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Original article

Effect of gable bend incorporated into loop mechanics on anterior tooth movement: Comparative study between en masse retraction and two-step retraction

Pao-Chang Chiang[a], Yoshiyuki Koga[b,*], Jun-ya Tominaga[a], Hiroya Ozaki[a], Ryo Hamanaka[a], Mayumi Sumi[a], Noriaki Yoshida[a]

[a] Department of Orthodontics and Dentofacial Orthopedics, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan
[b] Department of Orthodontics and Dentofacial Orthopedics, Nagasaki University Hospital, Nagasaki, Japan

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A B S T R A C T

Purpose: To verify whether en masse retraction or two-step retraction could provide more effective torque control of the anterior teeth when varying the degree of gable bend in loop mechanics.

Materials and methods: The forces and moments delivered by 10 mm high teardrop loops with gable bends of 0, 5, 10, 15, 20, 25, and 30° were calculated by the tangent stiffness method and applied to three-dimensional (3D) finite element (FE) models. FE models simulating en masse retraction and two-step retraction were constructed separately. The movement patterns of the maxillary central incisor, namely the degree of lingual crown tipping and the location of the center of rotation (CRo), were analyzed.

Results: The moment to force (M/F) ratio generated by activation of closing loops increased as the degree of gable bend was increased from 0 to 30°. The degree of lingual crown tipping increased in en masse retraction, whereas it decreased in two-step retraction as the degree of gable bend was increased. Although the location of the CRo remained almost at the same position in en masse retraction, it moved apically in two-step retraction when increasing the degree of gable bend.

Conclusion: Incorporation of gable bends into closing loops would provide effective torque control of the anterior tooth in two-step retraction. Conversely, it is considered that the movement patterns of anterior teeth are hardly influenced by gable bends placed into loops in en masse retraction.

* *Corresponding author at*: Department of Orthodontics and Dentofacial Orthopedics, Nagasaki University Hospital, 1-7-1 Sakamoto, Nagasaki 852-8588, Japan. Tel.: +81 95 819 7669; fax: +81 95 819 7670.
E-mail address: koga@nagasaki-u.ac.jp (Y. Koga).

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1. Introduction

Closing loops have been widely used for space closure in the treatment of four premolar extraction cases ever since the Tweed technique was established [1,2]. Since loop mechanics is a frictionless technique, 100% of the force generated by loops can be directly transmitted to each tooth from the archwire without losing force or moment, unlike sliding mechanics, which generate binding of the archwire in the bracket slots due to friction in the course of treatment [3]. Moreover, this technique has the potential to produce preprogrammed moment to force (M/F) ratios for achieving the desired type of tooth movement by incorporating gable bends into closing loops [4]. Treatment mechanics for space closure have mostly changed from loop mechanics to sliding mechanics in recent years due to its simplicity, improved patient comfort and reduced chair time, and as it is more applicable in combination with temporary anchorage devices. However, loop mechanics is still considered a much more efficient technique for controlling the position of the center of rotation (CRo), namely, the type of tooth movement by providing appropriate M/F ratios from the perspective of biomechanics.

There are two mainstream methods of anterior teeth retraction in loop mechanics. One is en masse retraction, in which six anterior teeth are retracted all at once. The other is two-step retraction, which includes a single canine retraction followed by retraction of four incisors. However, to date, a clear distinction between indications of en masse retraction and two-step retraction has not been established. Although many studies analyzed the force systems acting on the tooth during the activation of closing loops experimentally [4–6] or analytically [7,8], there have been very few attempts focusing on the resultant tooth movement. The aim of this study was thus to clarify the different effects of gable bends in loop mechanics on anterior tooth movement during en masse retraction and two-step retraction by means of the finite element (FE) method in combination with large deflection analyses based on tangent stiffness method.

2. Materials and methods

2.1. *Tangent stiffness method*

The forces and moments acting on the ends of closing loops associated with various degrees of gable bend (0, 5, 10, 15, 20, 25, and 30°) were calculated by means of a structural analysis based on the tangent stiffness method, in which large deflection can be handled [9]. The closing loop examined in this study was the teardrop type, which was 10 mm in height. The interbracket distance was 14 mm, and the loop was set in the centered position and was bent from a 0.017 × 0.022-in stainless steel archwire with Young's modulus of 200,000 MPa. The teardrop loop was idealized by 62 elements. Analysis of the loop is performed in two load steps. In case the gable bend of θ degree is given to the loop, forced rotation of $\theta/2$ is given to both ends. Then forced displacements of 1.0 mm are given to both ends, at which the model was restrained by all translations and rotations. Forces and moments acting on both ends of the loop were calculated upon each application of above-mentioned boundary conditions.

2.2. *Three-dimensional (3D) FE model and material parameters*

A multi-image cone beam computed tomography (CT) scanner (3DX, J. Morita, Kyoto, Japan), was used to take images of the maxillary dentition (left side only). The CT images were saved and converted to a 3D FE model using FE analysis pre- and postprocessor software (Patran 2013 64 bit, MSC Software Corp, Los Angeles, CA, USA). The details of the procedure have been described in previous articles [10,11]. Each 3D FE model for periodontal ligament (PDL), alveolar bone, bracket, and archwire were separately constructed using the same software. Thickness of the PDL was determined to be a uniform 0.2 mm and the material parameters used in this study are shown in Table 1 as stated in previous studies [12,13].

An appliance with 0.018-in bracket slots and a 0.017 × 0.022-in stainless steel archwire was generated to simulate the actual clinical situation. The 3D FE models consisted of 37,454 nodes and 189,595 elements or 33,690 nodes and 169,676 elements in the en masse retraction model and the two-step retraction model, respectively (Fig. 1).

2.3. *Experimental conditions*

The en masse retraction model was created based on the assumption that all six anterior teeth were retracted at one time by loop mechanics for a bilateral first-premolar extraction case. On the other hand, the two-step retraction model was reconstructed for simulating retraction of four incisors by loop mechanics after a single canine retraction.

The force systems calculated by the tangent stiffness method were applied to the points on the archwire corresponding to the ends of the brackets next to the extraction space (the distal end of the canine's bracket and the mesial end of the second premolar's bracket in the en masse retraction model or the distal end of the lateral incisor's bracket and the mesial end of the canine's bracket in the two-step retraction model) on the 3D FE model of the maxillary dentition. The displacement analyses were performed using a 3D FE program (Marc, MSC Software Corp, Los Angeles, CA, USA).

2.4. *Evaluation of movement pattern of maxillary central incisor*

To scientifically evaluate the effect of changes in the angle of gable bend on the movement patterns of anterior teeth, the

Table 1 – Material parameters of tooth, PDL[a], Alveolar Bone, Archwire, and Bracket.

Material	Young's modulus (MPa)	Poisson's ratio
Tooth	20,000	0.30
PDL	0.05	0.30
Alveolar bone	2000	0.30
Archwire/Bracket	200,000	0.30

[a] PDL indicates periodontal ligament.