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Journal of Prosthodontic Research

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

Original article

Investigation of accuracy and reproducibility of abutment position by intraoral scanners

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ARTICLE INFO

Article history:
Received 16 October 2016
Received in revised form
11 January 2017
Accepted 24 January 2017
Available online xxx

Keywords:
Intraoral scanner
CAD/CAM
Trueness
Precision
Optical impression

ABSTRACT

Purpose: We examined the accuracy, including trueness and precision, of the intraoral scanners comparing with laboratory scanner to reveal the error level of intraoral scanners.
Methods: Measurements were performed using a computer numerical control coordinate measuring machine (CNCCMM) of the reference models as a control. Subsequently, intraoral scanners and a laboratory scanner were used for measurements of the reference trueness and precision of the distance were evaluated by image analyzing software.
Results: With regard to reference model, there was a significant difference between in the trueness measured by C.O.S. (COS) and that measured by the other scanners. The trueness measured by the second-generation 3M^{TM} true definition scanner (TDS2) and third-generation 3M^{TM} true definition scanner (TDS3) was bigger than the one by TRIOS (TR) and KaVo (KA). With regard to reference model "B," error of the trueness measured by COS was significantly bigger, compared with the one measured by the other scanners. However, error range of intraoral scanners, except for COS, was considerably small and it should be covered with cement space.
Conclusions: The results of this study indicated that an optical impression method with an intraoral scanner could be applied to the implant therapy for multiple teeth missing.

1. Introduction

Recently, with the rapid progress of information technology, the optical impression method using an intraoral scanner may bring a new era of dentistry. Newly developed pieces of equipment and technology in dentistry have enabled us to respond to various patient requirements [1]. The development of the optical impression method has centered on a system for measuring the three-dimensional shape of a working cast. Measuring methods have changed from contact system to non-contact system and the measurement speed has been considerably improved [1]. The efficiency of the production process has improved because of the advancements of

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http://dx.doi.org/10.1016/j.jpor.2017.01.005

laboratory scanners. On the other hand, making optical impressions using intraoral scanners has also been developed in which working casts were not fabricated [2].

In this method using an intraoral scanner, static images or videos of the oral cavity are taken and used to rapidly construct a three-dimensional model in order to simplify the clinical and technical operations. Consequently, impression materials and plaster become unnecessary. In addition, the application of a small intraoral scanner can be used to patients having trismus or vomiting reflexes, in which conventional impression method was not acceptable. Optical impressions using intraoral scanners are also expected to enable the improvements of compatibility of prosthetic appliances and to simplify their production methods and techniques [3]. In a ceramic restoration, a one-day treatment system has already been established, in which the processes of preparing abutments, acquiring an impression, producing a prosthetic appliance, and fitting are completed in one visit, referred to as the one day treatment system [4].

The application of this method to patients missing many teeth has also been expected. However, very few reports related to measurement error are available, and much remains unknown regarding the acquisition of optical impressions over a wide range. Furthermore, the acquisition may be affected by elements of the oral cavity environment, such as saliva, depending on the location in the oral cavity, which necessitates a longer operation time and may make an accurate measurement impossible.

Recently, a number of reports regarding optical impression studies have focused on the compatibility of optical impressions with crowns and bridges produced on the basis of the data obtained from optical impression [5–10]. Optical impression has been clinically applied to implant treatment; however, much remains unknown regarding the positional reproduction calculated by the data from special scanning abutments [11,12]. Therefore, the applications of optical impression are currently limited to some cases, and involving the missing of a single tooth is recommended.

To determine whether an intraoral scanner can be applied to the production of prosthetic appliances for the replacement of multiple implant treatment, we measured the distance between two implant ball abutments and evaluated its accuracy.

2. Materials and methods

2.1. Fabrication of reference model

A lower jaw study model for dental implant training (D16-EP.27, NISSIN, Kyoto, Japan) was used in this study (Fig. 1).

A reference ball for calibration (chromium steel ball, ϕ 10mm, grade 28, Sato Tekko Co., Ltd, Yokohama, Japan) was fixed to a lingual part. Following this, reference model A was fabricated, in which two implants having an external hex connection system (Branemark System MKIII Groovy RP, ϕ 4.0mm × 10.0mm, Nobel Biocare, Zurich, Switzerland) were placed corresponding to a mandibular left second premolar and a mandibular left first molar. Reference model B was fabricated, in which two implants were placed corresponding to a mandibular right second premolar and a mandibular right second molar.

Titanium ball abutments, each of ϕ 5mm × 5mm (ball abutment, Branemark System regular platform 5mm, Nobel Biocare, Zurich, Switzerland), were placed on the top of the implant, using a torque wrench (prosthetic torque wrench, Nobel Biocare, Zurich, Switzerland) and a driver (machines driver, Nobel Biocare, Zurich, Switzerland) to 15N. In this study, the reference models A and B with ball abutments were used to measure the distance between the centers of two ball abutments.

2.2. Measurement method

2.2.1. Computer numerical control three-dimensional coordinate-measuring machine (CNCCMM)

A CNC three-dimensional coordinate-measuring machine (UPMC 550-CARAT:Curl ZEISS, Oberkochen, Germany) and a stylus of ϕ 0.8mm (Curl Zeiss, Oberkochen, Germany) were used to calculate the reference for trueness (Fig. 2). The CNCCMM can measure the dimensions with high accuracy. This system follows Japanese Industrial Standards (JIS B7440-2), allowing for a maximum error of $0.8+L/600\,\mu m$ (L=Length: mm) in the measurement of length. This system was calibrated before the measurement to adjust the error to be 1 μm or less. Subsequently, the three-dimensional coordinates of the center located on the top of the ball abutments mounted on reference models A and B were measured 10 times to calculate a reference for trueness.

2.2.2. Intraoral scanner

In this study, Lava™ C.O.S. (abbreviated as COS below, 3M, Minnesota, USA), second-generation 3M™ True Definition-scanner (abbreviated as TDS2 below, 3M), third-generation3M™ True Definition scanner (abbreviated as TDS3 below, 3M) with an active wavefront sampling method, and TRIOS (abbreviated as TR below, 3Shape, Copenhagen, Denmark) with a confocal method were used as intraoral scanners (Fig. 3). The characteristics of each scanner are shown in Table 1.

Before the measurement, titanium dioxide powders (Lava Powder: 3M) were sprayed onto the surface of the reference models for constant reflectivity. When the intraoral scanners were used, the reference model was fixed onto a laboratory table in a room excluding the influence of extraneous light for the accurate measurement.

The measurements were performed 10 times with each scanner following the instruction of each manufacturer by one operator. The measurements were performed facing an occlusal plane, a buccal plane, and a lingual plane, in that order, and no omission of the image data was confirmed. Following this, the obtained 3D data were converted and sent as STL (Standard Triangulated Language) data (Fig. 4).

2.2.3. Laboratory scanner

KaVo ARCTICA Auto Scan (abbreviated as KA below, KaVo Dental Excellence, Biberach, Germany) was used as a laboratory scanner (Fig. 3). After calibration, the measurement was performed 10 times, following the scan protocol of the manufacturer. No omission of the image data was confirmed,