New Designs for Intrusion Arch with Finite Element Method

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Abstract

Aim: previous designs like intrusion arch (Burstone) and Utility arch (Ricketts) to intrude anterior teeth in patients with deep bite had some advantageous, which required new consideration. The present study investigated new designs in making intrusion arch.

Materials and Methods: PATRAN and NASTRAN programs were used in this computerized simulation study. Burstone, Utility arch designs; proposed methods i.e. A and B were loaded in 11 different cross sections and in 3 situations.

Result: the results indicated a lower load-deflection rate in newly designed intrusion arches and a more appropriate condition for implementation of a light continues forces .otherwise, the extent and the type of this placement in posterior blocks due to intrusion arch reaction, were in better condition in new designs comparing with those impervious ones.

Conclusion: Considering the advantages of the proposed designs it seems that their implementation would lead to better results in incisor teeth intrusion.

Key words: Intrusion, Intrusion arch, Deep bite, Load-deflection rate

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Anterior deep bite clinically is a condition with lower teeth being overlapped vertically by anterior maxillary teeth more than a normal over bite. Deep over bite have both aesthetics and functional problems. Aesthetics problems include excessive anterior maxillary tooth show at rest, inappropriate inter-incisal angle, gummy smile and periodontal trauma. Deep bite malocclusions require a complex and time consuming treatment comparing to other orthodontic treatments.

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Some etiologic factors which leads to deep bite are as follows: inappropriate relation between maxilla and mandibular bones, large maxillary bone, deficiency of mandibular growth, inappropriate relation between alveolar process of maxilla and mandible, lingually tipped incisors, missing of posterior teeth, incomplete eruption of posterior teeth or a combination of above mentioned factors.[1-4]

Correct diagnosis of malocclusions and their treatment needs a careful and precise clinical examination of dentition, occlusion, jaw movements and facial soft tissue, as well as paraclinical examination such as cast, radiographs and photographs. Treatment of deep bite could be done through posterior teeth extrusion or uprighting, anterior teeth intrusion or increase in their inclination, change in vertical growth of alveolar process accompanied with surgical techniques or combinations of the above mentioned techniques.

One of the effective therapeutic methods for correction of deep bite is anterior teeth intrusion. Anterior teeth intrusion is an apical displacement of teeth geometric center in relation to occlusal plane or any other plane formed based on longitudinal axis of teeth.5 The advantage of anterior maxillary teeth intrusion in patient with deep bite are opening of the bite, decrease in the development of gummy smile following retraction, reduction of inappropriate tipping formation in occlusal plan, reduction in total use of elastics and decrease in possibilities of teeth roots contact with compact bone. Furthermore, Burstone (1997) indicated that it was necessary to intrude incisors for overbite correction and compensation for increase overbite after incisors retraction. The intrusion of anterior maxillary teeth by anterior high pull headgear would facilitate the mandibular growth and also it would have a favorable effect on facial aesthetics.[6]

In many cases, anterior teeth intrusion is the best choice and the side effects of this treatment is to a large extent preventable. [7] In the process of intrusion, it is possible to minimize damages occurred in pulp, dentin, and root resorption with low force implementation. [8-9] Furthermore with low force application and precise anchorage preservation it would be possible to reduce the intrusion reaction over anchorage unit. Thus; the method selected for anterior intrusion should have the following characteristics: possibility of maximum anchorage use; minimum of the force application in anterior teeth part; and least complexity.

Two major orthodontic intrusion techniques for the maxillary anterior dentition have been developed: the segmented arch [6, 13- 14] and the bioprogressive [15]. Both use intrusion arches with anchorage on posterior teeth but with different wire composition, shape, and point of force application.

Currently, a few clinical trials have evaluated variables such as side-effects 16-19 force magnitude and application point of the intrusive force 20 for the bioprogressive or the segmented arch techniques. A limited number of studies have also compared the segmented 21 or Ricketts11 technique with a continuous arch wire technique, whereas one study focused on incisor intrusion in patients with marginal bone loss using both techniques.[22]

In the present study two new designs of intrusion arch are presented and their results were compared with two common designs in relation to orthodontic force application by finite element method.

Materials and Methods

A copy of standard maxillary cast with 100% magnification was made and a point was selected on the copied sheet as the center of coordinates. For determining this point a horizontal line was drown from distal of first molar and another line was drown from the contact point of central teeth which is prependicular to the horizontal line. In the obtained coordinate system, the X axis shows mediolateral dimension, the Y axis represents anteroposterior dimension and the Z axis indicates occlusogingival dimension. After selecting points, 3mm apart from buccal of teeth, their coordinates were defined. The buccal cusp tip of first premolar ,the second premolar and canine, contact point between canine and lateral, contact point of central teeth in midline and a point at the tip of the mesiobuccal cusp of first molar were determined in 1mm from the teeth.

These points with their coordinates were given to the computer as the input of the study. The PATRAN software was used to make models. For all designs of study firstly a half of the models were constructed then its complete model was obtained by mirroring. For formation of helix design circles with 3mm diameter were drown in helix location. The circles were rotated in a way that their initial points were aligned in a same spiral. Then the points were formed by connected bows and helices. In this stage, primary circles were deleted and the geometric model was completed. The constructed model was elemented by use of bar element and choose of little element for stabilizing the stress rate .The lines and bows between points were divided into some segments. While the length of the segments in helix parts was about 0.5 mm. it was about 0.7- 0.8 mm in others areas. Then the models were given to the computer based on the elemented segments and the properties of stainless steel alloy including elastic modulus =170000 Mpa and poison ratio=./3.[10-12]

For determining the properties the Beam type element was given to the computer in order to choose the model, cross section form and its size. Three load cases including only one fixation and force application were considered for models. In the first case a 100gr force was applied at midline point of the active part of the model. In the second load case a 60 gram force was applied at two point distal to lateral teeth (30 gram for each side) and finally in the third load case a 40gram force at two point distal to lateral teeth was applied (20 gram for each side).

While the first load case was prepared for examining and comparing methods with different cross sections in Burstone loading condition; the second and third load cases were prepared for intrusion of maxillary and mandibular anterior teeth.

The methods under investigation were as follows:

Burstone (Base Arch) Design: This design has two tails located in the auxiliary tube of the molar tooth and gets a 4 mm step toward the gingival after exiting from the tube. In this part, it reaches a helix with 3mm diameter (2.5 turns), and it terminates to the arm. The arm gets a 2.5 mm step toward incisal in distal side of the lateral tooth and terminates to the anterior bow (Figure 1).

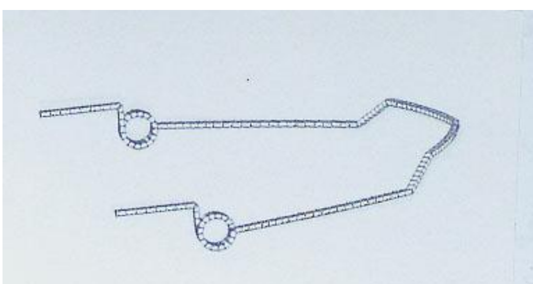

Figure 1: A constructed model from the intrusion arch of the Burstone design

Utility Arch (Ricketts) Design: This design has two tails for locating in the main tube of the molar tooth and has a 4 mm step toward gingival and inside vestibule in mesial side of the molar tooth tube and then continues toward the mesial. In distal side of the lateral teeth, again, it gets a 4 mm step toward incisal and terminates to the anterior bow. (Figure 2)

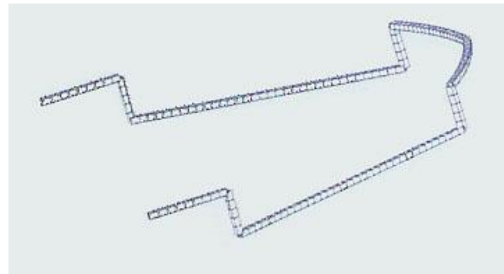

Figure 2: A constructed model from the Utility Arch design

Design A:This design also has two tails for locating in the main tube of the molar tooth. The tail continues in mesial direction and sites in the bracket of the second premolar tooth. In the mesial end of this bracket, it gets a 3 mm step toward gingival, and then returns to the distal and form a helix with 3 mm diameter and 2.5 turns about the mesial side of the first molar tooth tube and continues to the mesial. In distal point of the lateral tooth, it gets a 2.5 mm step toward the incisal and terminates to the anterior bow. (Figure 3)

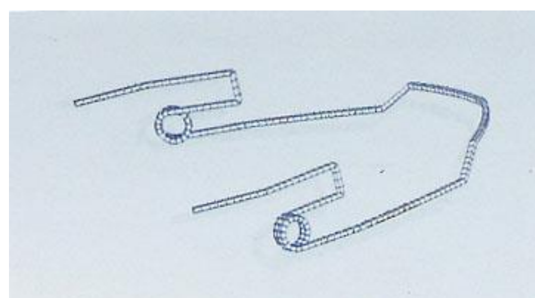

Figure 3: A constructed model from the design A

Design B: This design is based on the first premolar tooth as a subsidiary tooth over the anchorage unit. In this design, there are two tails in molar tooth site. Their mesial extension is in brackets of the first and the second premolar teeth; after that, it gets a 3mm step toward gingival and then returns to distal. A helix with 3 mm diameter and 2.5 turns is formed around the mesial tube of the first molar and extends toward the mesial. Finally, after making a 2.5

mm step in distal of the lateral tooth, it terminates to the anterior bow. (Figure 4)

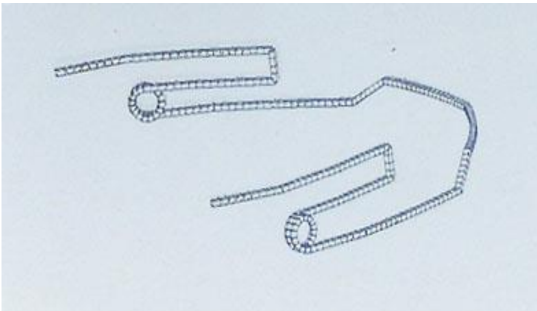

Figure 4: A constructed model from the suggested design B

Blocks similar to maxillary anterior and posterior teeth were modeled for comparing displacement of anterior and posterior segments caused by intrusion arches. Block designs were in a way that the ratio of their root surfaces with each other to the real ratio of the corresponding root surfaces became equal. The determined ratio of central and lateral root surfaces to the first and second premolar and first molar root surfaces was 0.43. Central and lateral teeth to the first molar was 0.88 and central and lateral root surfaces to the second premolar, first and second molar was 0.35. All ratios were followed through designed models.

After confirming finite element analysis through application test on Burstone design (already available); 11 different cross sections were chosen for each model and force application (load case) status. File was made for each of above combinations and transferred to the NASTRAN software for analysis.

Results

Tables 1 to 4 represent the rates of wire displacement in midline point in three different loading and cross section status in the Burstone, Rickettes, suggested A and B designs. In addition, the displacement extent and direction of posterior blocks (including the second premolar, the first and the second molar teeth) which have been formed as a result of extrusive force response by the intrusion arch in the suggested A and B designs are rendered in tables 5 and 6.

Table 1: Amount of wire displacement at midline point (mm) in three different mode of loading and cross section (Load-Deflection rate of each specimen are demonstrate in parenthesis) in the Burstone design

Amount and point of force application / Shape and cross section of wire	20 gram distal to lateral incisor teeth (40 gram in anterior segment)	30 gram distal to lateral incisor teeth (60 gram in anterior segment)	100 gram at midline point
Round 14	33/40(1/20)	50/20(1/19)	108/00(0/92)
Round 16	19/60(2/04)	29/40(2/04)	63/40(1/58)
Round 18	12/20(3/28)	18/40(3/26)	39/60(2/52)
Round 20	8/03(4/98)	12/00(5/00)	26/00(3/85)
R.A 16*16	11/70(3/42)	17/60(3/41)	38/00(2/63)
*R.A 16*22	8/21(4/87)	12/30(4/88)	26/50(3/77)
R.A 17*25	5/99(6/68)	8/98(6/68)	19/30(5/18)
R.A 18*22	5/83(6/86)	8/75(6/86)	18/90(5/29)
R.A 18*25	5/07(7/89)	7/60(7/89)	15/70(6/37)
R.A 19*25	4/33(9/24)	6/50(9/23)	14/00(7/14)
R.A 21*25	3/24(12/34)	4/86(12/34)	10/50(9/52)

*R.A: Rectangular

Table 2: Amount of wire displacement at midline point (mm) in three different mode of loading and cross section (Load-Deflection ratio of each specimen are demonstrated in parenthesis) in the Utility arch(Ricketts) design.

Amount and point of force application / Shape and cross section of wire	20 gram distal to lateral incisor teeth (40 gram in anterior segment)	30 gram distal to lateral incisor teeth (60 gram in anterior segment)	100 gram at midline point
Round 14	15/60(2/56)	23/30(2/57)	53/70(1/86)
Round 16	9/12(4/38)	13/70(4/38)	31/50(3/17)
Round 18	5/69(7/02)	8/54(7/02)	19/60(5/10)
Round 20	3/74(10/69)	5/60(10/71)	12/90(7/75)
R.A 16*16	5/42(7/38)	8/13(7/38)	18/70(5/35)
***R.A 16*22**	3/86(10/36)	5/80(10/34)	13/30(7/52)
R.A 17*25	2/83(14/13)	4/24(14/15)	9/73(10/28)
R.A 18*22	2/73(14/65)	4/10(14/63)	9/42(10/61)
R.A 18*25	2/39(16/74)	3/58(16/76)	8/22(12/16)
R.A 19*25	2/04(19/60)	3/05(19/67)	7/01(14/26)
R.A 21*25	1/52(26/31)	2/28(26/31)	5/23(19/12)

*R.A: Rectangular

Table 3: Amount of wire displacement at midline point (mm) in three different mode of loading and cross section (Load-Deflection rate of each specimen are demonstrated in parenthesis) in the suggested design A

Amount and point of force application / Shape and cross section of wire	20 gram distal to lateral inciso (40 gram in anterior segment)	30 gram distal to lateral incisor (60 gram in anterior segment)	100 gram at midline point
Round 14	37/30(1/07)	55/90(1/07)	120/00(0/83)
Round 16	21/80(1/83)	32/80(1/83)	70/60(1/42)
Round 18	13/60(2/94)	20/50(2/93)	44/10(2/27)
Round 20	8/95(4/47)	13/40(4/48)	28/90(3/46)
R.A 16*16	13/00(3/08)	19/50(3/08)	42/10(2/37)
***R.A 16*22**	9/19(4/35)	13/80(4/35)	29/70(3/37)
R.A 17*25	6/71(5/96)	10/10(5/94)	21/70(4/61)
R.A 18*22	6/51(6/14)	9/77(6/14)	21/00(4/76)
R.A 18*25	5/68(7/04)	8/51(7/05)	18/30(5/46)
R.A 19*25	4/84(8/26)	7/27(8/28)	15/70(6/37)
R.A 21*25	3/62(11/05)	5/43(11/05)	11/70(8/55)

*R.A: Rectangular

Table4: Amount of wire displacement at midline point (mm) in three different mode of loading and cross section (Load-Deflection rate of each specimen are demonstrated in parenthesis) in the suggested B design

Amount and point of force application / Shape and cross section of wire	20 gram distal to lateral incisor (40 gram in anterior segment)	30 gram distal to lateral incisor (60 gram in anterior segment)	100 gram at midline point
Round 14	38/20(1/05)	57/30(1/05)	124/00(0/81)
Round 16	22/40(1/78)	33/60(1/78)	72/70(1/37)
Round 18	14/00(2/86)	21/00(2/86)	45/40(2/20)
Round 20	9/17(4/36)	13/80(4/35)	29/80(3/35)
R.A 16*16	13/30(3/01)	20/00(3/00)	43/30(2/31)
***R.A 16*22**	9/57(4/18)	14/40(4/17)	30/90(3/24)
R.A 17*25	6/98(5/73)	10/48(5/72)	22/60(4/42)
R.A 18*22	6/76(5/92)	10/17(5/90)	21/90(4/57)
R.A 18*25	5/94(6/73)	8/86(6/77)	19/09(5/24)
R.A 19*25	5/06(7/91)	7/54(7/96)	16/42(6/09)
R.A 21*25	3/78(10/58)	5/66(10/60)	12/20(8/20)

*R.A: Rectangular

Table 5: The displacement extent and direction of posterior blocks (including the second premolar, the first and the second molar teeth) which have been formed as a result of extrusive force response by the intrusion arch in the suggested A design (in mm).

Direction of displacement / Considered point	X axis	Y axis	Z axis
Mesial point of the second premolar tooth	Lingual 0.223	Distal 1.95	Extrusion 2.78
Mesial point of the first molar tooth tube	Lingual 0.093	Distal 1.89	Extrusion 1.39
Mesial point of the second molar tooth tube	Lingual 0.047	Distal 1.89	Extrusion 0.086
Distal point of the second molar tooth	Buccal 0.176	Distal 1.89	Intrusion 1.43

forces). Thus, in the Burstone design and intrusion arch contact, the given force to the

Table 6: the displacement extent and direction of posterior blocks (including the second premolar, the first and the second molar teeth) which have been formed as a result of extrusive force response by the intrusion arch in the suggested B design (in mm).

Direction of displacement / Considered point	X axis	Y axis	Z axis
Mesial point of the first premolar tooth	Lingual 0.334	Distal 2.22	Extrusion 2.92
Mesial point of the second premolar tooth	Lingual 0.285	Distal 2.20	Extrusion 1.93
Mesial point of the first molar tooth tube	Lingual 0.203	Distal 2.16	Extrusion 0.286
Distal point of the first molar tooth tube	Lingual 0.138	Distal 2.16	Intrusion 1.05

Discussion

Ricketts and Burstone designs were considered more than other designs for intrusion because of their special advantages. In the Burstone design, the maximum posterior anchorage is used by applying the segmented arch technique. On the other hand, intruding by this technique requires bands with auxiliary tube which leads to a complex treatment. Moreover; when the auxiliary tube is located a little more buccal than the main tube (like triple bands of maxillary first molar), the moment arm which causes the palatal rotation of this teeth becomes longer in response to the obtained extrusive force and thus increases the side effect.

Burstone mentioned that for this force application, the rate of intrusion arch activation should be 16.5 millimeter at midline point. However, in this study it is manifested that for a 100 gram force application to the anterior segment, while the intrusion arch in distal points of the lateral teeth comes into contact with the anterior segment, it should be only activated 12.70 millimeter at midline (two 50 gram anterior segment at two distal points of the lateral teeth is increased which also leads to an increase in side effects. The reason is that by changing the contact point of the intrusion arch from midline to two distal points of the lateral teeth, the anterior part of the intrusion arch would be deleted from the active spiral arm. Reduction in the length of the active arm leads to an increase in load-deflection rate and it would deliver more forces by the same activation.

Utility arch design has also some disadvantages. One of its disadvantages is that the anterior part of the wire is located directly in the brackets of the incisors leading to an inappropriate torque. Moreover, using a molar tooth over anchorage unit and inappropriate displacement of molar teeth are more observed in this design comparing to those in other designs.

Comparing the suggested design A to the Burstone design with similar anchorage unit, apparently, lingual displacement of the posterior teeth in the A design is considerably less than that in the Burstone design. The reason could be the buccal location of the auxiliary tube as compared with the main tube, and lengthening of the lingual moment arm in the Burstone design. Furthermore, distal displacement and posterior teeth extrusion is less observed in the design A, since the contact point of intrusion arch to the posterior segment is more forwarded. Therefore, the distal moment arm and the applied extrusive in the design A is shorter than their correspondences in the Burstone design, leading to less side effects on posterior teeth.

In the suggested design B, although the root surface of the blocks decreases about 242.57 units, the extent of extrusive movement in some points of lingually displacement of the posterior teeth is less than that in the Burstone design because of the shortened applied movement arm in design B. In addition, all improper teeth displacements over anchorage unit are less in the design B than those in the Burstone design even with identical anchorage units, since the applied moment arm by intrusion arch is shorter in the design B.

Comparison of the designs A and B, indicates that inappropriate displacements of posterior blocks in lingual and distal directions are increased in the design B as a result of decreases in block root surfaces. Furthermore, reduction in extrusive displacement is observed in design B. The reason for the above mentioned phenomena is that in design B, the intrusion arch contact point to more mesial posterior segments leads to still a more shortened applied moment arm by intrusion arch. Therefore, by adding the second molar teeth to the anchorage unit, in design B a considerable reduction has been occurred in improper displacements of the posterior teeth following anterior teeth reduction.

The suggested designs in this study have the following advantages: possibility of getting benefit from the advantages of segmented arch system, ability to use the maximum existed teeth in anchorage unit, no need to use auxiliary tube in molar teeth, doing intrusion during treatment without waste of time, possibility of low force application with more appropriate load-deflection rate, shortening of the applied lingual moment arm to the posterior teeth, and reduction in side effects following lingual displacements of the posterior teeth after a more buccal position of the auxiliary tube as compared with the main tube. Moreover, the most mesial contact point of the wire to the posterior segments is more anterior than that of Burstone and Utility Arch designs. Thus, the applied moment arm to the posterior segments which leads to their extrusion and crown displacement toward distal become shorter, causing fewer side effects in anchorage units. Although the applied moment arm to the anchorage unit is shortened, the length of the active arm remains unchanged. This leads to the possibility of constant low force application. Therefore, fewer changes occurred in the direction of force application during teeth intrusion; since, during intrusion a long arm passes an open bow comparing to a short one. Furthermore, in these designs there is no limitation in using headgear or palatal arch.

In addition to the above mentioned advantages, the suggested designs have lower load-deflection rate comparing to the Burstone and Utility Arch designs. For example, in the Utility Arch design made by 0.016 * 0.016 inch wire, to apply a 30 gram force to the distal of the lateral teeth, the load -deflection rate is 7.38, while if the intrusion arch was made by utilizing one of the suggested designs, the ratio would be decreased to lower than 4, leading to application of constant lower forces.

Diagrams related to the load - deflection of intrusion springs in Burstone design are rendered in different sizes of arch length, while considering that arch length factor is not a proper criterion for showing different sizes of intrusion arch, since arch width factor is not included in it. Therefore the made intrusion arches for these dental arches have different load-deflection rates while their length is identical. Regarding this issue, arch circumference i.e. the length of intrusion arch bow from the mesial point of the unilateral first molar tube to its symmetrical point on the other side, is introduced as the measurement criterion of the intrusion arch. Thus, based on each factors of length and arch circumference, the orthodontist can consider his/her selected factor as the basis.

Although the suggested designs have some advantages, it should be noted that the designs were fulfilled in computer software and their being used in clinics was with limitation.

Therefore, the results of their clinical application should be evaluated.

Conclusion

Considering the advantages of the suggested designs in this investigation, it seems that their implementation could lead to a successful intrusion of four anterior teeth. Therefore, by referring to the rendered tables and knowing about the given force and the spring load-deflection rate, the orthodontist can use one of the suggested designs for making arch intrusion.

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