Consideration of accuracy of intraoral scanning and 3D printing and research on usefulness for orthodontics

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【INTRODUCTION】

The use of dental digital technology has been increasing in the last few decades. In particular, computer-aided design and manufacturing (CAD/CAM) systems has been widely accepted by the prosthodontic and restorative dentistry field. The first digital intraoral scanner was introduced by Mörmann and Brandestini in 1980s. The advantages of intraoral scanning were relieving patient's discomfort, reduction of consumption of impression materials and plaster, decreasing in storage space of cast models, identification in case of disaster. Furthermore, a part of the work at the chairside and the laboratory can be omitted by using 3D printer together. Conventional digital three-dimensional (3D) models are created by scanning impression and plaster models using a desktop scanner, or otherwise by cone-beam computed tomography. These methods have been widely accepted in clinical orthodontics. However, many studies that investigate the accuracy of digital models employ reference measurements taken by hand, typically using a caliper, which carries a risk of inaccuracy. The establishment of a reliable reference is an important consideration when investigating the accuracy and precision of digital models, and it is a process that must be considered carefully. For this, we employed a contact-type, high-accuracy coordinate measuring instrument to establish reliable reference values from linear-distance measurements.

The first purpose of this study is to compare the accuracy of models generated by desktop-scanning of cast models from conventional impression / plaster models versus intraoral scanning. The second purpose of it is to compare the accuracy of digital models generated by intraoral scanning versus three-dimensional printing models obtained from intraoral scanning. And considering the usefulness for orthodontics of dental models generated by intraoral scanning and 3D printing.

【MATERIALS AND METHODS】

1. Generation of reference measurements from dental models

A normal occlusion epoxy model was used for this study. Eight ceramic spheres (9/32 inches in diameter) were embedded half in buccal regions of the premolars and molars of this model. Contact measurements were taken from the reference model using a high-accuracy coordinate measuring instrument (H503, Mitutoyo). Center coordinates were calculated for each sphere. Twelve linear-distance measurements were calculated between these sphere-centers using the software associated with the coordinate-measuring instrument. These 12 distance measurements served as the reference values for this study. Non-contact measurements were also taken from the reference model using a desktop-scanner (REXCAN DS2, Sea Force) and 3D polygon editing software (RapidForm 2006, Inus Technology) and 3D analysis software (Imageware 10.6, Siemens PLM Software).

2. Measurements of digital models generated by desktop-scanning of plaster models from conventional impression (alginate and silicone) and generated by intraoral scanning

Ten alginate and ten silicone impressions were taken of each model. Each impression was then used to make a cast model of super-hard dental stone. Models were then scanned using a desktop-scanner to generate a total of 10 maxillary and 10 mandibular stone-model images. These digital dental models were designated as either the alginate-impression group (group 1) or the silicone-impression group (group 2). Ten intraoral scans of maxillary and mandible regions were performed using a dental intraoral scanner (TRIOS, 3shape). These models were designated as the intraoral-scanned group (group 3). 3D polygon editing software and 3D analysis software were used to

determine sphere-center coordinate (x,y,z). Six sphere-center distances were then calculated for each model using these coordinates. Mean values were calculated by subtracting each measured distance from its corresponding reference values. Mean values were then statistically compared using one-way analysis of variance (ANOVA) followed by Tukey's test, with $P < 0.05$ for statistical significance.

3. Measurements of digital models generated by intraoral scanning and 3D printing models

Ten intraoral scans of maxillary and mandible regions were performed using a dental intraoral scanner (TRIOS, 3shape). 3D polygon editing software and 3D analysis software were used to determine sphere-center coordinate (x,y,z). Six sphere-center distances were then calculated for each model using these coordinates. Then their 3D data were imported into the 3D printer (Objet 30 pro, Stratasys) and 3D printing models were obtained. The hard resin of light curing type (Objet Veroclear RGD810, Stratasys) was used as the material. Contact measurements were taken from the 3D printing models using a high-accuracy coordinate measuring instrument as with measurement of the reference models. Mean values were calculated by subtracting each measured distance from its corresponding reference value. Mean values were then statistically compared using Wilcoxon rank-sum test, with $P < 0.05$ for statistical significance.

【RESULTS】

1. Measurements of digital models generated by desktop-scanning of plaster models from conventional impression (alginate and silicone) and generated by intraoral scanning

There was significant difference the values with group 3 and the

others. All the values obtained with group 1 and group 2 were no significant difference. All other measurements for the group 3 were negative. In contrast, all measurements for group 1 and group 2 were positive, with the exception of the URP-URM distance value. The rate of transformation of digital models generated by intraoral scanning between 12 distance measurements was different from each other.

2. Measurements of digital models generated by intraoral scanning and 3D printing models

More than half the values obtained with intraoral scanner and 3D printer were significant difference. Digital linear-distance measurements calculated from intraoral scan and linear-distance measurements calculated from 3D printing model with a high-accuracy coordinate measuring instrument were smaller than reference values. The rate of transformation of 3D printing models generated by intraoral scanning between 12 distance measurements was different from each other.

【DISCUSSION】

1. Method of measurements

It is difficult that measurements of complexed shape like teeth because the result may change by different points of view. In this study, we used ceramic balls as standard markers of which we have already known the diameter and the shape. Therefore it can be reduced the possibility of selection of incorrect points, and we can obtained the high accuracy data.

2. About the result

1) Measurements of digital models generated by desktop-scanning of plaster models from conventional impression (alginate and

silicone) and generated by intraoral scanning

Digital linear-distance measurements calculated from intraoral scan were closer to the reference values than linear-distance measurements calculated from conventional impression/plaster model, because digital models by intraoral scanner can be omitted the complex work at the chairside and the laboratory. Furthermore, conventional impression/plaster model were influenced by expansion of gypsum and the error of using a desktop-scanner. The conventional impression/plaster models were more accurate than the digital models by intraoral scanner.

2) Measurements of digital models generated by intraoral scanning and 3D printing models

Digital linear-distance measurements calculated from intraoral scan were smaller than reference values. Linear-distance measurements calculated from 3D printing model with a high-accuracy coordinate measuring instrument were smaller than digital model by generated intraoral scanner. And the deformation was anisotropic.

【CONCLUSION】

Intraoral scanning may be more accurate compared to conventional impression/plaster model method. Digital linear-distance measurements calculated from intraoral scan and linear-distance measurements calculated from 3D printing model with using a high-accuracy coordinate measuring instrument were smaller than reference values. And the deformation of digital models generated by intraoral scanning and 3D printing models was anisotropic. Digital models generated by intraoral scanning and 3D printing models have not yet had high accuracy than conventional impression/plaster model. However the error between measuments of them and measuments of reference model was extremely small. So the intraoral scanner and the

3D printer were available in orthodontics.