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Original article

Trueness and precision of digital impressions obtained using an intraoral scanner with different head size in the partially edentulous mandible

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ABSTRACT

Purpose: It remains unclear whether digital impressions obtained using an intraoral scanner are sufficiently accurate for use in fabrication of removable partial dentures. We therefore compared the trueness and precision between conventional and digital impressions in the partially edentulous mandible.

Methods: Mandibular Kennedy Class I and III models with soft silicone simulated-mucosa placed on the residual edentulous ridge were used. The reference models were converted to standard triangulated language (STL) file format using an extraoral scanner. Digital impressions were obtained using an intraoral scanner with a large or small scanning head, and converted to STL files. For conventional impressions, pressure impressions of the reference models were made and working casts fabricated using modified dental stone; these were converted to STL file format using an extraoral scanner. Conversion to STL file format was performed 5 times for each method. Trueness and precision were evaluated by deviation analysis using three-dimensional image processing software.

Results: Digital impressions had superior trueness (54–108 μm), but inferior precision (100–121 μm) compared to conventional impressions (trueness 122–157 μm, precision 52–119 μm). The larger intraoral scanning head showed better trueness and precision than the smaller head, and on average required fewer scanned images of digital impressions than the smaller head ($p < 0.05$). On the color map, the deviation distribution tended to differ between the conventional and digital impressions.

Conclusions: Digital impressions are partially comparable to conventional impressions in terms of accuracy; the use of a larger scanning head may improve the accuracy for removable partial denture fabrication.

1. Introduction

Computer-aided design/computer-aided manufacturing (CAD/CAM) has various advantages, including a simplified approach [1] and more rapid manufacturing [2] compared with existing fabricating methods, and has been applied since the early 1980s [3]. Digital impression taking using an intraoral scanner, as one of the CAD/CAM processes, is used in the fabrication of bridges [4] as well as of single crowns [5,6]. Recently, the digital impression method has been applied to the fabrication of dental implant prostheses [7,8], complete dentures [1,9], and maxillofacial prostheses [10], and could be a suitable alternative to conventional impression-taking in future.

To fabricate prostheses with an excellent fit, it is necessary to reproduce the surface structure of oral tissues accurately during impression-taking and working cast fabrication. When taking digital impressions using an intraoral scanner, the surface structure of oral tissues is digitalized directly through optical measurements. Because this method eliminates the need for making an impression per se, various potential causes of error (such as inadequate tray selection, deformed elastic impressions, an incorrect powder–water ratio, and inadequate storage of impressions or stone casts) that come into play during the process of conventional impression-taking and stone cast fabrication can be avoided. Digital impression taking therefore has advantages [11–13] from the viewpoint of accuracy, as compared with conventional impression taking. On the other hand, reflection caused by saliva during scanning [14] and powder application to

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the object [15] can result in decreased accuracy in digital impression taking using an intraoral scanner.

According to the International Organization for Standardization (ISO), accuracy is evaluated in terms of trueness and precision (ISO5725-1) [16]. Trueness is defined as the measurement bias or systematic error between the reference object and the target object. Precision is defined as the random error (reproducibility) between the objects when the process is repeated. In previous studies, for full-arch models, it has been reported that the trueness and precision of conventional impressions, evaluated from stone casts, were 20–55 μm and 13–61 μm, respectively [17,18]. On the other hand, for full-arch models, it has been reported that the trueness and precision of digital impressions obtained using an intraoral scanner were 40–59 μm and 31–60 μm, respectively [17,18]. Additionally, it has been reported that the precision of digital impressions of the abutment tooth for fabrication of fixed prostheses was 30–48 μm [3]. Previous reports have suggested that digital impressions obtained using an intraoral scanner in the dental field would have an accuracy identical to that of the conventional impression method [3,5,6,17,19–21].

For removable partial denture fabrication, impressions are taken with the inclusion of soft tissue, such as a partially edentulous ridge, as well as the residual teeth. Therefore, it is not enough to evaluate only the accuracy for the abutment tooth or fixed prosthesis fabrication. An earlier study has reported that the trueness and precision of digital impressions for soft tissue in a completely edentulous ridge ranged from 44 to 598 μm and 21 to 698 μm, respectively [22]. However, there have been no reports on the accuracy of digital impressions involving soft tissue in a partially edentulous ridge.

Thus, the present study evaluated the trueness and precision of digital impressions taken using an intraoral scanner with partially edentulous mandibular models, with the view to illustrating the potential for clinical application of digital impressions obtained using an intraoral scanner in terms of accuracy. The null hypothesis tested in this study was that there is no difference in the trueness and precision between conventional and digital impressions of partially edentulous mandibles.

2. Materials and methods

2.1. Reference model

To evaluate the accuracy of digital impressions obtained under conditions where errors due to external factors, including reflections due to saliva, are minimized, mandibular Kennedy Class I (bilateral mandibular second premolars, and first and second molars missing) and III (left mandibular second premolar and first molar missing) models (D-16FE order made, Nissin, Tokyo, Japan), with simulated mucosa placed on the residual ridge, were used as a reference in the study.

2.2. Digital data of reference models

The digital data of the shape of the reference model were obtained using an extraoral scanner (ARCTICA Auto Scan, KaVo Dental GmbH, Biberach, Germany) for the dental CAD/CAM system. Reference models of each missing tooth type were scanned five times, and the scans were converted into STL data file format (reference data).

2.3. Digital data of models fabricated from conventional impressions

After impression taking of the reference models in the standard manner, working models were fabricated. First, impression taking was performed using a stock metal-tray and an alginate impression material, and the study models were fabricated using hard stone (New Plastone II, GC, Tokyo, Japan). On the study model, the custom tray was fabricated using an autopolymerizing acrylic resin, without applying a spacer to the residual ridge. Selective manual pressure impressions were taken using a hydrophilic vinyl-silicone impression material (EXAHIFLEX, GC) and a custom tray. Working models were fabricated using modified dental stone (New Fujirock, GC). The above-described operations were performed five times on the reference models of each missing tooth type, and the working models were converted into STL (conventional impression data) file format, using an extraoral scanner.

2.4. Digital impression using intraoral scanners

Digital impressions of the reference models were obtained using an intraoral scanner (IOS; Trophy Solutions, Carestream Health, Rochester, NY, USA). One experienced operator (HH) performed all scans using a large (scanning range: 16 mm × 12 mm) or small (scanning range: 12 mm × 9 mm) head. According to an earlier study [23], scanning started from the left central incisor and proceeded to the distal area, and ended at the right central incisor, by moving to the right dental arch (Fig. 1). For residual teeth, scanning was performed in a zig-zag fashion, in the order of the occlusal surface, the buccal surface, and the lingual surface. Additionally, for edentulous ridge mucosa, zig-zag scanning was performed while maintaining continuity of images. No powder application was applied in the study. The reference models of each missing tooth type were scanned five times; scanned data were converted into STL data file format (digital impression data). The number of images required for scanning was recorded.

2.5. Deviation analysis

Using a 3D modeling tool (Geomagic Studio 2014, 3D Systems, Rock Hill, SC, USA), the two different data sets were superimposed and deviation analysis was performed with the best-fit method [24]. A value obtained by calculating the root mean square (RMS) of the amount of deviation at each measurement point was taken to represent a deviation. Deviation analysis for the whole model, but also for the mucosal area only (by trimming STL data on the mesial side of the Kennedy Class I model and on the mesial and distal sides in the intermediate missing area of the Kennedy Class III model) was performed. Errors caused by trimming in the preliminary experiment were examined, and showed that the average RMS values for the large and small heads were 4.3 μm and 5.7 μm, respectively ($n = 10$).

Fig. 1. Scanning operation.

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