showed no statistically significant difference in rate of intrusive movement between the headgear and no headgear groups. In order to test the difference in initial measurements between both groups a one-way ANOVA was used for the initial measurements. This test revealed no statistically significant differences. To determine the measurement error the measurements on five patients were repeated. Paired student t-tests revealed no statistically significant differences between the second set of measurements and the original measurements.

Discussion

In order to make the measurement error as small as possible the digital image was enlarged to the extent that the cross hair symbol used for landmark identification was much smaller than the enlarged landmark itself. Initially landmark identification was done on the computer screen without enlargement, which resulted in several inaccuracies, which were not coincident with the clinical findings. The next step was to make tracings on acetate paper, make digital images of these tracings and of the cephs directly and trace both. In order to make the superimpositions more reliable it was decided to make structural superimpositions on maxillary skeletal structures which were made utilizing the tracings on acetate. This has the clear advantage over the computer superimposition, because the complete outlines of the skeletal structures are utilized and not just a few digitized points. This method was checked independently by reanalyzing the start and finish cephs of 5 patients, which did not reveal statistically significant differences with the earlier analyses.

The mean amount of maxillary incisor intrusion was 2.24 and 2.37 mm in the no headgear and headgear group respectively. Although the intrusion of both groups combined was statistically significant, the difference in intrusion between both groups was not. This, however, was not the purpose of this study.

The amount of steepening of the buccal segments was very small: 0.63 degrees for the no headgear group and 0.24 degrees for the headgear group. The difference between the groups was not statistically significant. The amount of steepening was so small that it could be concluded, that 20 grams of intrusive force per side did not steepen the occlusal plane and therefore a highpull headgear was not necessary to prevent steepening of the buccal segment if the buccal segment extended from canine to first molar.

The mean vertical movement of the buccal segment was 0.13 mm extrusion for the no headgear group and 0.13 mm intrusion for the headgear group. Both movements were not statistically significant nor was the difference in vertical movement between both groups. It can be concluded that by performing intrusion as described in this study no extrusion of buccal segments occurs. Apparently the occlusal forces were sufficient to prevent extrusion from happening.

The difference in change between the no headgear and headgear group in intermolar width was statistically significant. The mean changes, however, were small: 0.27 mm decrease in width for the no headgear group and 0.53 mm increase for the headgear group. The direction of these changes were what was expected. A decrease in the no headgear group could be explained from the extrusive force with a point of force application buccal to the center of resistance of the buccal segment. An increase in arch width in the headgear group was expected, because the intrusive component from the high pull headgear exceeds the extrusive force on the buccal segment from the intrusion arch, resulting in an intrusive force to the buccal segment and buccal to the center of resistance. To prevent changes in arch width a passive transpalatal arch was recommended[16]. The amount of change reported in this study was so small that in a situation where a large buccal segment could be used and the amount of force is around 20 grams per side, a transpalatal arch is not necessary.

The mean rate of intrusion was 0.15 mm per week for the no headgear group and 0.14 mm per week for the headgear group. This difference was not statistically significant. The weekly averages do not mean that the rate of intrusion was constant. In order to determine constancy in the rate of intrusion more lateral cephs had to be taken in between. When intrusion takes place the force decreases when the incisor and/or the buccal segments are moving. This study shows that movement of the buccal segment, with intrusion performed as described, was negligible and did not contribute to a decreased force on the anterior segment. It is important that, when force decreases, the force level does not get beyond the threshold level. A low load deflection wire like TMA is therefore important to maintain a constant force above the threshold level[17,18]. High pull headgear increases the intrusive force to the anterior segment[7], but this increase did not make a significant contribution to increase the rate of intrusion.

Conclusions

The null hypothesis can be partially accepted and partially rejected. High pull headgear had no effect on steepening and extrusion of the buccal segments nor on the rate of intrusion. High pull headgear did have an effect on narrowing of the buccal segments. The narrowing that occurred without using the high pull headgear and the widening that occurred because of the high pull headgear were so small, that they were considered clinically irrelevant.

This study shows that in a population of adolescents statistically significant intrusion of maxillary incisors can be performed without statistically significant side effects on the buccal segments. The possible side effects that were measured were change in axial inclination, extrusion and change in width of the buccal segments. Using 20 grams of intrusive force per side, a buccal segment extending from canine to first molar, with both premolars included, is sufficient to counteract side effects. A high pull headgear to prevent possible side effects is not necessary in this situation.

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CHAPTER 3

THE INFLUENCE OF SIZE OF A BUCCAL SEGMENT ON PREVENTION OF SIDE EFFECTS FROM INCISOR INTRUSION

This chapter is a modification of the following publication:
van Steenbergen E, Burstone CJ, Prahl-Andersen B, Aartman IHA. The influence of size of a buccal segment on prevention of side effects from incisor intrusion.
In press Am J Orthod Dentofacial Orthop.
Permission for use of this article was granted by the editor.

Introduction

The part of the study, which is presented in this chapter evaluated the influence of the number of teeth included in a buccal segment on prevention of side effects from incisor intrusion[1-7]. The side effects that could be expected are steepening, extrusion of the buccal segments and narrowing of the arch width[1,2,4]. Steepening of the buccal segment results in loss of intrusive force and could result in lower rate of intrusion[8,9,10]. The purpose of this part of the study was to determine if the size of the buccal segment influences the amount of steepening, extrusion and narrowing of the buccal segments and the rate of intrusion. The following null hypothesis was tested: the size of the buccal segment has no effect on steepening, extrusion and narrowing of the buccal segment nor on the rate of intrusion.

Materials and methods

Sample

In order to make the sample as homogeneous as possible the following inclusion criteria were used. Orthodontic patients needing maxillary central and lateral incisor intrusion of at least two millimeters were recruited for this study from all patients referred to the principal investigator's practice. Treatment was performed by this orthodontist only. Patients included in the sample had at least maxillary first molars, first and second premolars, canines and all maxillary incisors present and fully erupted and were between 10 and 15 years of age. Patients with extremely flared or upright (such as in Class II division 2 patients) incisors were excluded as well as patients with periodontal disease. Patients with crowding to the extent that they needed extractions in order to perform alignment were also excluded. No other form of orthodontic treatment was performed in these patients during the time of maxillary incisor intrusion. All patients willing to participate in this study were included in the sample if they met the above mentioned requirements. During a 4 year period 40 patients were recruited, 21 males and 19 females, which were divided into 4 groups by simple randomization[11]. In the present study two groups of 10 patients each were used: group 1 had a buccal segment including canine, both premolars and the first molar, group 2 had a buccal segment of only the first molar (figure 1).

Records

A lateral cephalometric x-ray, one set of impressions with a wax bite in centric occlusion, and intra-oral photographs were taken of each patient at the start of intrusion and when intrusion of the maxillary 4 incisors was completed or stopped in case of clearly visible side effects. The lateral cephalograms were taken with the aid of a cephalostat by the principal investigator. The patient's head position in the cephalostat was documented, so that pre- and post intrusion cephs were taken with

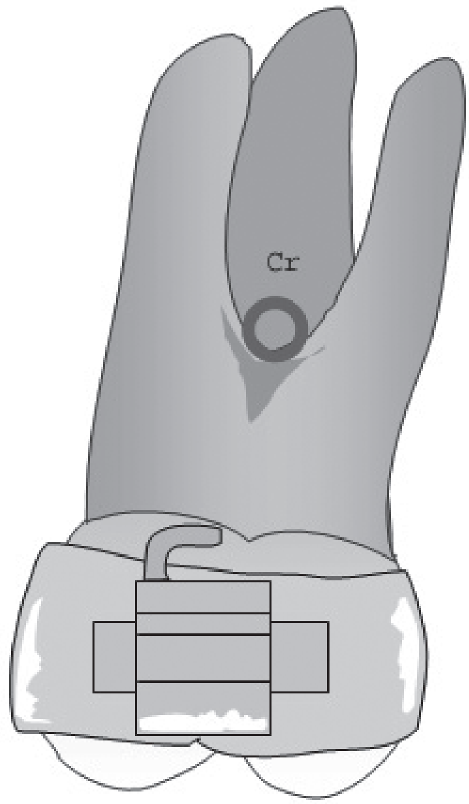

Figure 1
The circle in the furcation represents the location of the center of resistance of the maxillary first molar.

the patient's head in the same position. In order to distinguish the patients right and left side a ligature wire was tied around the right canine bracket in such a way that it was clearly visible on the lateral ceph. Impressions were poured in plaster and trimmed in centric occlusion.

Measurements

Lateral cephalograms were traced on a computer screen and on acetate paper[12,13]. From each set of lateral cephs a maxillary superimposition (structural) was made[14]. The tracings were digitized and analyses performed by computer[15]. The following measurements were performed:
1. Vertical movement of the center of resistance of the maxillary central incisor (indicating the amount of intrusion); vertical means perpendicular to the palatal plane (figure 2, measurement 1). The center of resistance (Cr) of the maxillary inci-

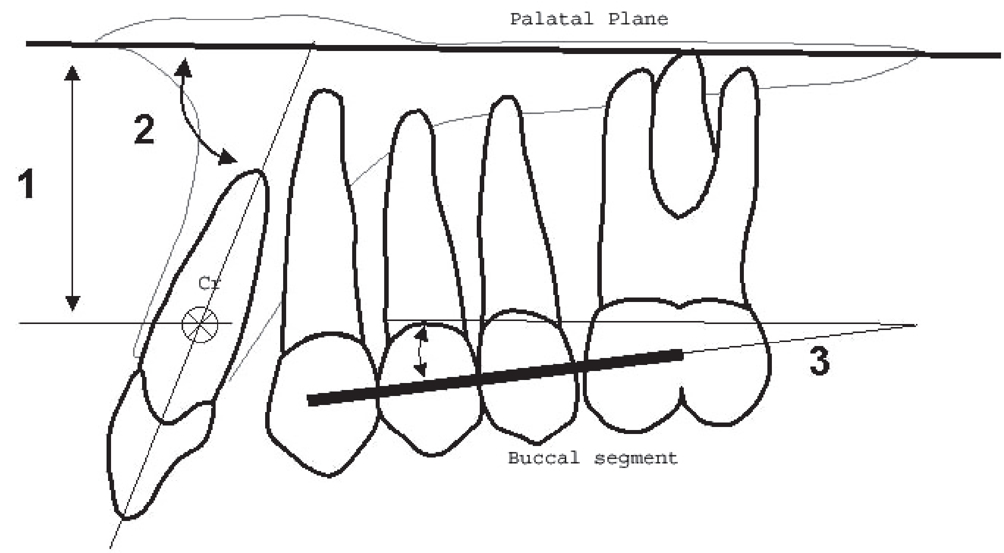

Figure 2
Measurement 1 indicates the distance between the center of resistance of the maxillary central incisor and the palatal plane, measurement 2 is the angle between the central incisor and the palatal plane, measurement 3 is the angle between the buccal segment and the palatal plane.

sor was selected as measurement instead of the center of resistance of the anterior segment, because of it's easier and more reproducible location. Because of the rigidity of the anterior segment and the small sagittal distance from Cr of the maxillary central incisor to Cr of the anterior segment in this sample to the center of resistance of the anterior segment, the possibility of an error, created by using this measurement, is small.

2. Change in axial inclination of the buccal segment, which was determined by measuring the angle between the buccal segment and the palatal plane (figure 2, measurement 3).
3. Change in axial inclination of the anterior segment, which was determined by measuring the angle between the maxillary central incisor and the palatal plane (figure 2, measurement 2).
4. Vertical movement of the buccal segment, which was determined by the distance between the center of resistance of the maxillary first molar and the palatal plane (figure 3, measurement 4). The center of resistance of the maxillary first molar was selected as measurement instead of the center of resistance of the buccal segment, because in the short buccal segment group the buccal segment consisted of the

maxillary first molar alone. The location of the center of resistance of the maxillary first molar was the trifurcation[1,2,3,10-14,16,17].

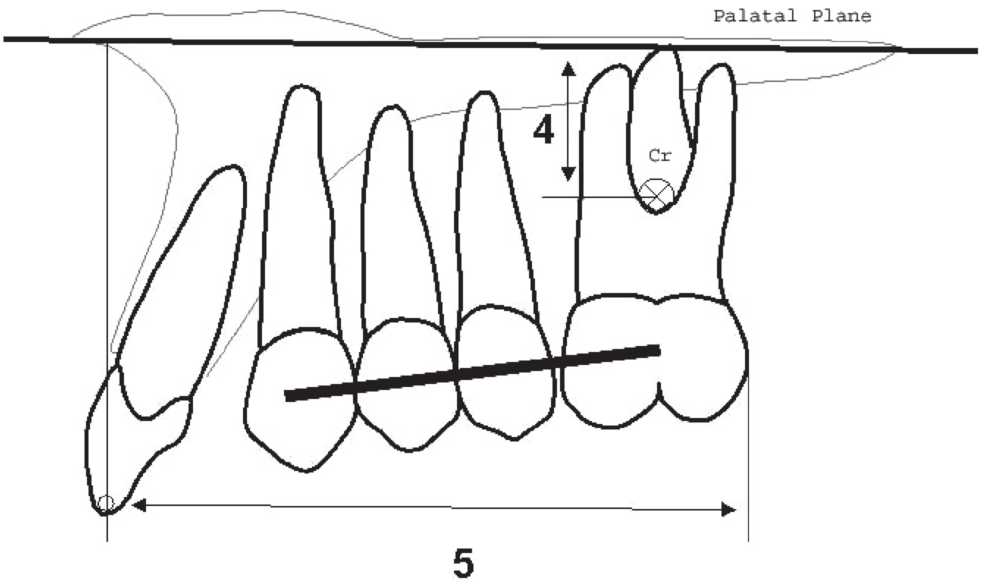

Figure 3
Measurement 4 is the distance from the center of resistance of the first molar to the palatal plane, measurement 5 the distance from the incisal edge to the distal side of the first molar parallel to the palatal plane.

5. Change in inter molar width, measured on the models.
6. Change in distance between the incisal edge of the maxillary central incisor and the distal side of the maxillary first molar, measured parallel to the palatal plane (figure 3, measurement 5).
7. Change in distance between the point of intrusive force application and the center of resistance of the maxillary central incisor, measured parallel to the palatal plane (figure 4, measurement 6).
8. Rate of intrusion, expressed in millimeters per week.

In order to make the measurement error as small as possible the digital image was enlarged to the extent that the cross hair symbol used for landmark identification was much smaller than the enlarged landmark itself. The next step was to make tracings on acetate paper, make digital images of these tracings and of the cephs directly and trace both. In order to make the superimpositions more reliable it was decided to make structural superimpositions on maxillary skeletal structures which were made utilizing the tracings on acetate. This has the clear advantage over the computer superimposition, because the complete outlines of the skeletal structures

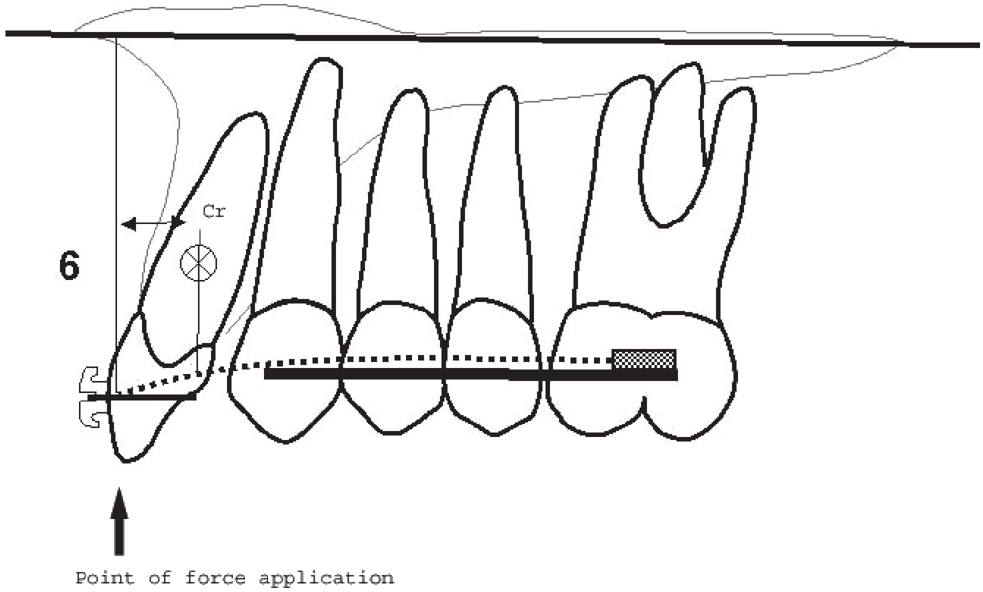

Figure 4
Measurement 6 is the distance from the point of force application to the center of resistance of the central incisor. To clarify the figure the point of force application was moved further anteriorly than it was in the study.

are utilized and not just a few digitized points. This method was checked independently by reanalyzing the start and finish cephs of 10 patients. The mean differences between both measurements varied from 0.01 degrees for the angular measurement between the central incisor and the palatal plane and 0.01 mm. between the distance from the auxiliary tube to the point of intrusive force application to 0.24 mm. for the distance between the incisal edge and the maxillary first molar. None of the differences were statistically significant.

Treatment protocol

Patients were recruited after explanation of the treatment plan by orthodontist. First bands and brackets (0.022" x 0.028" slot) were placed and segments aligned. Alignment was performed in segments, the anterior segment extending from right to left lateral incisor and the buccal segment from canine to first molar, while controlling vertical forces as much as possible[1,2,6,8,10]. When the wire segments were 0.018" x 0.025" stainless steel and passive, one lateral ceph, 5 intra-oral photographs (one frontal, two buccal, and 2 occlusal photographs), and one set of impressions with a wax bite in centric occlusion were taken. In order to be certain that the segments were passive, they were left in place for 5 weeks after insertion, before records were taken and intrusion was started. At the same visit the intrusion arch was placed with a force level of 40 grams measured in the midline (20 grams per side).

Visits were scheduled every 5 weeks. During each visit the intrusive force was measured, recorded, and, when necessary, adjusted to the proper level. When the incisors were intruded to the proper level, the intrusion arch was removed and a lateral ceph, impressions, and wax bite were taken. The same actions were undertaken when side effects were clearly present. Loose bands and brackets were recorded and replaced in a manner that the segment remained passive. Because the patients in group 2 had no buccal segment, a rigid extension was placed in the first molar buccal tube for the cephalogram and the photographs in order to measure the amount of tipping more accurately.

Results

To test the null hypothesis an ANOVA for repeated measures (measurements at start and finish) was used with group as the independent variable(General Linear Models ; GLM procedure in SPSS 10). The significance level a was set at 0.05. The power, 1-b, was set at 0.90. The amount of intrusion in both groups is shown in Table I. Both groups had about the same amount of incisor intrusion. The difference in the amount of intrusion between both groups is not statistically significant ($p = 0.88$).
In the long buccal segment group a small decrease in maxillary arch width was observed and in the short segment group a small increase (Table 1). The change in arch width between start and finish for both groups combined is not statistically significant ($p = 0.29$), but the difference in arch width change comparing both groups is statistically significant ($p = 0.01$).

In both groups the buccal segment steepened, in the short segment group almost 14 degrees more than in the long segment group (Table 1). Because the buccal segment in the short buccal segment group consisted only of the first molar, a rigid extension wire was used to facilitate more accurate measurement of change in axial inclination. The change in axial inclination between start and finish is statistically significant for both groups combined ($p <0.001$). The difference in change in axial inclination between both groups is also statistically significant ($p <0.001$); the short buccal segment group steepened a statistically significant larger amount than the long buccal segment group.

Both groups had a very small amount of extrusion of the buccal segments (Table 1). The difference in vertical movement of the buccal segment between start and finish of both groups was not statistically significant. The difference in vertical movement between both groups was also not statistically significant.

Both groups experienced flaring of the anterior segment (Table 1). This

Measurement	Group	Start (SD)	Finish (SD)	Difference (SD)
Vertical movement of center of resistance of central incisor (mm.)	Long buccal segment	10.44 (1.45)	8.20 (1.75)	2.24 (0.53)
Vertical movement of center of resistance of central incisor (mm.)	Short buccal segment	9.11 (1.92)	6.83 (1.91)	2.28 (0.54)
Arch width (mm.)	Long buccal segment	50.88 (3.80)	50.61 (3.33)	-0.27 (0.53)
Arch width (mm.)	Short buccal segment	49.53 (1.38)	50.11 (1.40)	0.58 (0.72)
Axial inclination of the buccal segment (degrees)	Long buccal segment	8.84 (3.60)	9.47 (4.06)	0.63 (1.25)
Axial inclination of the buccal segment (degrees)	Short buccal segment	7.96 (2.72)	22.19 (8.21)	14.23 (7.72)
Vertical movement of buccal segment (mm.)	Long buccal segment	9.38 (1.64)	9.51 (1.30)	0.13 (0.60)
Vertical movement of buccal segment (mm.)	Short buccal segment	7.94 (1.86)	8.37 (2.03)	0.43 (0.71)
Axial inclination of central incisor (degrees)	Long buccal segment	73.94 (3.15)	64.93 (4.46)	-9.01 (4.00)
Axial inclination of central incisor (degrees)	Short buccal segment	70.14 (5.18)	64.62 (5.82)	-5.52 (2.86)
Point of force application to center of resistance of central incisor (mm.)	Long buccal segment	3.11 (1.54)	4.99 (1.84)	1.88 (0.99)
Point of force application to center of resistance of central incisor (mm.)	Short buccal segment	3.82 (1.79)	4.97 (2.03)	1.15 (0.66)
Incisal edge to distal side of the first molar (mm.)	Long buccal segment	38.26 (3.15)	40.66 (3.01)	2.40 (1.56)
Incisal edge to distal side of the first molar (mm.)	Short buccal segment	38.66 (3.01)	39.69 (3.53)	1.03 (1.11)

Table 1
Change in position of anterior and buccal segments comparing the long- and short buccal segment groups.

measurement does not show if the axial inclination change was caused by crown and/or root movement. The change in axial inclination of the anterior segment of both groups combined was statistically significant ($p < 0.001$). The difference in change in axial inclination between the long- and short buccal segment groups was also statistically significant ($p = 0.04$).

Change in axial inclination of the anterior segment was also determined by measuring the change in distance from the point of force application to the center of resistance of the maxillary central incisor. An increase in distance indicates flaring of the anterior segment. In both groups an increase in distance was observed. This increase for both groups combined was statistically significant ($p < 0.001$). The difference in increase between both groups was not statistically significant ($p = 0.07$, Table 1).

Change in distance from the incisal edge to the distal of the first molar was measured to determine if labial incisor crown movement and/or distal maxillary molar crown movement had occurred. The increase in distance between the incisal edge and the maxillary molar for both groups combined was statistically significant ($p < 0.001$). The short buccal segment group had a statistically significant smaller increase in distance compared to the long buccal segment group ($p = 0.04$, Table 1).

The rate of intrusion and the range herein in both groups is shown in Table 2. An independent sample t-test showed no statistically significant difference in rate of intrusive movement between the long- and short buccal segment groups.

Group	Mean (mm./wk.)	SD	Median	Minimum	Maximum
Long buccal segment	0,15	0,05	0,15	0,08	0,26
Short buccal segment	0,12	0,03	0,13	0,07	0,17

Table 2
Rate of intrusion expressed in millimeters per week.

In order to test the difference in initial measurements between both groups, independent t-tests revealed no statistically significant differences. To determine the measurement error the measurements on five patients were repeated. Paired student t-tests revealed no statistically significant differences between the second set of measurements and the original measurements.

Discussion

In both groups a statistically significant amount of incisor intrusion was performed (2.24 mm. in the long buccal segment group and 2.28 mm. in the short buccal segment group) with no statistically significant difference between the groups.

The axial inclination of the buccal segment increased by a mean of 0.62 degrees in the long segment group and by a mean of 14.23 degrees in the short buccal segment group. This difference was statistically significant and showed the importance of a buccal segment of sufficient size.

The mean vertical movement of the long and short buccal segments, however, was small (0.13 and 0.43 millimeters respectively) and not statistically significant. Apparently was the extrusive force on the buccal segments small enough to be counteracted by the forces of occlusion.

The axial inclination of the anterior segments increased (proclined) a statistically significant amount, 9.01 degrees in the long buccal segment- and 5.52 degrees in the short buccal segment groups. Surprisingly the difference between the groups was statistically significant. This difference could have been explained by a larger distance between the point of force application to the anterior segment and the center of resistance of the maxillary incisor in the long buccal segment groups at the start of intrusion, which was not the case. In fact, the mean distance from the point of force application to the center of resistance in the long segment group was at the start of intrusion 3.11 mm. and thereby even smaller compared to the 3.82 mm. distance in the short segment group, but this difference was not statistically significant. The change in distance from the point of force application to the center of resistance of the maxillary central incisor increased a statistically significant amount in both groups combined, which was expected from the incisor flaring. The larger increase in incisor flaring in the long buccal segment group (1.88 mm. compared to 1.15 mm. in the short segment group) was however not statistically significant.

The overall horizontal change was measured from incisal edge to the distal side of the maxillary molar. The mean increase was statistically significant for both groups, 2.40 mm. in the long segment group and 1.03 mm. in the short segment group. The difference between the groups was also statistically significant. These amounts are small, however, compared to the changes in axial inclination, indicating that especially the axial inclination change of the maxillary molar consisted of more mesial root movement than distal crown movement. As mentioned previously, the maxillary anterior segment did move labially to some extent, because the distance between the point of force application and the center of resistance increased. Possibly the construction of the one piece intrusion arch, in which anterior and posterior segments are connected, even though the intrusion arch was not cinged back, provided through friction enough horizontal force to prevent a large amount of flaring and tip back from occurring.

Although the axial inclination change in the small buccal segment group was statistically significant larger than in the long segment group, there was no statistically significant difference in rate of intrusion. When the buccal segment is tipped back, the amount of intrusive force on the anterior segment decreases, but apparently not to a degree that it influenced the rate of intrusion. Within each group there was quite a variety in rate of intrusion.

Because of the relatively small sample size a possibility of asymmetric distribution on either side of the mean exists. In order to give an insight in this distribution median, minimum and maximum were added. The data showed a normal distribution, which justified the parametric tests (ANOVA) that were performed.

Conclusions

The null hypothesis was partially accepted and partially rejected. Size of the buccal segment had an influence on steepening and narrowing of the buccal segments and no influence on extrusion of the buccal segments and the rate of incisor intrusion. The intermolar width increased in the short buccal segment group and decreased in the long buccal segment group. Even though the changes were small, the difference between the groups was statistically significant. The short buccal segment steepened more than 14 degrees, whereas the long buccal segment steepened a clinically insignificant 0.6 degrees. There was almost no extrusion of the buccal segments in either group. In both groups the mean intrusion of the maxillary anterior segment exceeded 2 mm. In order to keep side effects from incisor intrusion to a minimum, this part of the study showed that a buccal segment extending from canine to first molar is sufficient.

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CHAPTER 4

THE INFLUENCE OF FORCE MAGNITUDE ON INTRUSION OF THE MAXILLARY ANTERIOR SEGMENT

This chapter is a modification of the following publication:
van Steenbergen E, Burstone CJ, Prahl-Andersen B, Aartman IHA. The influence of force magnitude on intrusion of the maxillary anterior segment. Angle Orthod 2005;75(5):723-729.
Permission for use of this article was granted by the editor.

Introduction

The part of the study presented in this chapter, evaluated the influence of the magnitude of intrusive force on side effects in the buccal segments and the rate of incisor intrusion[1-7]. The side effects from incisor intrusion on the buccal segments that could be expected are steepening, extrusion of the buccal segments and narrowing of the arch width[1,2,4]. The force level has been reported as low as five grams per tooth in patients with decreased periodontal attachment.[4] Commonly 10-20 grams of force is advocated for maxillary incisor intrusion.[1-3] This recommendation is based on clinical experience. A comparison of different force levels would be meaningful in creating a more efficient approach toward intrusion. It is important to investigate which amount of force intrudes incisors most efficiently, meaning as fast as possible with the least amount of side effects and tissue damage (root resorption).

The purpose of the present study was to determine if the intrusive force level influences the amount of steepening, extrusion and narrowing of the buccal segments and the rate of intrusion. In this study the following null hypothesis was tested: the intrusive force level has neither an effect on steepening, extrusion and narrowing of the buccal segment nor on the rate of intrusion.

Materials and methods

<u>Sample</u>

Orthodontic patients needing maxillary central and lateral incisor intrusion of at least two millimeters were recruited for this study from all patients referred to the principal investigator's practice. Treatment was performed by one orthodontist only. Patients included in the sample were between 10 and 15 years of age and had at least maxillary first molars, first and second premolars, canines and all maxillary incisors present and fully erupted. Patients with extremely flared or upright (such as in Class II division 2 patients) incisors were excluded as well as patients with periodontal disease. Patients with crowding to the extent that they needed extractions in order to perform alignment were also excluded. No other form of orthodontic treatment was performed in these patients during the time of maxillary incisor intrusion. All patients willing to participate in this study were included in the sample if they met the above mentioned requirements. During a 4 year period 40 patients were recruited, which were divided into 4 groups by simple randomization.[8] In the present study two groups of 10 patients each were used. In Group 1 patients the teeth in the maxillary anterior segment were intruded using 40 grams, whereas in Group 2 patients 80 grams was used.

<u>Records</u>

A lateral cephalometric radiograph, one set of impressions with a wax bite in centric occlusion and intra-oral photographs were obtained from each patient at the start of intrusion and when intrusion of the maxillary four incisors was completed. The lateral cephalograms were taken with the aid of a cephalostat by the principal investigator. The patient's head position in the cephalostat was documented, so that pre- and post intrusion cephalograms were taken with the patient's head in the same position. In order to distinguish the patients right and left side a ligature wire was tied around the right canine bracket in such a way that it was clearly visible onthe lateral ceph. Impressions were poured in plaster and trimmed in centric occlusion.

Measurements

Lateral cephalograms were traced on a computer screen and on acetate paper.[9,10] From each set of lateral cephs a maxillary superimposition (structural) was made.[11] The tracings were digitized and analyses performed by computer.[12] The following measurements were performed:

1. Vertical movement of the center of resistance of the maxillary central incisor (indicating the amount of intrusion); vertical means perpendicular to the palatal plane (Figure 1, measurement 1). The center of resistance (Cr) of the maxillary incisor was selected as measurement instead of the center of resistance of the anterior

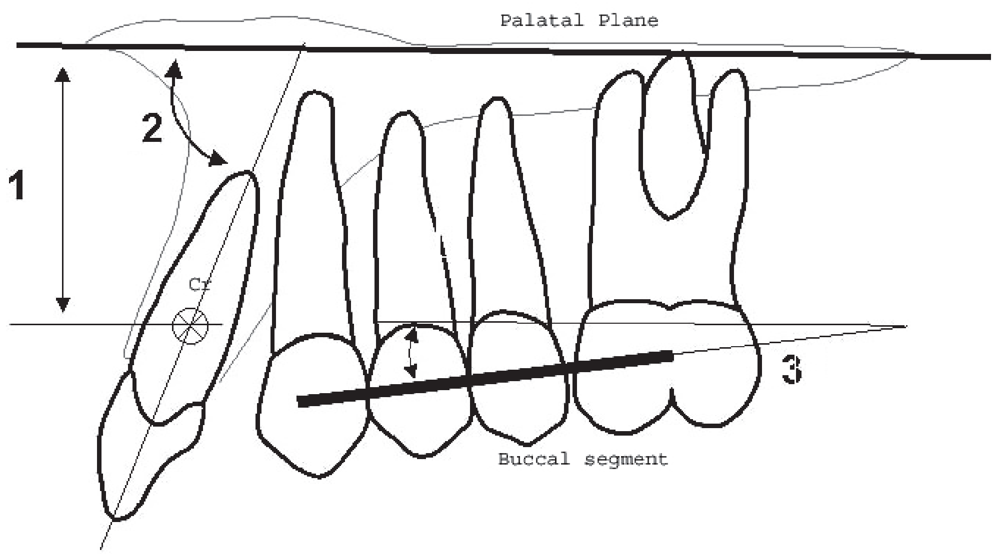

Figure 1

Measurement 1 indicates the distance between the center of resistance of the maxillary central incisor and the palatal plane, measurement 2 is the angle between the central incisor and the palatal plane, measurement 3 is the angle between the buccal segment and the palatal plane.

segment, because of it's easier and more reproducible location. Because of the rigidity of the anterior segment and the small sagittal distance from Cr of the maxillary central incisor to Cr of the anterior segment in this sample to the center of resistance of the anterior segment, the possibility of an error, created by using this measurement, is small.
2. Change in axial inclination of the anterior segment, which was determined by measuring the angle between the maxillary central incisor and the palatal plane (Figure 1, measurement 2).
3. Change in axial inclination of the buccal segment, which was determined by measuring the angle between the buccal segment and the palatal plane (Figure 1, measurement 3).
4. Vertical movement of the buccal segment, which was determined by the distance between the center of resistance of the maxillary first molar and the palatal plane (Figure 2, measurement 4). The center of resistance of the maxillary first molar was selected as measurement instead of the center of resistance of the buccal segment, because of it's easier and more reliable and reproducible location. The location of the center of resistance of the maxillary first molar was the trifurcation.[1,2,7,13-15]
5. Change in inter molar width, measured on the models.

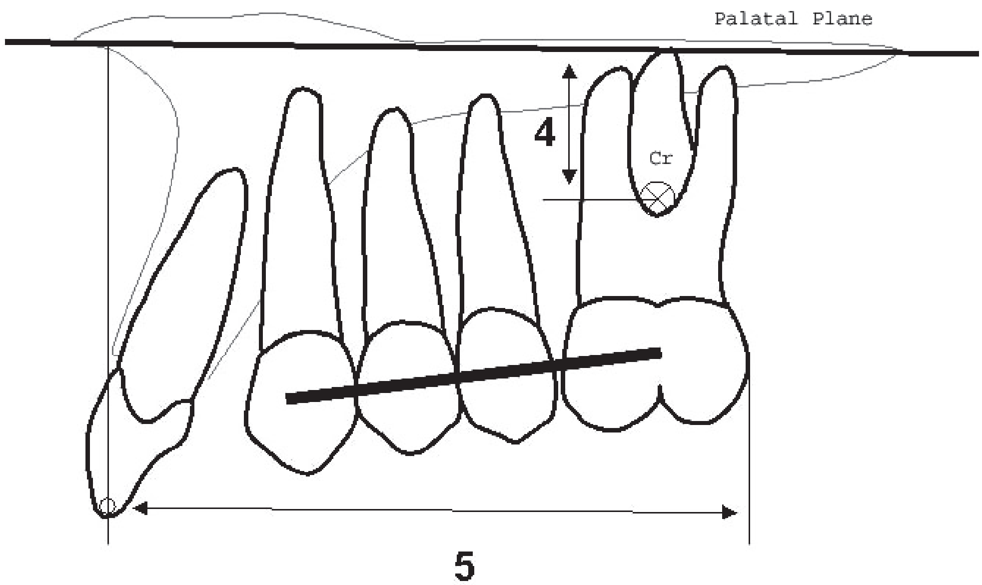

Figure 2
Measurement 4 is the distance from the center of resistance of the first molar to the palatal plane, measurement 5 the distance from the incisal edge to the distal side of the first molar parallel to the palatal plane.

6. Change in distance between the incisal edge and the distal side of the maxillary first molar, measured parallel to the palatal plane (Figure 2, measurement 5).
7. Change in distance between the point of intrusive force application and the center of resistance of the maxillary central incisor, measured parallel to the palatal plane (Figure 3, measurement 6).
8. Rate of intrusion, expressed in millimeters per week.

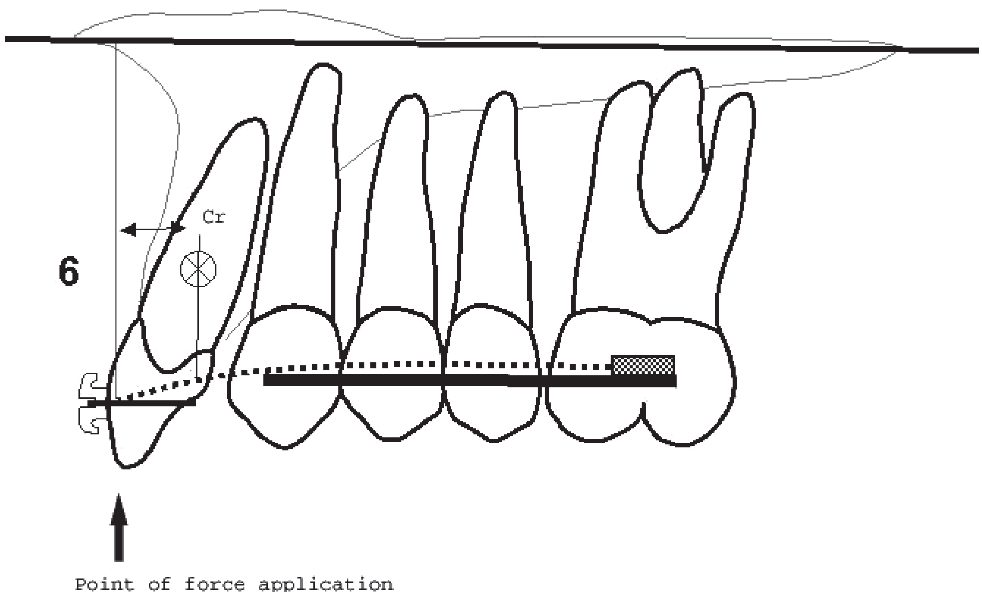

Figure 3
Measurement 6 is the distance from the point of force application to the center of resistance of the central incisor. To clarify the figure the point of force application was moved further anteriorly than it's actual location in the study.

In order to make the measurement error as small as possible the digital image was enlarged to the extent that the cross hair symbol used for landmark identification was much smaller than the enlarged landmark itself. The next step was to make tracings on acetate paper, make digital images of these tracings and of the cephs directly and trace both. In order to make the superimpositions more reliable it was decided to make structural superimpositions on maxillary skeletal structures which were made utilizing the tracings on acetate. This has the clear advantage over the computer superimposition, because the complete outlines of the skeletal structures are utilized and not just a few digitized points. This method was checked independently by reanalyzing the start and finish cephs of 10 patients. The mean differences between both measurements varied from 0.01 degrees for the angular measurement between the central incisor and the palatal plane and 0.01 mm. between the distance from the auxiliary tube to the point of intrusive force application to 0.24 mm. for the distance between the incisal edge and the maxillary first molar. None of the differences were statistically significant.

Treatment protocol

Patients were recruited after explanation of the treatment plan by orthodontist. First bands and brackets were placed and segments aligned. Alignment was performed in segments, the anterior segment extending from right to left lateral incisor and the buccal segment from canine to first molar. When the wire segments were rigid and passive, one lateral ceph, five intra-oral photographs (one frontal, two buccal and two occlusal photographs), and one set of impressions with a wax bite in centric occlusion were taken. In order to be certain that the segments were passive, they were left in place for five weeks after insertion, before records were taken and intrusion was started. At the same visit the intrusion arch was placed with a force level of 40 grams measured in the midline (20 grams per side) in group 1 and 80 grams in group 2.

Visits were scheduled every five weeks. During each visit the intrusive force was measured, recorded, and, when necessary, adjusted to the proper level. When the incisors were intruded to the proper level, the intrusion arch was removed and a lateral ceph, impressions, and wax bite were taken. The same actions were undertaken when side effects were clearly present. Loose bands and brackets were recorded and replaced in a manner that the segment remained passive.

Results

To test the null hypothesis an ANOVA for repeated measures (measurements at start and finish) was used with group as the independent variable (General Linear Models; GLM procedure in SPSS 10). Table 1 and 2 display the differences and the statistical significance of these differences between both groups in intrusion, arch width, axial inclination change of the buccal segment and extrusion of the buccal segment.

Table 3 shows the changes in vertical incisor position, arch width, axial inclination of the buccal segment and vertical movement of the buccal segment of both groups combined between start and finish of incisor intrusion.

The mean intrusion of the anterior segment in both groups was more than two millimeters (Table 1). There was no statistically significant difference in the amount of intrusion between the groups (Table 2). The vertical incisor movement of both groups combined was statistically significant (Table 3).

The mean intermolar width decreased slightly (0.27 mm, Table 1) in the 40

Measurement	Group	Start (SD)	Finish (SD)	Difference (SD)
Vertical movement of cr of central incisor (mm.)	f = 40 g	10.44 (1.45)	8.2 (1.75)	2.24 (0.67)
Vertical movement of cr of central incisor	f = 80 g	10.36 (1.44)	7.88 (1.34)	2.48 (0.67)
Arch width (mm.)	f = 40 g	50.88 (3.80)	50.61 (3.33)	0.27 (0.53)
Arch width	f = 80 g	50.86 (1.47)	50.90 (1.91)	0.04 (0.93)
Axial inclination of the buccal segment (degrees)	f = 40 g	8.84 (3.61)	9.47 (3.92)	0.63 (1.15)
Axial inclination of the buccal segment	f = 80 g	5.68 (3.49)	7.17 (3.29)	1.49 (1.76)
Vertical movement of buccal segment (mm.)	f = 40 g	9.38 (1.64)	9.51 (1.30)	0.13 (0.60)
Vertical movement of buccal segment	f = 80 g	9.97 (1.68)	10.03 (1.71)	0.06 (0.32)

Table 1
Start and finish measurements and the differences between them of the 40- and 80 gram groups. The standard deviations are in parentheses.

Measurement	F (1,18)	p
Vertical movement of center of resistance of central incisor	0.64	0.43
Arch width	0.84	0.37
Axial inclination of the buccal segment	1.68	0.21
Vertical movement of buccal segment	0.11	0.75
Rate of intrusion	1.15	0.34

Table 2
Statistical significance of the differences between the 40- and 80 gram groups for the different measurements, showing the F values with the degrees of freedom in parentheses and the p values.

Measurement	F (1,18)	p
Vertical movement of center of resistance of central incisor	248.77	< 0.001
Arch width	0.43	0.52
Axial inclination of the buccal segment	10.19	0.005
Vertical movement of buccal segment	0.79	0.39

Table 3
Changes of the 40- and 80 gram groups combined between start and finish.

gram group and remained about the same (0.04 mm increase, Table 1) in the 80 gram group. The difference between both groups was not statistically significant (Table 2). The change in intermolar width of both groups combined was also not statistically significant (Table 3).

In both groups the buccal segment steepened a small amount: 0.63 degrees in the 40 gram group and 1.49 degrees in the 80 gram group (Table 1). The difference was not statistically significant (Table 2). The steepening in both groups combined, however, was statistically significant (Table 3).

Both groups experienced a small amount of buccal segment extrusion: 0.13 mm in the 40 gram group and 0.06 in the 80 gram group (Table 1). This difference was not statistically significant (Table 2). Also the extrusion of both groups combined was not statistically significant (Table 3).

The mean rate of intrusion was 0.15 (sd 0.05) mm. per week with a range from 0.08 to 0.26 mm per week in the 40 gram group. In the 80 gram group the mean rate was 0.16 (sd 0.05) mm. per week with a range from 0.07 to 0.23 mm per week. The difference between the groups was not statistically significant (Table 2).

Discussion

In both groups a statistically significant amount of incisor intrusion of more than two millimeters was performed with no statistically significant difference between the groups. Since the amount of intrusion was predetermined by the patient's treatment plan, a difference in amount of intrusion between the groups was not expected.

A higher intrusive force results in a higher extrusive force buccal to the center of resistance, which increases the likelihood of maxillary arch constriction.[1,2] There was however no statistically significant difference between the 40 and 80 gram groups in intermolar width. This indicates that, in this intrusive force range, the occlusal forces in combination with the size of the buccal segments were sufficient to hold the maxillary intermolar width.

In the 80 gram group the mean angulation of the buccal segment increased less than one degree more than that of the 40 gram group. The difference between the groups was not statistically significant. The change in axial inclination change in both groups combined was statistically significant, even though the absolute change was small. These findings suggest that up to 80 grams intrusive force does not result in a clinically significant amount of steepening of the buccal segments when the segments consist of canines, first- and second premolars and first molars.

A higher intrusive force on the incisors results in a higher extrusive force on the buccal segments and thereby increases the likelihood of extrusion of the buccal segment.[1,2,7,13] In this study the amount of extrusion in the 40- and 80 gram groups was not statistically significant. The difference in extrusion between the two groups was also not statistically significant. These findings indicate that intrusive forces of up to 80 grams do not result in significant extrusion of the buccal segments when canines, first- and second premolars and first molars are present and included in the buccal segments.

In order to make treatment as efficient as possible a high rate of intrusion combined with the smallest possible amount of side effects is preferred. In this study the effect of intrusive force on the rate of intrusion was tested. Between the 40- and 80 gram groups no statistically significant differences were observed. The range in rate was quite large, but similar when comparing both groups. This indicates that increasing the force from 40 to 80 grams does not increase the rate of intrusion.

Force magnitude can be related to anchorage loss.[1,2,3,4,7,13-15] This is of particular interest when intrusion is combined with space closure. This was however not the purpose of this investigation. In order to determine the influence of force level on anchorage loss more different force levels, with higher and lower forces than the ones used in this study, will have to be studied.

A recent study demonstrated that high forces create more root resorption than light forces[16]. Therefore the lowest amount of force capable of intruding the incisors is preferred.

Conclusions

The null hypothesis was accepted. Maxillary incisors can be intruded with forces of 10 to 20 grams per tooth without statistically significant difference in extrusion of the buccal segments between the 40 and 80 gram groups. The amount of force had no influence on the inclination of the buccal segments. The amount of intrusive force in the range between 40 and 80 grams had no influence on the intermolar width and the rate of intrusion.

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CHAPTER 5

THE RELATION BETWEEN THE POINT OF FORCE APPLICATION AND FLARING OF THE ANTERIOR SEGMENT

This chapter is a modification of the following publication:
van Steenbergen E, Burstone CJ, Prahl-Andersen B, Aartman IHA. The relation between the point of force application and flaring of the anterior segment. Angle Orthod 2005;75(5):730-735.
Permission for use of this article was granted by the editor.

Introduction

In this chapter the influence of the location of the point of force application on change in axial inclination (in the sagittal plane) of the maxillary anterior segment was evaluated. The location of the point of force application in relation to the center of resistance of the anterior segment can alter the axial inclination of that segment. A more anterior location of the point of force application causes flaring, whereas a more posterior location will cause uprighting of the anterior teeth.[1-5] Studies on dry skulls have determined that the center of resistance for a segment of 4 maxillary incisors with a normal axial inclination lies apical of a point in the sagittal plane between the distal side of the canine[3] and the distal side of the lateral incisor.[4] Therefore, if an intrusion arch is attached at that point the anterior segment, the incisors will move bodily in apical direction. When the axial inclination of the incisors is different, so is the location of the center of resistance in relation to the position of the incisor crowns. More flared incisors should have a more distal point of force application through the center of resistance than retroclined incisors.[1-4]

The purpose of the present study was to determine if, in patients with a normal axial inclination (within two standard deviations) of the anterior segment, application of an intrusive force at the distal wings of the lateral incisor brackets causes a change in axial inclination of that segment. In this study the following null hypotheses were tested:

Application of an intrusive force by tying the intrusion arch at the distal wings of the lateral incisor brackets onto the anterior segment causes no change in axial inclination of that segment while it is being intruded.

There is no correlation between the distance from the point of force application to the center of resistance of the maxillary anterior segment at the start of intrusion and the change in axial inclination of the anterior segment.

There is no correlation between the distance from the point of force application to the center of resistance of the maxillary anterior segment at the start of intrusion and the change in distance from the incisal edge to the first molar between start and finish of intrusion.

There is no correlation between the distance from the point of force application to the center of resistance of the maxillary anterior segment at the start of intrusion and at the end of intrusion.

There is no correlation between the distance from the point of force application to the center of resistance of the maxillary anterior segment at the start of intrusion and the change in this distance between the start and end of intrusion.

There is no correlation between the amount of intrusion and the change in axial inclination of the anterior segment.

Materials and methods

Sample

Orthodontic patients needing maxillary central and lateral incisor intrusion of at least two millimeters were recruited for this study from all patients referred to the principal investigator's practice. Treatment was performed by this orthodontist only.

Patients included in the sample had at least maxillary first molars, first and second premolars, canines and all maxillary incisors present and fully erupted and were between 10 and 15 years of age. Patients with extremely flared or upright (such as in Class II division 2 patients) incisors were excluded as well as patients with periodontal disease. Patients with crowding to the extent that they needed extractions in order to perform alignment were also excluded. No other form of orthodontic treatment was performed in these patients during the time of maxillary incisor intrusion. All patients willing to participate in this study were included in the sample if they met the above mentioned requirements. During a 4 year period 40 patients were recruited.

Records

A lateral cephalometric radiograph, one set of impressions with a wax bite in centric occlusion and intra-oral photographs were taken of each patient at the start of intrusion and when intrusion of the maxillary 4 incisors was completed. The lateral cephalograms were taken with the aid of a cephalostat by the principal investigator. The patient's head position in the cephalostat was documented by recording the positions of the ear rods and nasal rest, so that pre- and post intrusion cephalograms were taken with the patient's head in the same position. In order to distinguish the patient's right and left side a ligature wire was tied around the right canine bracket in such a way that it was clearly visible on the lateral cephalogram. Impressions were poured in plaster and trimmed in centric occlusion.

Measurements

Lateral cephalograms were traced on a computer screen and on acetate paper.[6,7] From each set of lateral cephalograms a maxillary superimposition (structural) was made.[8] The tracings were digitized and analyses performed by computer[9] utilizing the Quick Ceph Image program (Quick Ceph Systems, San Diego, CA). The following measurements were performed:

• Vertical movement of the center of resistance of the maxillary central incisor (indicating the amount of intrusion); vertical means perpendicular to the palatal plane (Figure 1, measurement 1). The center of resistance of the central incisor was selected instead of the center of resistance of the anterior segment, because of its easier and therefore more reliable and reproducible location (the point halfway between the cemento-enamel junction and the apex in the center of the root). Because of the rigidity of the anterior segment the displacement of the center of resistance of the central incisor is a good representation of the displacement of the center of resistance of the anterior segment.

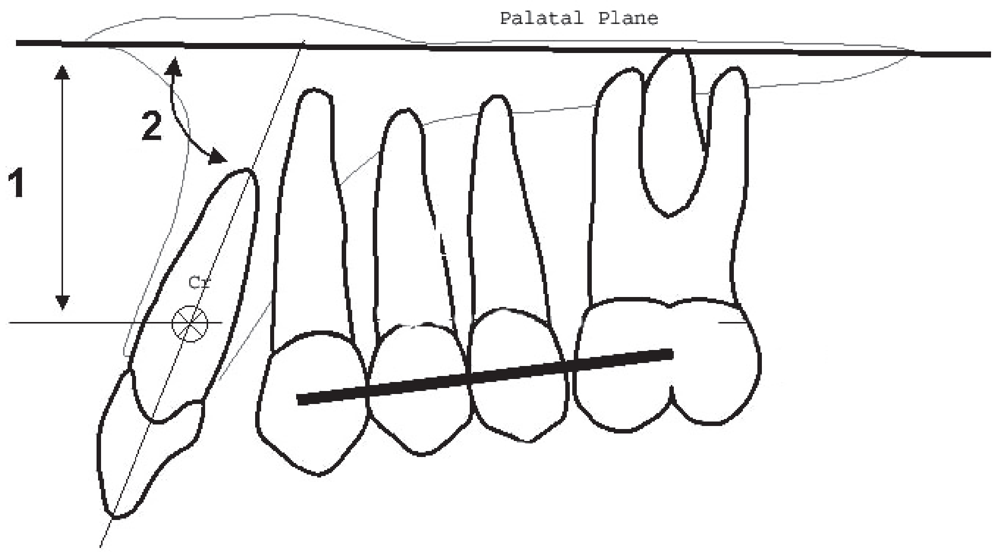

Figure 1 *Incisor intrusion and axial inclination*

• Distance from the center of resistance to the palatal plane (Figure 1, measurement 1).
• Axial inclination of the anterior segment in the sagittal plane, which was determined by measuring the angle between the central incisor and the palatal plane (Figure 1, measurement 2).
• Distance from the point of intrusive force application to the center of resistance of the central incisor. The greater this distance the greater the chance of incisor flaring (Figure 2, measurement 3).
• Distance from the incisal edge to the distal side of the maxillary first molar (Figure 3, measurement 4). This measurement in the sagittal plane indicates the amount of flaring of the maxillary incisor in combination with distal tipping of the buccal segment.

In order to make the measurement error as small as possible the digital image was enlarged to the extent that the cross hair symbol used for landmark identification was much smaller than the enlarged landmark itself. The next step was to make tracings on acetate paper, make digital images of these tracings and of the cephalograms directly and trace both. In order to make the superimpositions more reliable it was decided to make structural superimpositions on maxillary skeletal structures which were made utilizing the tracings on acetate. This has the clear advantage over

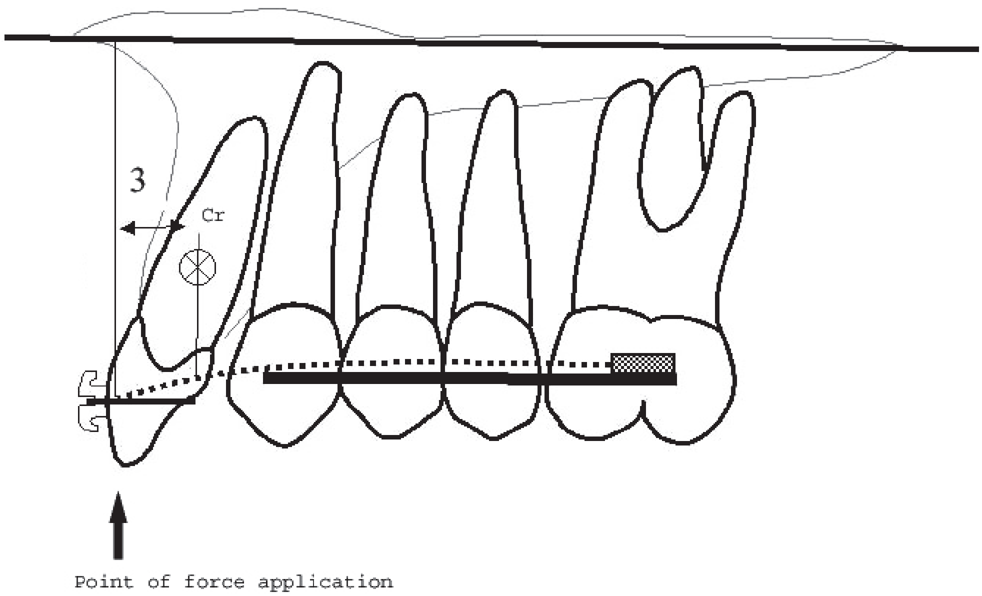

Figure 2 *Distance between the point of force application to the center of resistance.*

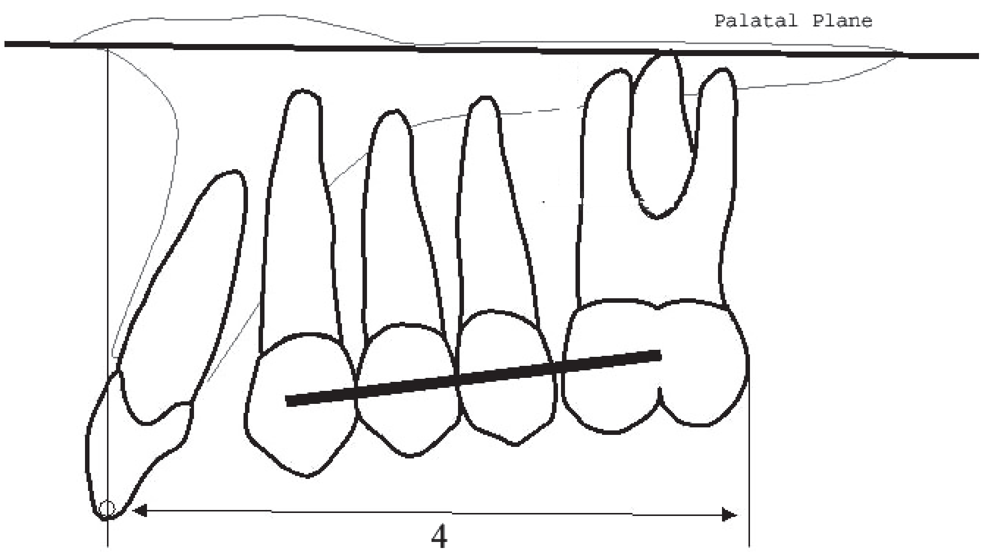

Figure 3 *Distance from incisal edge to first molar.*

the computer superimposition, because the complete outlines of the skeletal structures are utilized and not just a few digitized points. This method was checked independently by reanalyzing the start and finish cephalograms of 10 patients. The mean differences between both measurements varied from 0.01° for the angular measurement between the central incisor and the palatal plane and 0.01 mm between the distance from the auxiliary tube to the point of intrusive force application to 0.24 mm for the distance between the incisal edge and the maxillary first molar. None of the differences were statistically significant.

Treatment protocol

Patients were recruited after explanation of the treatment plan by orthodontist. First bands and brackets were placed and segments aligned. Alignment was performed in segments, the anterior segment extending from right to left lateral incisor and the buccal segment from canine to first molar. When the wire segments were rigid and passive, one lateral cephalogram, five intra-oral photographs (one frontal, two buccal, and two occlusal photographs), and one set of impressions with a wax bite in centric occlusion were taken. In order to be certain that the segments were passive, they were left in place for five weeks after insertion, before records were taken and intrusion was started. At the same visit the intrusion arch was placed (Figure 4).

***Figure 4** Patient at the start of intrusion.*

Visits were scheduled every five weeks. During each visit the intrusive force was measured, recorded, and, when necessary, adjusted to the proper level. When the incisors were intruded to the proper level, the intrusion arch was removed and a lateral cephalogram, impressions, and wax bite were taken (Figure 5). The same actions were undertaken when side effects were clearly present. Loose bands and brackets were recorded and replaced in such a manner that the segment remained passive.

Figure 5 *Patient at end of intrusion*

To test the null hypotheses (see Introduction) Pearson's product moment correlation coefficients (r; 2-tailed) were calculated.[10,11]

Results

Table 1 demonstrates that the maxillary central incisor was flared a mean of 8.74°, which was statistically significant ($P < .001$). The first null hypothesis was therefore rejected.

Measurement	Mean	SD
incisor angulation at start (degrees)	71.03	6.09
incisor angulation at finish	62.30	7.05
incisor angulation change (degrees)	8.74	3.71

Table 1
Change in axial inclination of the maxillary central incisor

There was no statistically significant correlation between the distance from the point of force application to the center of resistance of the incisor at the moment when the intrusion was started and the change in axial inclination of the incisor between the start and end of intrusion (Table 2). Null hypothesis two was therefore accepted.

	D pF-Cr	D Mx1-PP	D Mx1-Mx6
pF-Cr	0.16 (0.31)	0.11 (0.49)	-0.15 (0.37)
Mx1-PP		0.03 (0.88)	
D Cr-PP		-0.20 (0.21)	

Table 2
Pearson's product moment correlation coefficients (r) with the significance in parentheses (2-tailed).
Distance from the point of force application to the center of resistance of maxillary central incisor : pF-Cr (measurement 3)
Change in distance from the point of force application to the center of resistance of maxillary central incisor: D pF-Cr (change in measurement 3)
Angle between the central incisor and the palatal plane: Mx1-PP (measurement 2)
Change in angle between the central incisor and the palatal plane: D Mx1-PP (change in measurement 2)
Change in distance from the center of resistance of the central incisor to the palatal plane:
D Cr-PP (change in measurement 1)
Change in distance from incisal edge to the distal side of the first molar: D Mx1-Mx6 (change in measurement 4)

The correlation between the distance from the point of force application to the center of resistance of the maxillary anterior segment at the start of intrusion and the change in distance from the incisal edge to the first molar between start and finish of intrusion was not statistically significant (Table 2). Null hypothesis three was therefore accepted. The mean distance from the point of force application to the center of resistance of the maxillary central incisor was 2.1 mm (standard deviation 1.56) at the start of intrusion.

The correlation between the distance from the point of force application to the center of resistance at the start and at the end of intrusion was not statistically significant (Table 2), which leaded to acceptance of null hypothesis four.

The correlation between the distance from the point of force application to the center of resistance of the central incisor at the start of intrusion and the change in this distance between start and end of intrusion was not statistically significant (Table 2). Null hypothesis five was therefore accepted.

There was no statistically significant correlation between the amount of intrusion and the change in axial inclination of the central incisor (Table 2). Therefore also the sixth null hypothesis was accepted. The duration of treatment ranged from 9 to 31 weeks with a mean of 17.77 weeks.

Discussion

According to studies on dry skulls, the center of resistance for a segment of four maxillary incisors with a normal axial inclination lies apical of a point between the distal side of the canine[3] and the distal side of the lateral incisor.[4] In this study a one-piece intrusion arch was used.[1,2] The most distal point of force application is at the distal side of the lateral incisor bracket, which is approximately 3 mm anterior to the distal side of the lateral incisor. This study evaluated the clinical effects of the selection of this point of force application. The mean axial inclination of the central incisor increased a statistically significant 8.74° (Table 1). It was no surprise that this increase in axial inclination occurred, because the point of force application was anterior to the center of resistance as determined by both dry skull studies[3,4].

Based on this finding it would be logical to assume that the larger the distance from the point of force application to the center of resistance at the start of intrusion, the larger the change in axial inclination of the central incisor between start and end of intrusion would be. An increase in axial inclination would increase the distance between the point of force application and the center of resistance.[1,2]

The second hypothesis described the correlations between the distance from the point of force application to the center of resistance of the maxillary incisor and the change in axial inclination. The third hypothesis described the correlations between the distance from the point of force application to the center of resistance of the maxillary incisor and the distance from incisal edge to first molar. In case the incisor was flared, this distance would increase. The fourth hypothesis described the correlations between the distance from the point of force application to the center of resistance of the maxillary incisor and the distance from the point of force application to the center of resistance at the end of intrusion. The fifth hypothesis described the correlations between the distance from the point of force application to the center of resistance of the maxillary incisor and the change in distance from the point of force application to the center of resistance between start and end of intrusion.

In this study none of the correlations as tested for the second through the fifth hypothesis were statistically significant. The most likely explanation for finding no statistically significant differences within the sample is that, in this sample, the axial inclination at the start of intrusion was normal. The differences in distance between the point of force application and the center of resistance were therefore small within the sample and caused no statistically significant differences in axial inclination and incisal edge position.

Each patient included in this study needed a minimum of 2 mm intrusion of the maxillary anterior segment. This was determined from the initial records. The decision to stop intruding the maxillary incisors was made clinically by observing the overbite. When incisors are flared the overbite decreases.[1,2,12] The amount of intrusion in this study is defined by the vertical movement in cranial direction of the center of resistance of the maxillary central incisor. Based on the assumption that an increase in axial inclination of the incisors can be related to a decrease in vertical movement of the center of resistance, the correlation between the amount of incisor intrusion and the change in incisor axial inclination was measured and found not statistically significant.

In a clinical situation where maxillary incisor intrusion is wanted and the incisor axial inclination can be increased, incisor intrusion can be performed with a one-piece intrusion arch with the point of force application at the distal side of the lateral incisor bracket. If an increase in axial inclination is not wanted, the clinician should change the point of force application in the distal direction.

Conclusions

The first null hypothesis was rejected. Intrusion of the maxillary anterior segment by application of the intrusive force at the distal side of the lateral incisor bracket caused a statistically significant mean increase in axial inclination of the central incisor of 8 to 9°.

The other null hypotheses were accepted. There was no statistically significant correlation between the distance from the point of intrusive force application to the center of resistance at the start of intrusion and the change in axial inclination of the incisor.

No statistically significant correlation was found between the distance from the point of intrusive force application to the center of resistance at the start of intrusion and the change in distance from the incisal edge to the distal side of the first molar.

There was no statistically significant correlation between the distance from the point of intrusive force application to the center of resistance at the start of intrusion and at the end of intrusion.

No statistically significant correlation between the distance from the point of intrusive force application to the center of resistance at the start of intrusion and the change in this distance between start and end of intrusion was found in this study.

There was no statistically significant correlation between the amount of intrusion and the change in axial inclination.

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CHAPTER 6

GENERAL DISCUSSION

In the 1950's Burstone developed the segmented arch technique[1], which applies the laws of physics to orthodontics. This technique has several advantages over continuous arch therapy in space closure in extraction cases[2] and facilitates genuine intrusion of the anterior teeth[3,4,5]. One of the limitations of continuous arch therapy has been its inability to produce genuine intrusion of incisors[6]. Only a few clinical studies evaluating incisor intrusion with the segmented arch technique have been published[4,6,7]. Gottlieb's study evaluated intrusion radiographically[4]. The sample size was unfortunately very small and there was no randomization in the selection of patients. Weiland, Bantleon, and Droschl compared in a retrospective study two methods of deep overbite correction[6]. All patients in this study were adults, no headgear was used and the point of intrusive force application was individually adjusted. This study clearly indicated that deep overbite correction with a one-piece intrusion arch did produce incisor intrusion. Leveling with a continuous arch technique corrected the overbite by extrusion of posterior teeth. In order to deliver a high quality of evidence based orthodontic care and increase efficiency, more clinical research is needed to evaluate the side effects from incisor intrusion and to test the methods to prevent side effects as recommended in previous studies[1-11]. Although observational and in vitro studies give the clinicians rough treatment guidelines, clinical trials are indispensable for evidence based orthodontics.

In order to investigate the factors causing unwanted side effects a prospective randomized clinical trial was designed to answer the following questions:
1. Does high pull headgear wear prevent steepening, extrusion and narrowing of the buccal segments and does it influence the rate of intrusion? (chapter 2)
2. Does the size of the buccal segment influence the amount of steepening, extrusion and narrowing of the buccal segments and the rate of intrusion? (chapter 3)
3. Is the magnitude of intrusive force of influence on the amount of steepening, extrusion and narrowing of the buccal segments and the rate of intrusion? (chapter 4)
4. In patients with a normal axial inclination (within two standard deviations) of the anterior segment, does application of an intrusive force at the distal wings of the lateral incisor brackets causes a change in axial inclination of that segment? (chapter 5)

In the following paragraph the inclusion criteria for the patients in this study are discussed. Orthodontic patients between the ages of 10 and 15 years, needing maxillary central and lateral incisor intrusion of at least two millimeters and willing to participate in this study were recruited from all patients referred to the principal investigator's practice. This age range was selected, because it represents the majority of the population that is being treated in orthodontic practices, adolescents. The 2 millimeter limit was chosen, because this distance exceeds the margin of error. They had at least maxillary first molars, first and second premolars, canines and all maxillary incisors present and fully erupted. Patients with extremely flared or upright incisors (deviating more than 2 standard deviations from the norm) as well as patients with periodontal disease were excluded. The reason for excluding patients with extremely flared or upright incisors is, because the distance between the point of force application and the center of resistance differs from patients with a normal axial inclination. These patients need a modified force system for effective intrusion[1,3,5,10]. The force system in patients with periodontal disease is also different from patients with a healthy periodontium. The center of resistance lies further apically in patients with loss of periodontal attachment compared to patients with a healthy periodontium[7]. Patients with crowding to the extent that they need extractions in order to perform alignment were also excluded. When premolars are extracted the buccal segment decreases in size, which can increase the side effects.

After registration the patients were randomly assigned to one of 4 groups of 10. In all 40 patients intrusion was performed using a one-piece intrusion arch[3,4,5,10], which was attached to the anterior segment at the distal wings of the lateral incisor brackets. This location was selected, because it is the closest to the center of resistance in the one-piece intrusion arch configuration. It was therefore assumed that by selecting this location the axial inclination of the incisors will experience the least change in a one-piece intrusion arch system. One group was considered the reference group. The intrusive force in this group was 10 grams per incisor, the buccal segments extended from canine to the first molars, the anterior segment included al four incisors, and no transpalatal arch or headgear was used. This force level and size of the buccal segments was selected in order to test the recommended appliance design[1,3,10]. The transpalatal arch was not used in order to test it's necessity for maintaining arch width. Patients from the second group were instructed to wear a high pull headgear at night, which was the only difference from the reference group. In the third group only the intrusive force differed from the reference group: 20 grams per incisor. The last group had a buccal segment which only included the first molars; all other parameters were the same as the reference group. The reason for selecting only the first molar as buccal segment was to magnify the observed side effects by reducing the buccal segment. A slightly larger buccal segment, for example first molars and second bicuspids, would furthermore make correction of side effects more difficult, because an increase in steepening of the buccal segments would be accompanied by extrusion of the bicuspid.

This study demonstrated that with a one-piece intrusion arch, applying either 10 or 20 grams of force per incisor and with a buccal segment extending from canine to first molar or including just the first molar, with or without high pull headgear, maxillary incisors could be intruded more than 2 millimeters (mean amount of intrusion was 2.34 mm). This is in line with previous studies from which the recommendation of 10 to 20 grams of force per tooth for maxillary incisor intrusion comes[3-6].

High pull headgear wear was recommended in previous studies to counteract steepening and extrusion of buccal segments[3,5]. No previous study compared groups with and without high pull headgear and its relation to incisor intrusion. In this study the difference in the amount of steepening and extrusion of the buccal segments between the two groups was not statistically significant (chapter 2). The patients were instructed to wear the high pull headgear for 8 hours a day, but we had no means, beside asking and clinical judgment, to verify this. When the buccal segments do not include as many teeth as in this study (canines, first and second premolars and first molars) and where the anchorage situation is critical, a high pull headgear with a passive transpalatal arch could be important to prevent side effects[3,5,10,11]. The difference in rate of intrusion was also not statistically significant between the groups, which indicates that the amount of intrusive force does not decay beyond a threshold level. A difference in rate of intrusion between these groups was not expected from previous studies[3,4,5]. The difference in intermolar width was statistically significant, but small. In order to prevent any change in arch width a passive transpalatal arch can be applied as recommended by Burstone and Manhartsberger[11]. In this study no transpalatal arch was used.

No previous study has reported on the effect of the size of the buccal segment in relation to side effects from intrusion. Based on recommendations from Burstone buccal segments commonly include first and second premolars, first molars and sometimes the canines[3,4,5]. In chapter 3 the influence of the size of the buccal segment on side effects of the buccal segments and on the rate of intrusion was evaluated. The short segment group had a buccal segment, which included only the first molars. In the long segment group the buccal segment extended from canine to first molar. In the short segment group the buccal segment steepened a statistically significant greater amount than in the long segment group. There was, however, no statistically significant difference in rate of intrusion. When the buccal segment is tipped back, the amount of intrusive force on the anterior segment decreases, but apparently not to a degree that it influenced the rate of intrusion. The intermolar width increased in the short buccal segment group and decreased in the long buccal segment group. Even though the changes were small, the difference between the groups was statistically significant. From previous studies a decrease in intermolar width was expected in the short segment group, but not an increase in width[3,5]. The increase in width could be explained by the distal tipping of the first molars. This tipping occurred along the dental arch, which caused the molar to move in a buccal as well as in a distal direction. Possibly the decrease in width was prevented by occlusal interferences. In clinical situations where the buccal segment is smaller due to a lack of posterior teeth, measures like a high pull headgear and transpalatal arch[1] are necessary to prevent side effects.

A higher force level of twenty grams per tooth did not intrude teeth faster than 10 grams per tooth did (chapter 4). Changes in intermolar width, axial inclination and extrusion of buccal segments were however not different between the higher and lower force groups. Even though there was no difference between the groups in axial inclination change of the buccal segments, the change of both groups combined was statistically significant. The absolute amount of steepening of the buccal segment was however so small, that it was clinically insignificant. From earlier studies[3,4,5] an increase in side effects could be expected with an increase in intrusive force, although no previous study has compared different levels of intrusive force. Apparently the amount of delivered force was still not so high, that side effects were observed in the group with the higher force level. Higher force levels in general however, are known to cause more root resorption[12]. Melsen used an even lower force level than 10 grams per tooth in patients with a periodontally compromised dentition[7]. These findings indicate that there is no reason to increase the amount of intrusive force over 10 grams per incisor. It would be interesting to find out if maxillary incisor intrusion can be realized with forces lower than 10 grams per tooth.

According to studies on dry skulls, the center of resistance for a segment of four maxillary incisors with a normal axial inclination lies apical of a point between the distal side of the canine[8] and the distal side of the lateral incisor[9]. When the point of force application is anterior to the center of resistance of the anterior segment flaring of that segment is expected[3,4,5,8,9]. In the study by Weiland, Bantleon , and Droschl the point of intrusive force application was individually adjusted in each patient[6]. In this study the point of force application was at the distal side of the lateral incisor bracket in all 40 patients. The mean axial inclination of the central incisor increased statistically significant (between 8 and 9 degrees, chapter 5). In a clinical situation where maxillary incisor intrusion is wanted and the incisor axial inclination can be increased, incisor intrusion can be performed with a one-piece intrusion arch with the point of force application at the distal side of the right and left lateral incisor bracket. If an increase in axial inclination is not wanted, the clinician should change the point of force application in the distal direction. A 3-piece intrusion arch[5] can be used to apply the intrusive force further distal than the lateral incisor bracket. Adding a horizontal force to the one-piece intrusion arch changes the direction of intrusive force more distally and can be applied in a situation where incisor retraction is wanted[10].

This clinical evaluation of a frequently applied method for incisor intrusion is a step forward towards evidence based orthodontics. Because the clinical side effects have been described, intrusion can be performed more efficiently, thereby reducing treatment time. Furthermore because high pull headgear and transpalatal arches are not necessary (in the situation as described in this study) to prevent side effects from intrusion, patient comfort will be improved and reliance on patient cooperation reduced. Although the effects of force level, high pull headgear wear and size of the buccal segment on the rate of intrusion was studied, none of these factors were of significant influence. There was however quite a range in rate of intrusion among all patients. Individual variation in bone turnover and response to orthodontic force could be a possible explanation. Further studies will be necessary to evaluate intrusion in more diverse clinical situations and to improve appliance design for a more posterior direction of intrusive force.

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CHAPTER 7

SUMMARY AND CONCLUSIONS

This study focussed on deep overbite correction by intrusion of maxillary incisors and evaluated the use of a one-piece intrusion arch and methods to prevent side effects. The use of a high pull headgear, different sizes of buccal segments and different force levels were evaluated. The purpose of the present study was to determine if:

- High pull headgear wear has an effect on steepening, extrusion, and narrowing of the buccal segments and the rate of incisor intrusion.
- The size of the buccal segment influences the amount of steepening, extrusion and narrowing of the buccal segments and the rate of intrusion.
- The intrusive force level influences the amount of steepening, extrusion and narrowing of the buccal segments and the rate of intrusion.
- In patients with a normal axial inclination (within two standard deviations) of the anterior segment, application of an intrusive force at the distal wings of the lateral incisor brackets causes a change in axial inclination of that segment.

Orthodontic patients needing maxillary central and lateral incisor intrusion of at least two millimeters and between 10 and 15 years of age were recruited for this study from all patients referred to the practice of orthodontist Van Steenbergen. Treatment was performed by this orthodontist only. Patients included in the sample had at least maxillary first molars, first and second premolars, canines and all maxillary incisors present and fully erupted and were adolescents. Patients with extremely flared or upright (such as in Class II division 2 patients) incisors were excluded as well as patients with periodontal disease. Patients with crowding to the extent that they needed extractions in order to perform alignment were also excluded. No other form of orthodontic treatment was performed in these patients during the time of maxillary incisor intrusion. All patients willing to participate in this study were included in the sample if they met the above mentioned requirements. During a 4 year period 40 patients were recruited, 21 males and 19 females, which were divided into 4 groups by simple randomization. Of each patient a lateral head film, impressions with a wax bite in centric occlusion, and intra-oral photographs were taken at the beginning and end of intrusion.

The mean amount of maxillary incisor intrusion in all 40 patients included in this study exceeded 2 millimeters. This indicates that a one-piece intrusion arch is effective in intruding maxillary incisors. The duration of treatment ranged from 9 to 31 weeks with a mean of 17.8 weeks.

The influence of high pull headgear wear on steepening and extrusion of the buccal segments, arch width, and the rate of incisor intrusion was investigated in chapter 2. Two groups of 10 patients each were studied. Patients in one group wore a high pull headgear at night and patients in the other group did not. This part of the study demonstrated that high pull headgear had no effect on steepening and extrusion of the buccal segments nor on the rate of intrusion, but did have an effect on narrowing of the buccal segments. The narrowing that occurred without using the high pull headgear and the widening that occurred because of the high pull headgear were so small, that they were considered clinically irrelevant. By performing intrusion as described in chapter 2 no statistically significant side effects took place in the buccal segments while a statistically significant amount of incisor intrusion of 2.2 mm in the no headgear group and 2.4 mm in the headgear group was observed.

The extent to which the size of the maxillary buccal segment influences the amount of steepening, extrusion and narrowing of the buccal segments and the rate of intrusion was studied in chapter 3. Two groups of 10 patients were evaluated. Patients in one group had maxillary buccal segments including canines, both premolars, and first molars. In the other group the buccal segments consisted of only the maxillary first molars. This part of the study demonstrated a slight increase in intermolar width in the short buccal segment group and a slight decrease in the long buccal segment group, more steepening of the buccal segment in the short segment group, and more proclination of the anterior segment in the long segment group. The size of the buccal segment had no influence on the rate of incisor intrusion nor on the amount of buccal segment extrusion. In both groups the mean amount of incisor intrusion exceeded 2 millimeters. In order to keep side effects from incisor intrusion to a minimum, this study showed that a buccal segment extending from canine to first molar is sufficient. A buccal segment consisting of only the first molar is insufficient in preventing side effects.

The influence of the magnitude of intrusive force to the maxillary incisors on the amount of steepening, extrusion and narrowing of the buccal segments and the rate of intrusion was described in chapter 4. Twenty patients were assigned to one of two equal groups. In Group 1 the teeth in the maxillary anterior segment were intruded using 40 grams, whereas in Group 2, 80 grams was used. The maxillary incisors could be intruded with forces of 10 to 20 grams per tooth. There was no statistically significant difference either in extrusion and steepening of the buccal segments or in intermolar width and rate of incisor intrusion between the 40 and 80 gram groups.

The consequences of application of an intrusive force at the distal wings of the lateral incisor brackets was presented in chapter 5. All forty patients included in this study were used. Intrusion of the maxillary anterior segment caused a statistically significant mean increase in axial inclination of the central incisor of 8.7°. Several relations which could demonstrate a relation between the point of intrusive force application and the change in axial inclination of the incisor were investigated. No correlations were found not to be statistically significant.

In chapter 6 a general discussion of the results and their clinical importance was presented. The results were compared with previous studies and expected outcomes.

Intrusion of the maxillary anterior segment can be performed with a one-piece intrusion arch, applying 10 grams of force per incisor and using a buccal segment extending from canine to first molar. In this situation use of a high pull headgear and/or transpalatal arch are not necessary to prevent side effects on the buccal segments. Some increase in axial inclination of the anterior segment occurs due to the point of force application. If this increase is not indicated by the treatment plan the force system needs to be changed.

This study is a clinical evaluation of intrusion of maxillary incisors with a one-piece intrusion arch. The side effects of this treatment modality have been demonstrated and appliance design recommendations have been given. This study is intended as a guideline to deliver evidence based orthodontics and as a baseline for further clinical studies.

CHAPTER 8

INTRUSIE VAN DE MAXILLAIRE INCISIEVEN

SAMENVATTING EN CONCLUSIES (SUMMARY AND CONCLUSIONS IN DUTCH)

Deze studie richtte zich op correctie van diepe overbeet door intrusie van maxillaire incisieven en evalueerde het gebruik van een 1-delige intrusieboog en verschillende methoden om neveneffecten te voorkomen. Het gebruik van een high pull headgear, buccale segmenten en verschillende hoeveelheden intruderende kracht zijn geëvalueerd. Het doel van deze studie was om te bepalen of:

• Het dragen van een high pull headgear een effect had op kanteling en extrusie van de buccale segmenten, verkleining van de tandboogbreedte in de bovenkaak en op de intrusiesnelheid.

• De grootte van het buccale segment de hoeveelheid kanteling en extrusie van dat buccale segment beïnvloedt evenals verkleining van de tandboogbreedte en de intrusiesnelheid.

• De grootte van de intrusiekracht de hoeveelheid kanteling en extrusie van het buccale segment beïnvloedt evenals verkleining van de tandboogbreedte en de intrusiesnelheid.

• Het uitoefenen van een intruderende kracht aan de distale vleugels van de laterale incisief bracket een verandering in de sagittale inclinatie van de maxillaire incisieven veroorzaakt.

Orthodontiepatiënten tussen de 10 en 15 jaren oud, uit de praktijk van orthodontist Van Steenbergen, die tenminste twee millimeter intrusie van maxillaire centrale en laterale incisieven nodig hadden, werden gevraagd deel te nemen aan deze studie. Behandeling werd alleen door de bovengenoemde orthodontist uitgevoerd. Patiënten in deze studie hadden tenminste alle maxillaire eerste molaren, eerste en tweede premolaren, cuspidaten en alle incisieven volledig doorgebroken in de tandboog aanwezig. Patiënten met sterke eversie of inversie van incisieven evenals patiënten met parodontitis werden uitgesloten van deze studie. Patiënten met zodanig veel crowding, dat extracties nodig waren om de elementen in de rij te zetten, werden ook uitgesloten. Geen enkele andere vorm van orthodontische behandeling werd uitgevoerd tijdens de periode van intrusie van de maxillaire incisieven. Gedurende 4 jaren werden 40 patiënten verzameld, 21 jongens en 19 meisjes, die op basis van toevalsgetallen in 4 groepen werden verdeeld. Van elke patiënt werd een laterale schedelfoto, afdrukken van het gebit met een wasbeet in centrale occlusie en intra orale foto's aan het begin en aan het eind van de intrusie genomen.

De gemiddelde hoeveelheid intrusie van alle 40 patiënten was meer dan 2 millimeters. Dit geeft aan, dat een 1-delige intrusieboog effectief maxillaire incisieven kan intruderen. De behandelduur liep uiteen van 9 tot 31 weken met een gemiddelde van 17.8 weken.

Het doel van het deel van de studie in hoofdstuk 2 was te evalueren of het dragen van een high pull headgear kanteling en extrusie van de buccale segmenten kan voorkomen, de boogbreedte onveranderd kan houden en de intrusiesnelheid kan vergroten. Twee groepen van elk 10 patiënten werden hiervoor gebruikt. Patiënten in de ene groep droegen 's nachts een high pull headgear en de patiënten uit de andere groep niet. Dit deel van de studie toonde aan, dat het dragen van een high pull headgear geen effect had op kanteling en extrusie van de buccale segmenten noch op de intrusiesnelheid, maar wel effect had op de tandboogbreedte. Het uitvoeren van intrusie, met of zonder het dragen van een high pull headgear, veroorzaakte geen statistisch significante neveneffecten op de buccale segmenten en intrudeerde de incisieven een statistisch significante hoeveelheid van 2.2 mm. in de headgear groep en 2.4 mm. in de groep zonder headgear.

In hoofdstuk 3 is de invloed van de grootte van het buccale segment op de hoeveelheid kanteling en extrusie van dit segment evenals de breedte van de tandboog en de intrusiesnelheid bestudeerd. Twee groepen van 10 patiënten werden hiervoor gebruikt. Bij patiënten in de ene groep bestonden de maxillaire buccale segmenten uit de cuspidaten, beide premolaren en de eerste molaren (lange segment groep) en in de andere groep alleen uit de eerste molaren (korte segment groep). Een geringe toename in boogbreedte ter plaatse van de eerste molaren aan in de korte segment groep en een geringe afname in boogbreedte in de lange segment groep werd aangetoond. In beide groepen werd het maxillaire frontsegment gemiddeld meer dan 2 millimeter geïntrudeerd. Om neveneffecten van intrusie te beperken is een buccaal segment van cuspidaat tot en met eerste molaar voldoende. Een buccaal segment, dat alleen uit een eerste molaar bestaat voorkomt neveneffecten onvoldoende.

In hoofdstuk 4 wordt de invloed beschreven van de grootte van de intruderende kracht op neveneffecten ter plaatse van de buccale segmenten en op de intrusiesnelheid. Hiervoor werden 2 groepen van 10 patiënten bestudeerd, waarbij in de ene groep het frontsegment met een kracht van 40 gram werd geïntrudeerd en in de andere groep met een kracht van 80 gram. Het frontsegment kon met beide hoeveelheden kracht worden geïntrudeerd. Er waren geen statistisch significante verschillen tussen de groepen in kanteling en extrusie van de buccale segmenten noch in boogbreedte en intrusiesnelheid.

Het deel van de studie, dat in hoofdstuk 5 wordt beschreven, evalueerde of het plaatsen van een intruderende kracht ter plaatse van de distale vleugels van de bracket van de laterale maxillaire incisief een verandering in de axiale inclinatie, in het sagittale vlak, van het frontsegment veroorzaakt. Alle 40 patiënten uit de studie werden hiervoor gebruikt. Intrusie van het maxillaire frontsegment veroorzaakte een statistisch significante gemiddelde toename in axiale inclinatie van de centrale maxillaire incisief van 8.7 graden. Verschillende correlaties met betrekking tot de relatie tussen de plaats van de intruderende kracht en de verandering in de asrichting van de centrale maxillaire incisief zijn onderzocht, maar bleken geen van allen statistisch significant.

In hoofdstuk 6 wordt een algemene discussie van de resultaten en hun klinische belang gepresenteerd. De resultaten zijn vergeleken met eerdere studies.
Geconcludeerd kan worden, dat intrusie van het maxillaire frontsegment kan wor-

den uitgevoerd met een 1-delige intrusieboog, waarbij 10 gram kracht per incisief wordt aangebracht en waarbij het buccale segment van cuspidaat tot en met eerste molaar loopt. In deze situatie zijn gebruik van high pull headgear en/of transpalatinale boog niet nodig om neveneffecten op de buccale segmenten te voorkomen. Enige toename in de axiale inclinatie van het maxillaire frontsegment vindt plaats vanwege het toegepaste locatie van het aangrijpingspunt van de intruderende kracht. Indien dit niet gewenst is, dient het krachtsysteem te worden aangepast. De neveneffecten van deze behandeling zijn aangegeven evenals aanbevelingen op het gebied van apparatuurontwerp. Deze studie is bedoeld als richtlijn voor het toepassen van "evidence based orthodontics" en als uitgangspunt voor verdere klinische studies.

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CURRICULUM VITAE

Edsard van Steenbergen was born on September 9, 1965 in Assen. After finishing VWO in 1983 he started studying dentistry at the University of Groningen in 1984 and obtained his dental degree in 1990. In the same year he started his orthodontic training at the University of Connecticut, where he obtained his Masters degree and Orthodontic Certificate in 1993. He continued his orthodontic education at the University of Connecticut as a fellow in orthodontics until the summer of 1994. He was registered as a specialist in orthodontics in The Netherlands in 1994. A few months later, in 1995, he started his orthodontic practice in Apeldoorn. In 1996 he started the research project on maxillary incisor intrusion. In 2000 he obtained his certification by the American Board of Orthodontics. He became an active member of the Edward H. Angle Society of Orthodontics in 2003. Edsard is married to Caroline. Together they have two boys: Bas and Tom.