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Research Article

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Torque Control of Upper Incisor in Intrusive Loads and Comparison of the Lingual and Labial Bracket Systems: A Finite Element Analysis

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Abstract:

Objective: The aim of present study was to investigate the difference of torque control during intrusion force in incisors with normal, under and over-torque in lingual and labial orthodontic systems through finite element analysis.

Material and Methods: 3D models of an upper right central incisor with different torques were designed in Solid Works 2006.The models were transferred to the ANSYS Workbench Version 12.1.An intrusive force of 0.15 N was applied to the bracket slot in different models and the displacements along a path of nodes in the central incisor was assessed.

Results: Intrusive force in under-torqued model in Labial system induced labial crown movement but in Lingual system caused lingual movement in the apical and incisal parts. The same forces in normal-torqued central incisor led to a palatal movement in apical and labial displacement of incisal edge in Lingual system and a palatal displacement in apical area and a labial movement in the incisal edge in Labial system. In over-torqued upper central incisor, the labial crown displacement in Labial system is more than Lingual system.

Conclusions: Application of the same forces in labial and lingual system in upper central incisor with different inclinations induce different responses. Torque control in Labial orthodontic system was more difficult than Lingual system in each situation.

Keywords: Finite element method; Intrusion; Labial orthodontic system; Lingual orthodontic system

Introduction

During the past decade, the number of adults looking for orthodontic treatment had increased. Lingual orthodontics (LiO) is a solution for aesthetic concerns among these patients who are not willing to have visible brackets on labial surface. Other advantages reported for LiO may be a decreased risk and severity of decalcified lesions (Vander Veen et al. 2010) and improved patient compliance (Kafle et al. 2012). Besides, higher bracket failure and patient inconvenience is also reported. (Kurz et al. 1998)

Main different attributes between labial orthodontics (LaO) and LiO which may be due to anatomic variations of different tooth surface and precision in bracket bonding can affect orthodontic treatment objectives.

Various studies had dedicated their attention to the differences of response in anterior teeth to vertical forces. A finite element study by Jost-Brinkmann showed that lingual force application when compared to labial force can induce more favorable response during intrusion in the periodontal ligament. (Jost-Brinkmann et al. 1993) Lombardo et al. in a study on a three-dimensional geometric model of a lower incisor demonstrated while intrusive force in LiO leads to bodily movement, labial tipping would be the result of the same loading in LaO. (Lombardo et al. 2012)

From biomechanical point of view, one difference of two systems would be the ability in torque control. Demling and colleagues in a comparative analysis of slot dimension claimed that slot precision in LiO is an important factor for minimal play of wire which results in three-dimensional control. (Demling et al. 2009) In contrast, Liang demonstrated that loss of torque control during retraction of upper incisors is more probably happen in extraction cases in LiO treatment. During retracting incisors in LiO, the control of incisor torque is so important that since when lingual crown tipping appears, it is much more difficult to correct than in LaO. (Liang et al. 2009) In LaO, Application of the intrusion force provides the retraction force and the net force vector passes from the C res but in LiO the same force induce lingual tipping and vertical bowing effect. (Gupta A. 2005)

Different types of tooth movement may be produced depending on distance between point of application and Cres. (Hocevar 1981) Considering a smaller distance between point of application and Cres in LiO than LaO (Geron et al. 2004), slight vertical displacement of the lingual bracket may have greater effect on torque than labial system.

Finite Element Analysis (FEA) is a computational method to analyze stress distribution. With this method, one can investigate the solution of challenges arised in theoretic situations (Geramy 2000), normal situations such as tooth movement (Geramy et al. 2010), bone resorption during tooth movement (Geramy 2002), orthodontic mechano therapy (Geramy et al.2008) as well as clinical situations (Geramy 2009).

Since few studies had compared the torque control of LiO and LaO, the aim of present study was to investigate the difference of torque control during intrusion force in incisors with normal, under and over-torque in lingual and labial orthodontic systems through finite element analysis.

Materials and methods

Six 3D models of an upper right central incisor and its supporting structure were designed in Solid Works 2006 (Solid Works, Concord, Massachusetts, USA). The tooth was modeled according to Ash's dental anatomy. (Nelson. 2009) It contained an upper right central incisor, its PDL, the cortical and spongy bone, and the bracket. The models were the same except for two points, their torque (which was under-torqued, normal-torqued, and over-torqued) and the bracket location (Lingual and Labial). The models were transferred to the ANSYS Workbench Version 12.1 (Ansys Inc., Southpointe, Canonsburg, PA, USA). Boundary conditions restricted displacements of the base of the models in all direction to prevent their rigid body motion. Mechanical properties (Table 1) were then applied and the models were meshed with 14596 nodes and 7300 elements. (There was a slight difference between node and element numbers between models not worth mentioning) The labial bracket dimensions were 4.5 mm width and 3.3 mm in height; while the lingual bracket was 3.65 mm width and 4 mm in height (Figure 1) A force of 0.15 N which is the appropriate magnitude of intrusion force (Proffit et al.) was applied to the bracket slot in different models and the displacements along a path of nodes in the central incisor was assessed.

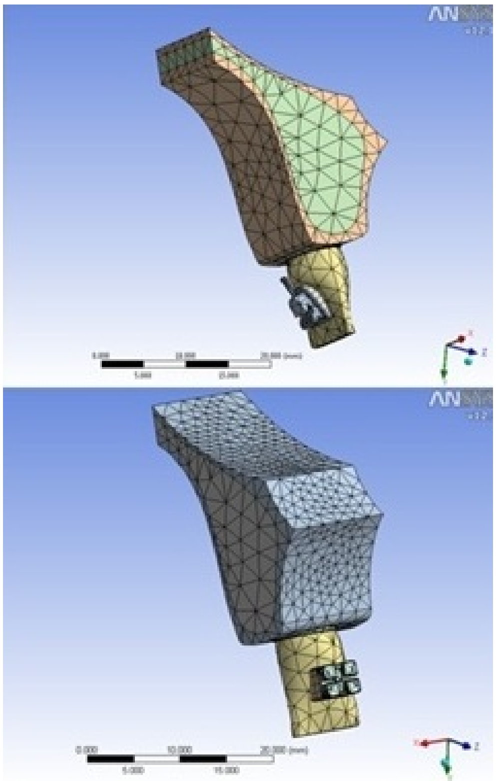

Figure 1: 3D meshed models of the normal torqued teeth with labial bracket (top) and lingual bracket (bottom)

	Young's Modulus (MPa)	Poisson's Ratio
Tooth	20300	0.26
PDL	0.667	0.49
Spongy Bone	13400	0.38
Cortical Bone	34000	0.26
Stainless steel	200000	0.26

Table 1: Mechanical properties of the materials used in models

Results

Negative findings represent a palatal displacement and positive ones show a labial movement.

Intrusive force of 0.15 N in under-torqued model in Lao induced labial crown movement (=0.000513 mm) and palatal root displacement (= -0.000316 mm) but in Lio caused lingual movement in the apical (-0.0000508 mm) and incisal parts (0.000116 mm) of the tooth. (Figure 2)

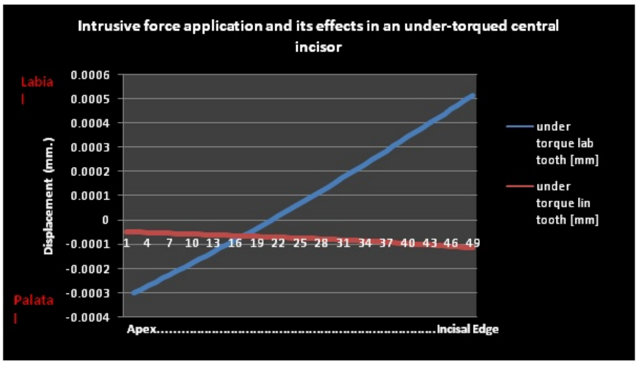

Figure 2: Tooth displacement in under-torqued upper central incisor subjected to intrusive force.

Application of the same force in normal-torqued central incisor led to a palatal movement in apical (-0.000123 mm) and labial displacement in incisal edge (0.0000326 mm) inLiO. The same situation induced a palatal displacement in apical (-0.000352 mm) area and a labial movement in the incisal edge (0.000505 mm) in LaO. (Figure 3)

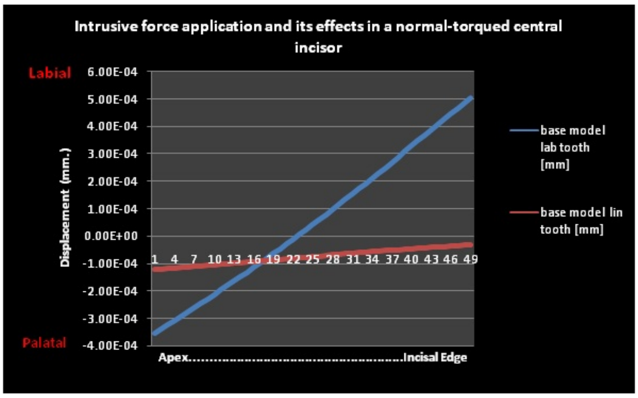

Figure 3: Tooth displacement in normal-torqued upper central incisor subjected to intrusive force

Over-torqued upper central incisor subjected to intrusive force showed labial crown displacement of the incisal edge in LaO (0.000521 mm) and LiO (0.0000623 mm). (Figure 4) The labial crown displacement in LaO is more than LiO. Palatal displacement of the apical area is noticed in both techniques, more in LaO (-0.000374 mm) than LiO (-0.000192 mm).

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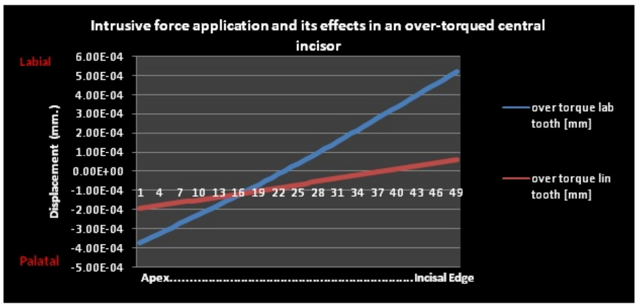

Figure 4: Tooth displacement in over-torqued upper central incisor subjected to intrusive force.

Discussion

The present study was to investigate the response of the upper incisor with normal, under and over torques to vertical load in labial and lingual orthodontic system through finite element analysis.

According to the findings, in three situations above, the magnitudes of torque loss in intrusive movements in normal, under and over-torqued upper incisors were higher in LaO than LiO. This is in accordance with the findings of Jost-Brinkmann and colleagues who claimed that during the vertical loading of upper incisors in LiO, a uniform stress distribution is generated which leads to more predictable tooth movements. (Jost-Brinkmann et al. 1993)Application of force to a determined transitional point at which pure intrusion moments generated may induce the same results. Since the moments created in LaO are often greater than LiO in the same force, magnitude of crown displacement is more noticeable in LaO. (Geron et al. 2004) The findings are also in agreement with previous statement of Shum who showed that due to the closer distance of Cres and point of application in LiO during intrusion of a normal or over-torqued upper incisor, lesser moment and labial tipping is expected. Due to the shorter distance between the force application point and C res, the magnitude of lingual root torque during the intrusive loads is smaller in LiO than LaO. (Liang et al. 2009)

In this study, in normal and over-torqued incisors, in both systems a labial crown tipping was observed. Intrusive load induced lingual crown torque with labial root torque in LiO while the same force produce labial crown torque in LaO. The counterclockwise moment which causes labial crown torque in LaO by application of intrusive force was also reported in previous investigations. (Geron et al. 2004) The counterclockwise moment induced by lingual intrusive load in an under-torqued one would increase retroclination. (Shum et al. 2004)

Conclusion

Application of the same intrusive forces in labial and lingual systems in upper central incisor with different inclinations induced different responses. The magnitudes of torque Loss during intrusive loads in incisors with normal, under and over-torque were higher in Labial system than Lingual orthodontic appliances.

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