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Original article

Comparison of repeatability between intraoral digital scanner and extraoral digital scanner: An in-vitro study

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ABSTRACT

Purpose: The aim of this study was to compare the repeatability of intraoral digital impression scanning with the repeatability of extraoral scanning by using Geomagic Qualify 12 as the software of analysis.

Methods: One Nissin Dental Study Model (upper jaw) with prepared abutments were designed to form 5 set of arrangements according to the layout of prepared abutments (arrangement 1: single prepared maxillary central incisor; arrangement 2: single prepared maxillary first molar; arrangement 3: prepared central incisor and canine with the lateral incisor absent; arrangement 4: half of upper arch with 7 prepared teeth; arrangement 5: entire upper arch with 14 prepared teeth). Each arrangement of Nissin Dental Study Model was scanned by TRIOS intraoral digital scanner (experimental group) and D800 extraoral scanner (control group) for 10 times exporting 100 STL files in total. The data were processed and analyzed using Geomagic Qualify 12 software to evaluate the repeatability of intraoral digital scanning.

Results: 3D standard deviations were 13.33, 7.0, 16.33, 41.56, 88.44 μm for arrangements 1–5 respectively in experimental group and 14.89, 8.67, 24.33, 14.22, 12.67 μm for arrangements 1–5 respectively in the control group. Mann–Whitney test revealed a significant difference between the 2 groups with regard to arrangements 2–5 ($p < 0.05$).

Conclusions: Precision decreases with the increased scanning scope. Precision was clinically acceptable when scanning scope was less than half arch. Precision of extraoral scanning was acceptable in scanning any scope of arch region.

1. Introduction

The technique of computer aided design and computer aided manufacturing (CAD/CAM) has been used to produce ceramic restorations including all-ceramic crowns and fixed dental prostheses since 1980s [1]. Many CAD/CAM systems are capable of designing and fabricating prostheses on plaster cast made from conventional silicone impressions. In those cases an extraoral scanner captures three-dimensional data

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by scanning the plaster cast followed by the procedures of computer aided design and manufacturing. Over the last twenty years of development in the field of CAD/CAM technique based on extraoral scanning, restorations generated by this technique exhibit the high performance of being eminently functional and esthetical [2]. However, nonstandard operation during impression taking and deformation of clinical material will affect the accuracy of plaster model, consequently affecting the accuracy of 3D model data and the quality of prostheses. On the other hand, dental clinical procedure started with conventional impression taking still has not met the goal of complete digitization and automation which is the major trend of dental prosthesis industry. Therefore, it is desirable to develop a facility which can take digital impressions directly from oral cavity to remove any possible error and also economize on impression materials used in conventional impression procedures.

The first digital intraoral impression system commercially available was invented and brought to use in 1987 known as CEREC 1 system [3]. It worked on the principle of ''triangulation of light'' and needed an opaque powder coating on the surface of abutments before scanning to improve the quality of scan [1]. Since then, several digital intraoral impression devices have been developed. Other than CEREC, Lava^{TM} C.O.S, iTero, E4D and TRIOS are some of the intraoral digital impression systems available in the current dental field [4].

However, there remain some difficulties and defects that need to be addressed in regards to intraoral digital impression taking. Unlike the working process of extraoral scanner which has been proved to be steady and accurate, intraoral digital impression systems are facing a major problem of scanner displacement during the scanning process which may affect the accuracy of scanning. Up to data there are few published literature studies on the performance of digital intraoral impression system, especially concerning the accuracy and precision of intraoral scanners.

The aim of this study was to evaluate the precision of intraoral digital scanning methods (TRIOS, 3Shape, Denmark) by analyzing the repeatability using Geomagic Qualify 12 (Raindrop Geomagic, Inc., Morrisville, NC) as software of analysis.

2. Material and methods

2.1. Arrangements of study model

One Nissin Dental Study Model of upper jaw (500A, Nissin, Japan) was used as the original model. Standard prepared and intact artificial teeth (Nissin, Japan) in particular distribution were seated on the original model selectively to simulate 5 clinical scenarios. The 5 arrangements were designed as followed: (1) the single central incisor was the prepared tooth, (2) the first molar was the prepared tooth, (3) central incisor and canine were the prepared teeth with lateral incisor absent, (4) 7 teeth from right first incisor to right second molar were the prepared teeth (half of the upper arch), (5) 14 teeth were the prepared teeth (the entire upper arch) (Fig. 1). For all these 5 arrangements, parameters of artificial prepared teeth were designed as: incisal/occlusal reduction of 2.0 mm, axial reduction of 1.0 mm, chamfer margin of 1.0 mm and convergence angle of 6°. The rest of tooth positions were filled with intact standard artificial teeth (Nissin, Japan).

2.2. Data capturing of intraoral and extraoral scan

For the experimental group, before the scanning work the calibration and pre-heating for scanner tip were accomplished to the intraoral digital scanner (TRIOS cart, 3Shape, Denmark) according to the instruction of the manufacturer. The original model with the first arrangement (with the single central incisor being the prepared tooth) was examined for intactness of model and artificial teeth, and afterwards, it was held in the operator's hand ready for scanning. The operator used the scanner tip to capture the contour of the selective region including the prepared teeth without scanning the whole dental arch. After a primary scan being accomplished the software inside the system would point out any possible missing areas on the main screen, and the operator proceeded with an additional scanning of these areas until a complete contour of the selective region was obtained. The same scanning operation was performed 10 times to the original model with the first arrangement. Thus the TRIOS system exported 10 files of DCM format for the first arrangement. A special software was used to convert the 10 DCM files to 10 STL files. Once the original model of the first arrangement was completed for 10 round of scanning, the artificial teeth of the second arrangement were seated on the original model to replace the former ones followed by the second round of scanning. After all the 5 arrangements of original model were scanned for 10 times, up to 50 STL files were generated.

For the control group, before the extraoral scanning, a device-dependent calibration was carried out according to the instruction of the extraoral scanner (D800 3D scanner, 3Shape, Denmark). Precision of D800 is high sub 20 microns. The resolution of D800 scanner is 1.5 mega pixels. Then the Nissin model was given a standard layer of powder coating (CEREC optispray, Sirona, Germany) on the teeth surface. The model was placed on the platform of extraoral scanner to start scanning for 10 times. When changing the arrangement of teeth, the former powder coating was removed and a respray was conducted. Like the experimental group, scanning of control group also generated 50 STL files for all the 5 arrangements.

2.3. Data processing

A 3D data analyzing software of Geomagic Qualify 12 was used to evaluate the discrepancy among these STL files. 10 STL files were obtained from every arrangement for both the control and the experimental groups. The 1st STL file out of 10 files for each arrangement was defined as reference [5]. The other 9 files were matched with the reference file respectively by a best fit algorithm. Selecting and cutting tools inside the software were used on the matched imaging data to eliminate the irrelevant area. Therefore, the ultimate 3D data of prepared teeth were generated for discrepancy analysis (Fig. 2). Using the function of ''deviation analyzing'', the Geomagic software exported an analysis report displayed in a color map (Fig. 3) [6–8]. Therefore, 9 analysis reports were