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Original article

Qualitative and quantitative evaluation of central incisor movement by integration of three-dimensional images of dental cast and cephalogram

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ARTICLE INFO

Article history:
Received 2 October 2014
Received in revised form
22 December 2014
Accepted 6 February 2015
Available online 25 April 2015

Keywords:
3D model analysis
Surface laser scanning
Tooth movement
Superimposition
Center of rotation

ABSTRACT

Purpose: The present study aimed to establish a method for qualitatively and quantitatively determining tooth movement by integrating three-dimensional (3D) model analysis and cephalometric analysis.

Materials and methods: Superimposition of 3D images of dental casts before and after orthodontic treatment was performed in two steps. First, initial and final 3D images of dental casts were superimposed at the central incisor and then the reference axis of the incisor was constructed. Second, another superimposition was carried out at the medial points of the third palatal rugae and the palatal vault. The changes in the inclination of the central incisor were measured using an established method of 3D model analysis and cephalometric analysis. The error of measurement in 3D model analysis was compared with that in cephalometric analysis.

Results: There was no significant difference in the degree of incisor tipping between times (Time 1 and Time 2) for cephalometric analysis and 3D model analysis, and between the averaged (Time 1 and Time 2) measurements from cephalogram and the 3D model. The error of measurement for 3D model analysis was 0.58°, and the 95% confidence interval (CI) was [−0.62, 0.62]. Corresponding values for cephalometric analysis were 2.02° and [−1.49, 2.73], respectively.

Conclusion: The 3D model superimposition method established in the present study was found to be reliable enough to determine the degree of tipping and the location of the center of rotation of the incisor before and after orthodontic treatment.

1. Introduction

Proper evaluation of the outcome of orthodontic treatment is important for further improvement of therapeutic efficiency in treatment mechanics. Cephalometric superimposition has been widely used to assess orthodontic tooth movement. However, conventional two-dimensional (2D) cephalometric measurements have several shortcomings, including the difficulty of identifying landmarks due to overlapping

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http://dx.doi.org/10.1016/j.odw.2015.02.003
1344-0241/

anatomical structures and the consequent low contrast, and enlargement and distortion due to divergent X-ray beams [1,2]. Moreover, rotation of the patient's head when taking serial cephalograms induces errors of projection [2,3]. For these reasons, the reproducibility of cephalometric measurements is considered to be low [4]. Another disadvantage is that the patient is exposed to radiation.

As an alternative method to cephalometric analysis, three-dimensional (3D) analysis of orthodontic tooth movement using serial dental casts has been performed since the 3D surface scanning system was developed [5–7]. Although many studies have been conducted in order to establish a method for qualitatively and quantitatively evaluating tooth movement based on 3D images of serial dental casts [8,9], most measurements were limited to only determination of 3D displacement of an arbitrary point on the crown and/or amount of tipping and rotation [10,11], which is insufficient for understanding the movement pattern of each tooth. Hayashi et al. [12,13] successfully established a sophisticated method for analyzing 3D tooth movement that is presented as rotation about and translation along the finite helical axis. However, the complexity of descriptions makes it somewhat difficult for clinicians to intuitively understand the tooth movement patterns in the course of treatment.

A lack of positional information about root apices of teeth in dental cast analysis can be a major obstacle preventing the accurate analysis of tooth movement. Such information can be complemented by the integration and registration of the images of dental casts and cephalograms. Therefore, the present study was conducted with the following aims: (1) to establish a method for qualitatively and quantitatively determining tooth movement by integrating 3D images of dental casts and cephalograms; and (2) to compare the errors of measurements in cephalometric analysis with those in 3D model analysis.

2. Materials and methods

2.1. *Sample*

The initial (T1) and final (T2) lateral cephalograms and dental casts obtained from 10 patients (4 males and 6 females) who were undergoing orthodontic treatment after a diagnosis of maxillary protrusion and extraction of bilateral maxillary first premolars at the Department of Orthodontics, Nagasaki University Hospital. The patients' ages ranged from 17 years 3 months to 24 years 9 months (mean age: 22 years 6 months).

2.2. *Measurements using cephalometric and 3D model analyses*

The changes in the inclination of the central incisor were measured using the lateral cephalograms and dental casts before and after orthodontic treatment. For the radiograph, the conventional cephalometric superimposition method was employed. That is, initial and final lateral cephalograms were superimposed on SN plane at S, and the change of U1 to SN angle was measured. For the model analysis, impressions for maxillary dental casts were taken using alginate impression material (Aroma Fine Plus, GC Corp., Tokyo, Japan), and

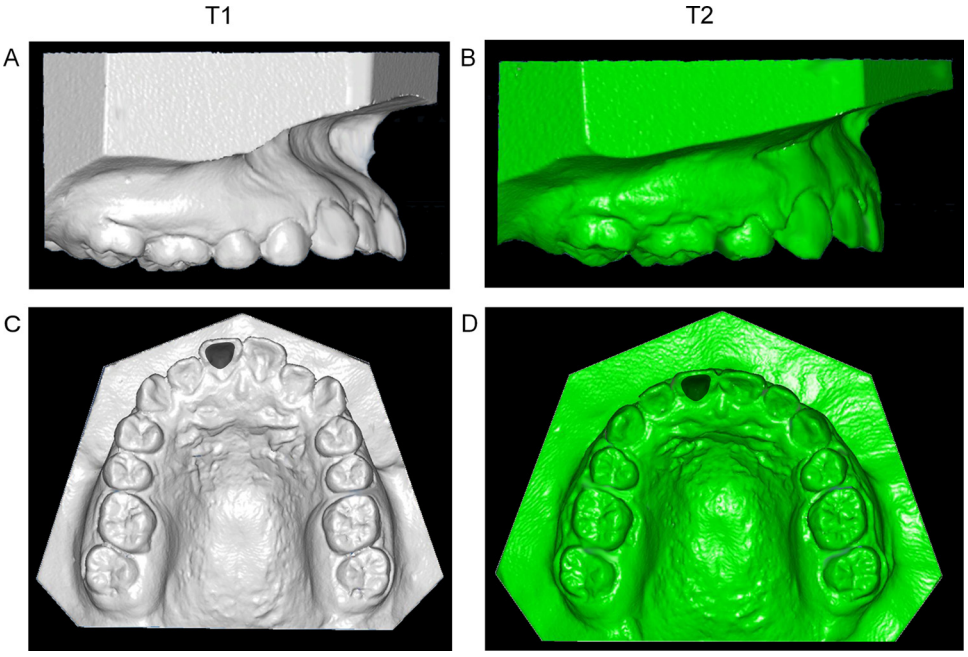

Fig. 1 – Reconstructed 3D laser-scanned images of dental casts. Lateral view before (A) and after treatment (B). Occlusal view before (C) and after treatment (D). The reference area for first superimposition is blackened on the lingual surface of the central incisor.