ORIGINAL ARTICLE

Torque control of the maxillary incisors in lingual and labial orthodontics: A 3-dimensional finite element analysis

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Introduction: Lingual orthodontics has developed rapidly in recent years; however, research on torque control variance of the maxillary incisors in both lingual and labial orthodontics is still limited, especially studies with 3-dimensional finite element methods. Thorough understanding of the biomechanical differences of incisor torque control during lingual and labial orthodontic treatment is critical for the best results. **Methods:** A 3-dimensional finite element model of the maxilla and the maxillary incisors was made with 98,106 nodes, 71,944 10-node solid elements, and 5236 triangle shell units. Horizontal retraction force, vertical intrusive force, and lingual root torque were applied to simulate labial and lingual orthodontic treatment. Then the distribution of the stress-strain (maximum and minimum principal stresses; maximum and minimum principal strains) in the periodontal ligament, the total displacement, and the vector graph of displacement of the nodes of the maxillary central incisor were analyzed and compared between labial and lingual orthodontics. **Results:** Loads of the same magnitude produced translation of the maxillary incisor in labial orthodontics but lingual crown tipping of the same tooth in lingual orthodontics. This suggests that loss of torque control of the maxillary incisors during retraction in extraction patients is more likely in lingual orthodontic treatment. **Conclusions:** Lingual orthodontics should not simply follow the clinical experience of the labial techniques but should increase lingual root torque, increase vertical intrusive force, and decrease horizontal retraction force properly to achieve the best orthodontic results. (Am J Orthod Dentofacial Orthop 2009;135:316-22)

Lingual orthodontics (LiO), the highest esthetic orthodontic technique, has developed rapidly in recent years, with over 10,000 new patients in American, European, and Asian countries each year. Moreover, LiO can achieve as excellent treatment results as labial orthodontics (LaO).[1,2] Many lingual cases have been reported, and the results were as good as in LaO, including nonextraction, extraction, and orthognathic cases.[3-5]

There are many clinical and biomechanical differences between LiO and LaO, especially torque control of the maxillary incisors during the movement of retraction.[1-6] As we all know, it is not difficult to control the torque of the incisors during retraction in LaO, but, in LiO, it is difficult to correct once torque control of the incisors is lost.[1-3] Therefore, it is essential for better orthodontic results to completely understand the biomechanical differences of torque control of the maxillary incisors during retraction between LiO and LaO.[2,3]

The purpose of this study was to provide the lingual technique with valuable information by using a 3-dimensional (3D) finite element method (FEM). The FEM has proved to be effective in simulating tooth movement and optimizing orthodontic mechanics.[7-20] However, few studies have compared torque control of the incisors between LiO and LaO with the FEM.[21,22] In this study, a 3D FEM model of the maxilla and the maxillary incisors was constructed. Loads were applied to the model to simulate retraction of the maxillary incisors. Then the torque control of the maxillary incisors and the biomechanical differences between LiO and LaO were analyzed.

MATERIAL AND METHODS

The 3D FEM model of the maxilla and the maxillary incisors was established (Fig 1) with 98,106 nodes,

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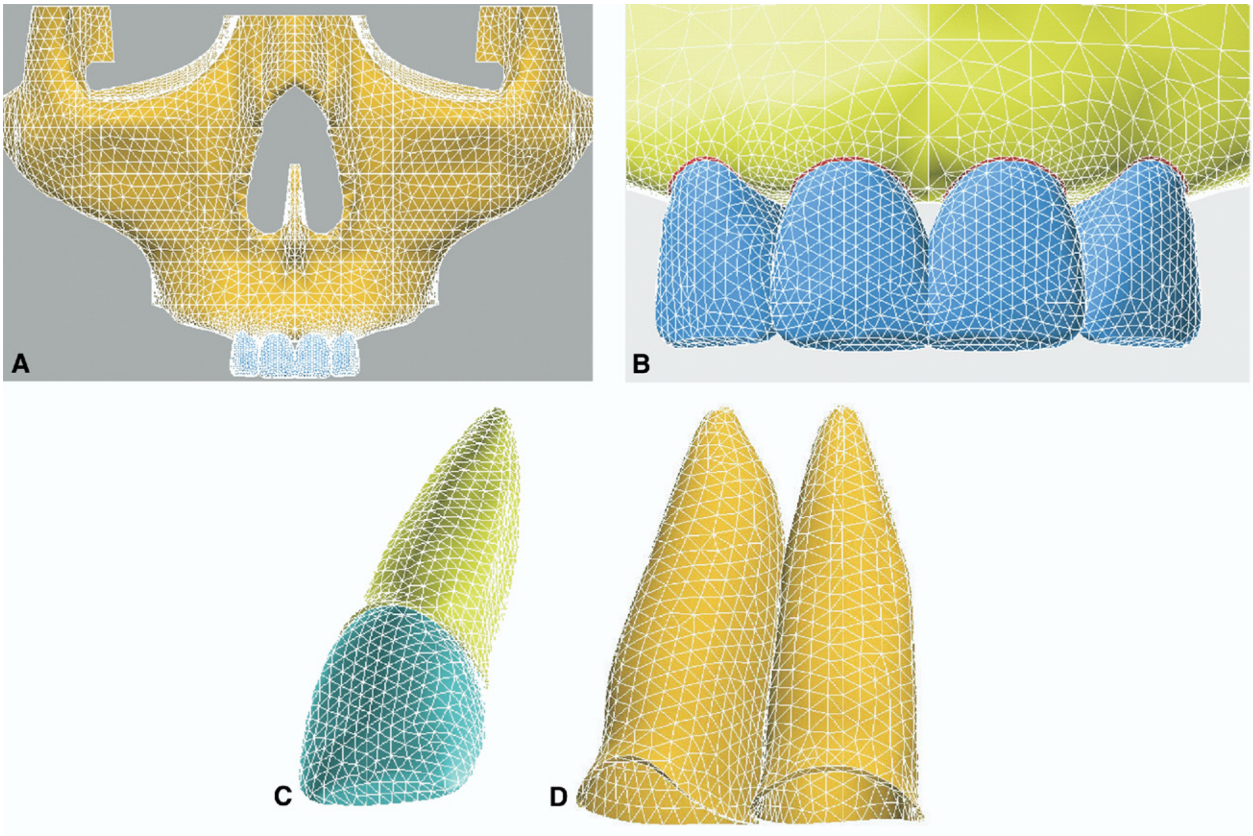

Fig 1. A, 3D FEM model of the maxilla and the maxillary incisors; **B,** enlarged image showing incisors, PDL, and alveolar bone; **C,** maxillary central incisor with the PDL; **D,** PDL of a maxillary central incisor and a lateral incisor.

71,944 10-node solid elements, and 5236 triangle shell units (cortical bone). The data of the maxilla model came from Karlsruhe University, Karlsruhe, Germany, and were modified with software ANSYS (version 7.0, ANSYS Inc, Canonsburg, Pa). The geometric models of the maxillary incisors were based on standard sample teeth with general morphologic conditions from the School of Stomatology, Peking University, Beijing, China. The heights of the maxillary central and lateral incisors were 23.55 and 22.84 mm, respectively; the root lengths were 14.4 and 14.07 mm, respectively. The periodontal ligament (PDL) was simulated as a 0.2-mm thick layer around the roots, and the cortical bone was 0.5 mm thick.[9-18] When designing the 3D FEM model, smaller elements were assigned to the areas with the potential for high-stress gradients, such as teeth, PDL, and adjacent alveolar bone. ANSYS for Windows was used to fuse the models of the maxilla and the maxillary incisors and analyze the results. Isotropic and linearly elastic behavior was assumed for all materials, and the mechanical properties were taken from previous studies[7-15] (Table). The boundary condition was defined as the exterior border of the maxilla.

Table. Mechanical properties for maxilla, tooth, and PDL

Material	*Young's modulus (N/mm^2)*	*Poisson's ratio*
Cortical bone	1.37×10^4	0.26
Cancellous bone	1.37×10^3	0.30
Tooth	1.96×10^4	0.30
PDL	0.667	0.45

Load 1, $M_0 + F_0 + F_Z$ (Fig 2), was applied to the midpoint of the labial surface of the crown of maxillary central and lateral incisors, according to the center of the labial brackets in LaO: (1) M_0 was a -5×10^{-3} N · M couple in the lingual root direction (a pair of horizontal forces of equal magnitude acting in parallel but opposite directions), (2) F_0 was a 1-N horizontal retraction force in the lingual direction, and (3) F_Z was a 0.64-N vertical intrusive force (Fig 2).