ORTHODONTIC WAVES 74 (2015) 93–98

Available online at www.sciencedirect.com

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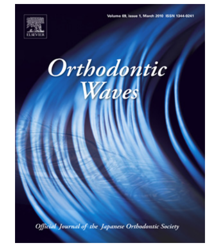
journal homepage: www.elsevier.com/locate/odw



Original article

Effect of power arm on anterior tooth movement in sliding mechanics analyzed using a three-dimensional digital model

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ARTICLE INFO

Article history:
Received 27 October 2014
Received in revised form
16 June 2015
Accepted 16 June 2015
Available online 9 July 2015

Keywords:
3D model analysis
Sliding mechanics
Power arm
Superimposition
Center of rotation

ABSTRACT

Purpose: The present study tested the hypothesis that the type of anterior tooth movement is correlated with the height level of the power arm with respect to the center of resistance (CRe) of a tooth, but not with the power arm length itself in sliding mechanics using three-dimensional (3D) model analysis.

Materials and methods: Anterior teeth were retracted with sliding mechanics using power arms of different lengths in five subjects with maxillary protrusion. Anterior tooth movements during three months' retraction were assessed by means of 3D model analysis, and the relationship between the power arm length and the distance from the center of rotation (CRo) to CRe, and the relationship between the distance from the level of the power arm hook to CRe and the CRo-CRe distance were evaluated.

Results: The height level of the power arm relative to CRe was significantly correlated with the CRo-CRe distance, but there was no significant correlation between the power arm length and the CRo-CRe distance.

Conclusion: Anterior tooth movement during retraction varied with the anatomical parameters of individual patients, even if the same power arm length was employed. The present findings suggest that the height level of the power arm relative to CRe is the most influential factor determining the tooth movement, while the power arm length itself has less impact on subsequent tooth movement. Therefore, it is recommended that an optimal power arm length be calculated back from the location of CRe at the beginning of treatment and treatment progress be monitored using 3D model analysis.

1. Introduction

Premolar extraction is frequently indicated in the treatment of Class II Division 1 malocclusion with increased over-jet caused by proclined maxillary incisors. To improve facial esthetics and obtain the desired closed spaces within the arch, it is essential to maintain control of the movement of the anterior teeth. Two types of mechanics have been employed for space closure; however, sliding mechanics has replaced loop mechanics due

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http://dx.doi.org/10.1016/j.odw.2015.06.001

to its simplicity, reduced chair time and improved patient comfort [1].

The utilization of sliding mechanics has become increasingly widespread in recent years because it is more applicable for temporary anchorage devices (TADs) than loop mechanics [2–8]. The advantage of sliding mechanics is that the force system involving the direction and the height level of retraction force can be freely adjusted by attaching various lengths of power arms onto the archwire. It is therefore believed that the use of power arms allows clinicians to perform effective torque control of the anterior teeth in sliding mechanics. However, the mechanical conditions for achieving the desired type of anterior tooth movement are still unknown. To date, no guidelines on biomechanical parameters, such as power arm length or its relative height to the center of resistance (CRe) of the anterior tooth in sliding mechanics have been established.

In previous studies, the movement patterns of the anterior teeth before and after space closure in sliding mechanics with the combined use of TAD have been evaluated, mostly using cephalometric analyses [3–8], which could impose additional radiation risks on patients. Some studies have investigated the effect of power arm length on anterior tooth movement based on *in vivo* measurements or the numerical analysis of initial tooth displacement by means of a magnetic sensing device [9,10] or finite element method (FEM) [11–14]. However, the initial tooth displacement obtained in these studies only reflected the physical distortion of the periodontal ligament, thereby only momentary displacement was observed. Consequently, there is a need for an alternative method for precise cephalometric analysis of long-term orthodontic tooth movement. Such a method would also prevent unnecessary radiation exposure to the patient. Superimposition of digital images of serial dental casts using a three-dimensional (3D) surface scanning system [15–17] may be a suitable method for assessing orthodontic tooth movement following bone remodeling. To our knowledge, no previous study has investigated the effect of power arms in sliding mechanics using 3D model analysis.

The aims of the present study were as follows: (1) to assess the movement pattern of the anterior teeth when the length of power arms varied depending on individual patients in sliding mechanics with the combined use of TADs by means of 3D model analysis; and (2) to test the hypothesis that the type of anterior tooth movement correlates with the height level of power arm with respect to CRe of a tooth, but not with the power arm length itself.

2. Materials and methods

2.1. Sample

The sample consisted of dental casts obtained from 5 patients (2 males, 3 females; mean age, 18 years 7 months; age range, 18 years 6 months to 19 years 8 months) who were undergoing orthodontic treatment after a diagnosis of maxillary protrusion at the Department of Orthodontics, Nagasaki University Hospital.

2.2. *En masse retraction with sliding mechanics*

As part of orthodontic treatment, the bilateral maxillary first premolars were extracted, and two titanium screws (1.6 mm in diameter, 8 mm in length, Dual-Top, Jeil Medical Corp., Seoul, South Korea) or plates (SMAP system, Dentsply-Sankin, Tokyo, Japan) were inserted in the buccal region between the second premolars and first molars or between the first and second molars on both sides. Preadjusted 0.018 in. $\times$ 0.025 in. slot edgewise appliances with Roth prescription (Sincere Brace, Rocky Mountain Morita Corp., Tokyo, Japan) were bonded in all patients. A 0.017 in. $\times$ 0.022 in. stainless steel archwire was used as a working archwire. Power arms were attached to the archwire between lateral incisors and canines. To perform en-masse retraction with sliding mechanics, a force of 250 g parallel to the occlusal plane was applied to the power arm hooks with elastic chains (Super Chain, Tomy International Inc., Tokyo, Japan).

2.3. *3D model analysis*

Impressions for maxillary dental casts were taken twice just after the completion of the leveling phase and three months after the initiation of the retraction phase using alginate impression material (Aroma Fine Plus, GC Corp., Tokyo, Japan). Dental casts were made with extra hard dental die stone (New Fujirock, GC Corp., Tokyo, Japan) and then scanned by a laser surface scanning system (VMD-25, UNISN, Osaka, Japan). Based on scanned data, reconstruction and analysis of 3D images were performed using commercial software (Imageware 9, UGS PLM Solutions, Plano, TX, USA). 3D images of dental casts before and after three months of retraction were superimposed and then anterior tooth movements were evaluated according to the method described in a previous study [18]. The location of the center of rotation (CRo) of the left maxillary central incisor, which represents the pattern of tooth movement during retraction, was determined according to the above-mentioned procedure. Although there are several definitions of CRo, the present study used the definition of Christiansen and Burstone [19], wherein CRo is the intersection of two lines coincident with the extensions of the tooth axis before and after displacement (Fig. 1). The location of CRe was measured from the cephalogram according to the finite element study [20] that determined its location for a single-root tooth at two-fifths of the root length from the alveolar crest.

2.4. *Mechanical, biomechanical and anatomical parameters*

A geometric representation of the mechanical, biomechanical and anatomical parameters of sliding mechanics with the combined use of power arms and TADs is shown in Fig. 2. An intraoral view of the treatment mechanics employed in this study is shown in Fig. 2. Both power arm length (PAL) and the perpendicular distance from the level of the power arm hook to CRe (PAH-CRe) are initial loading conditions. If stated in detail, PAL indicates the height of retraction force, and PAH-CRe represents the height of retraction force relative to the level of CRe. Therefore, they are considered to be mechanical