Free Vector and Different Bracket Base Designs: 3D analysis using Finite Element Method

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Abstract

Aim: Introduction of new bracket designs in market and use with a range of inciso-apical dimension and base thickness arises a question in mind as" Is it necessary to standardize various bracket bases from torque delivery efficiency?"

Materials and Methods: Two bracket bases of different incio-apical dimension (3 and 6 mm.) and also two different base thicknesses (1.6 and 3.5 mm.) were modeled and moments were applied. All displacements along a defined incio-apical path were monitored to be evaluated.

Results and Conclusion: No difference was found between the displacements along the defined path in each phase of study. In this way, it was concluded that torque delivery of different brackets is not related to their base size (inciso-apical) and dimenson which is in complete agreement and confirmation of the principle of free vectors. (IJO 2006; 1: 71 - 74)

Keywors: Bracket Design, Base Thickness, Base Dimensions, Torque Delivery, Finite Element Method, FEM
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Introduction

Brackets are the main part of different fixed orthodontic appliances. In this way, much effort in bracket design improvement is observed. Different prescriptions of brackets are now in market.1This process seems to be accelerated after introduction of straight wire techniques.[2] Studying orthodontic texts reveal that various bracket forms exist.[3,4,5]

In the end of a group discussion on biomechanics, a question arose when dealing with different bracket designs with their advantages claimed by their manufacturers as "Is it necessary to standardize the size of bracket bases?" In other words, is there any relationship between the bracket base thickness, dimension (inciso - apically) and their ability to apply torque?

Bracket bases are more or less rectangular with curved sides (except for the lower anterior ones). The importance of its mesio-distal length is clear biomechanically. It has a direct effect on the inter-bracket distance which in turn affects the forces generated by arch wires and on the timing of wire progress and many other points which is beyond the scope of this study. I preferred to give answer to the question analytically instead of giving a very short one.

As we know, a force vector is defined by its magnitude, point of application, its line of action, direction, and its sense.[6-8] Forces produce displacement or deformation [6,7]. An important feature of rigid body mechanics is the possibility of sliding a force vector along its line of action which is most convenient for analysis purposes. This principle is called "Transmissibility". In this way, mechanical and whole-body effects of a concentrated force is unchanged by replacing the given force by another one which has the same characteristics but acting in other point along its line of action. [9]

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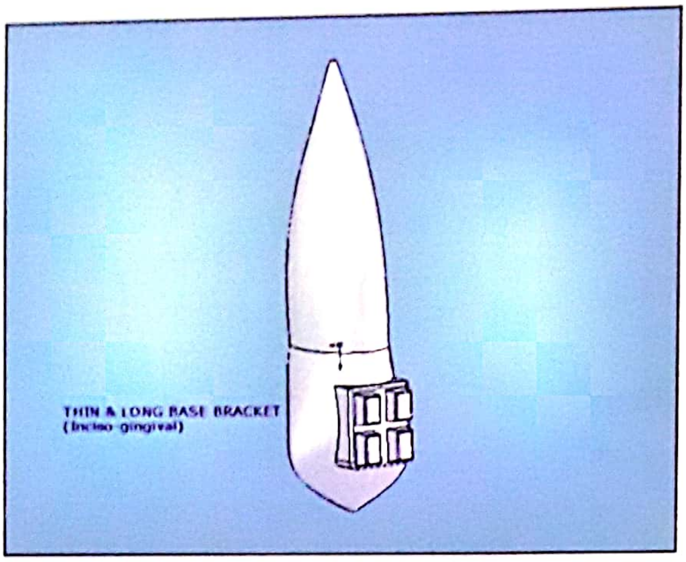


Fig 1a.

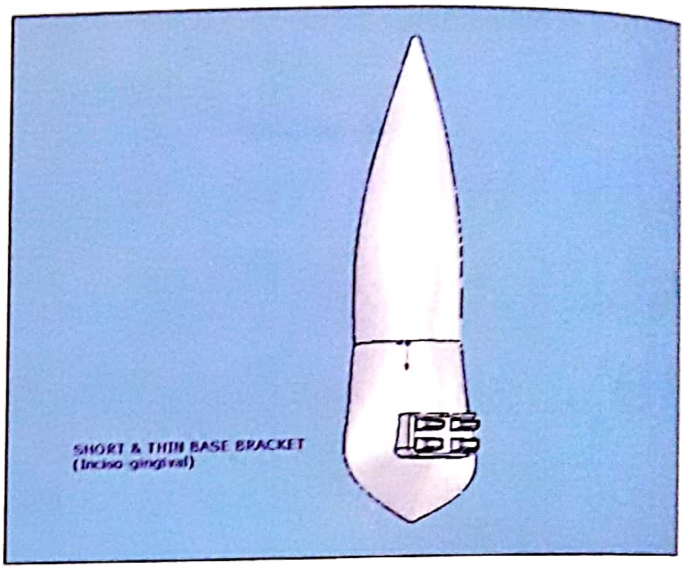


Fig 1b.

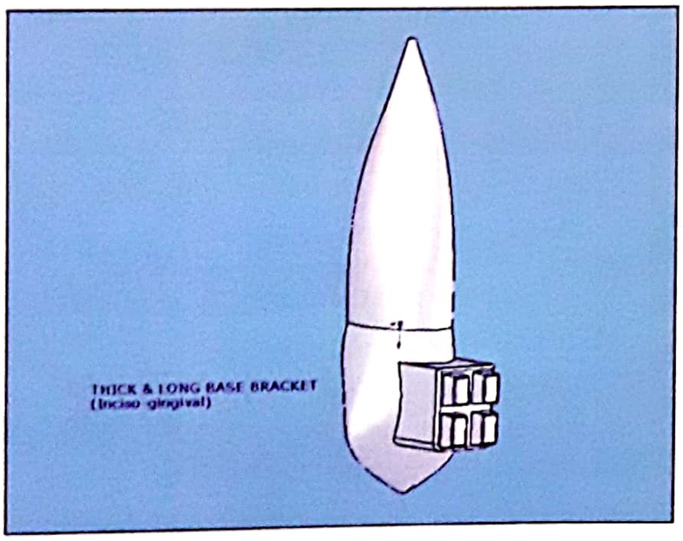


Fig 1c.

A moment, has a tendency to rotate the body acting on. A couple is applied to produce a moment. It is taught in biomechanic lectures that a couple has an inherent moment which is not related to the point where the calculations are done. So, the moment of a couple is the same with respect to every moment axis perpendicular to the plane of the forces. The vector has not a particular line of acton location and may be drawn through any point of the plane of the couple. This "freedom" associated with the couple vector has far-reaching implications with respect to certain force-analysis procedures.

Less than half a century ago, finite element method (FEM) was introduced in aerospace industry and soon entered in biologic sciences. From the very beginning of its application in biologic sciences, FEM has proven its efficiency in different ways from confirming a basic topic [10] to evaluating a theoretic background [11] and from normal situations concerning tooth movements [12] to special situations like alveolar bone resorption in orthodontic tooth movements [13-15] and from extra oral force application in orthodontics 16 to optimization of orthodontic mechanotherapies [17] or treatment procedures 18 and also in finding an answer to a clinical question. [19,20] FEM is now a well-known method of analyzing complex structures and has been successful in different parts of research puzzles

The main goal of this study was to evaluate the importance of the inciso-apical dimension of the bracket bases and their thicknesses on their toqure delivery,

Materials and Methods

A three-dimensional (3D) finite element model (FEM) of a maxillary canine was designed in Solidworks 2006 (300 Baker Avenue, Concord, Massachusetts 01742 USA.) based on Ash's dental anatomy 21 with minor modifications to obtain the best shape.

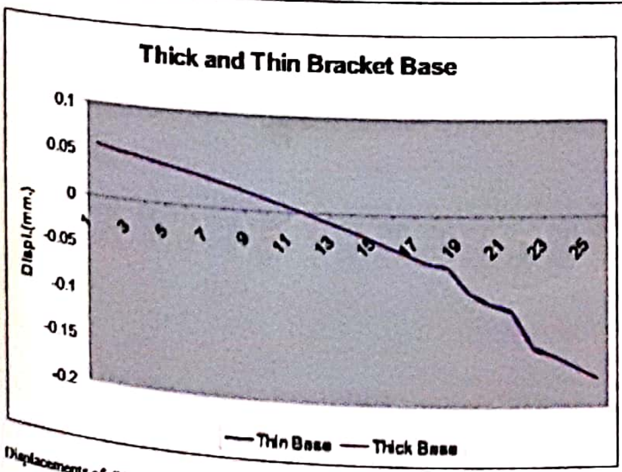
At the first stage, two bracket bases with different sizes (inciso - apically) were modeled. The first one was 3 mm and the second one was 6 mm. (Figure 1 a,b). At the second phase of this study, the first one was modified to have a thick base bracket with the same dimension (Inciso- apical). The first thickness was 1.6 mm and the second one was 3.5 mm. The models were transferred to ANSYS (Ver. 5.71 ANSYS (ANSYS Inc. Southpointe, 275 Technology Drive Cononsburg PA 15317, USA). In this study, for the analysis phase. The models were meshed with 3D brick isoparametric octahedral element. In order to evaluate the behavior of tooth under these conditions, an inciso-apical path of nodes were defined and all labio-lingual displacements in these nodes were derived and superimposed. An arbitrary moment of100 gr-mm was applied to the same position in two models containing brackets with different inco-gingival base sizes. At

	Long(=6mm)	Short(=3 mm)
1	0.009962	0.009953
2	0.009144	0.009137
3	0.008299	0.008292
4	0.007421	0.007416
5	0.006475	0.00647
6	0.005429	0.005426
7	0.004296	0.004294
8	0.003067	0.003067
9	0.001787	0.001788
10	0.000432	0.000434
11	-0.00099	-0.00099
12	-0.00248	-0.00248
13	-0.00224	-0.00225
14	-0.00565	-0.00564
15	-0.00731	-0.0073
16	-0.00907	-0.00906
17	-0.01089	-0.01088
18	-0.01178	-0.01176
19	-0.01663	-0.01662
20	-0.0184	-0.01972
21	-0.02049	-0.02191
22	-0.02257	-0.02409
23	-0.02468	-0.02628
24	-0.02675	-0.02539
25	-0.02884	-0.02757
26	-0.03093	-0.03063
27	-0.03278	-0.03258

Table 1. displacements produced in two models with different bracket base lengths (incio-apically).

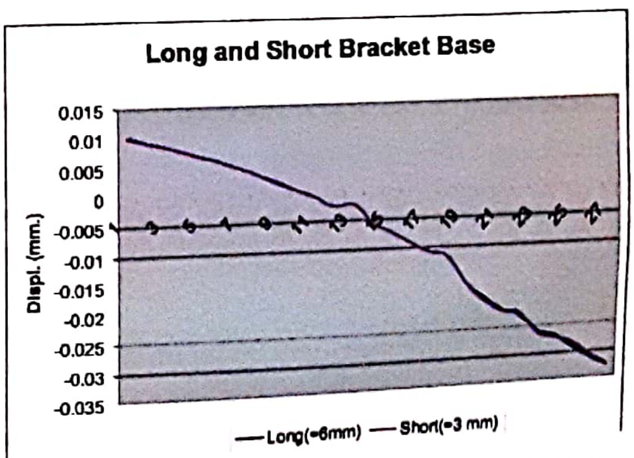
	Thin Base	Thick Base
1	0.05603	0.05601
2	0.052249	0.052239
3	0.048327	0.048312
4	0.044203	0.04419
5	0.03967	0.039659
6	0.034593	0.034583
7	0.029015	0.029006
8	0.022915	0.022907
9	0.016513	0.016506
10	0.009666	0.009659
11	0.002418	0.002412
12	-0.0052	-0.00521
13	-0.01315	-0.01316
14	-0.02159	-0.02159
15	-0.03025	-0.03025
16	-0.0395	-0.0395
17	-0.04908	-0.04909
18	-0.05347	-0.05375
19	-0.07985	-0.07985
20	-0.09102	-0.09102
21	-0.09908	-0.09902
22	-0.13715	-0.13685
23	-0.14675	-0.14672
24	-0.15792	-0.1579
25	-0.1691	-0.16909

Table 2. displacements produced in two models With different bracket base thicknesses.



Displacements of different nodes along the inciso-apical path with various bracket base thickness.

Fig 2a.



Displacements of different nodes along the inciso-apical path with various bracket base length.

Fig 2b.

the second phase of analysis, a 900- gr-mm moment was applied to the models arbitrarily and assessed in the same way as the first phase. The model consisted of 13260 nodes and 2465 elements.

Any difference between two sets of output data could be explained by the presence of a difference between two displacements and their abi;ity to delive torque.

Results

All displacements in labio-lingual direction was derived and prepared at Table 1. The highest displacements were at the incisal edge which were 0.032578 mm for the model with short base (Inciso-apically) and 0.032782 mm for the model with the long base.

The same amount of displacement was also noticed in the apical area of both models, 0.0099529 mm for the short base and 0.0099616 for the long base one.

The findings for the second phase followed almost the same behavior except for the amount of displacements. The greater the amount of torque applied the higher displacement produced. Occurrence of the highest displacements at the incisal edge was anticipated; 0.16910 mmfor the thin base bracket and 0.16909 mm for the thick based one. 0.056030 mm and 0.056010 mm of displacement was produced at the incisal edge for the thin and thick based bracket respectively. (Table 2)

Discussion

The importance of bracket base thickness and size (inciso-apically) was assessed numerically. There are certain principles in mechanics that are taught inlectures. A pile of data which are expected to be learned by students most of which need to be thought over accurately before recognized. Free vectors are such an important one among the others. It is stated that the effects of a free vector is independent of its point of application. A moment is a free vector. We are dealing with a solid body composed of the tooth, a thin layer of the bonding material, and the bracket itself. As viewed in figure 2 a, b the curves of displacements produced in the nodes along the inciso-apical path are overlapped. The easiest explanation of these findings was to confirm the freeness of the moment vector, no matter where it is applied. Not only the base size but also the base thickness is not considered important in torque delivery of the brackets designed. In this way, it is not needed to standardize the base size and thickness. Of course, there are considerations in modifying bracket base size Mesio-distally which are beyond the scope of this article to be assessed.

This study was limited to the displacements produced and could be expanded to stress assessments in the interface (composite layer) or bracket base. At that situation, some differences between stress output of two stages could be anticipated.

References

1- Graber TM, Vanarsdall RL, Vig KWL. Orthodontics Current Principles and Techniques. StLouis, The C.V.Mosby Co. 2005; PP 717-25.
2- McLaughlin RP, Bennette JC, Trevisi HJ. Systematized orthodontic treatment mechanics.
3- Proffit WR., fields HW. Contemporary Orthodontics. St Louis, The C.V.Mosby Co. 1993.
4- Graber TM, Swain BF. Orthodontics Current principles and techniques. StLouis, The C.V.Mosby Co. 1985, Chp. 9-11.
5- McLaughlin RP, Bennette JC, Trevisi HJ. Systematized orthodontic treatment mechanics. P29.
6- Marcotte M. Biomechanics in orthodontics. Philadelphia B.C.Decker 1990, Chap 1.
7- Beer FP, JohnstoneER. Vector mechanic for engineering:Static snd SI edition, McGraw-Hill Book Co.1990.
8- Meriam JL. Engineering mechanics, Statics, SI Version. John Wylie & Sons Co.1975.
9- Nikolai RJ: Bioengineering analysis of orthodontic mechanics, Lea & Febiger, Philadelphia,1985.
10- Geramy A. Harmonious translation of the Cres in different tooth movements while the force is remained constant. Journal of Dentistry, Shiraz University of Medical Sciences 2002:3(1-2); 59-65.
11- Geramy A. Faghihi SH. Secondary trauma from occlusion: 3D analysis using Finite Element method. Quintessence Intl.2004; 35:835-843.
12- Geramy A. Moment/Force ratio and the center of rotation alteration: 3D analysis by means of the F.E.M. J. Dent. Shiraz University of Medical Sciences 2000; 1(2); 26-34.
13- Geramy A. Alveolar bone resorption and the center of resistance modification: 3D analysis by means of the F.E.M. AJO/DO 2000; 117:399-405.
14- Geramy A. Initial Stress Produced in the Periodontal Membrane by Orthodontic Loads in the presence Of Alveolar Bone Loss of Varying Extent: Three dimensional analysis using Finite Element Method. European Journal of Orthodontics.2002; 24:21-33.
15- Geramy A. Stress Tensor Modification in alveolar Bone resorption: 3D analysis using FEM Journal of Dentistry, Shiraz University of Medical Sciences 2002:3(3-4); 39-49.
16- Geramy A. Cervical Headgear Force System: 3D analysis by means of the finite element method. J. Dent. Shiraz Univ. of Medical sciences 2001; 2(1); 21-30.
17- Geramy A. Optimization of unilateral overjet management: 3D analysis using finite element method. Journal of the Angle Orthodontist2002; 75(6):585-592.
18- Geramy A, Morgano S. Finite element analysis of three designs of an implant-supported molar crown. J Prosthetic Dent2004; 92:434-40.
19- Geramy A. Sharafodding F. Abfraction: 3D analysis using Finite Element Method Quintessence Intl 2003; 34: 526-533.
20- Geramy A. V-bend Force System: 3D analysis using Finite Element Method. IJO 2006, 1; 12-17.