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A new method for assessing the accuracy of full arch impressions in patients

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ABSTRACT

Objective: To evaluate a new method of measuring the real deviation (trueness) of full arch impressions intraorally and to investigate the trueness of digital full arch impressions in comparison to a conventional impression procedure in clinical use.
Methods: Four metal spheres were fixed with composite using a metal application aid to the lower teeth of 50 test subjects as reference structures. One conventional impression (Impregum Penta Soft) with subsequent type-IV gypsum model casting (CI) and three different digital impressions were performed in the lower jaw of each test person with the following intraoral scanners: Sirona CEREC Omnicam (OC), 3 M True Definition (TD), Heraeus Cara TRIOS (cT). The digital and conventional (gypsum) models were analyzed relative to the spheres. Linear distance and angle measurements between the spheres, as well as digital superimpositions of the spheres with the reference data set were executed.
Results: With regard to the distance measurements, CI showed the smallest deviations followed by intraoral scanners TD, cT and OC. A digital superimposition procedure yielded the same order for the outcomes: CI ($15 \pm 4\,\mu m$), TD ($23 \pm 9\,\mu m$), cT ($37 \pm 14\,\mu m$), OC ($214 \pm 38\,\mu m$). Angle measurements revealed the smallest deviation for TD ($0.06° \pm 0{,}07°$) followed by CI ($0.07° \pm 0.07°$), cT ($0.13° \pm 0.15°$) and OC ($0.28° \pm 0.21°$).
Conclusion: The new measuring method is suitable for measuring the dimensional accuracy of full arch impressions intraorally. CI is still significantly more accurate than full arch scans with intraoral scanners in clinical use.
Clinical significance: Conventional full arch impressions with polyether impression materials are still more accurate than full arch digital impressions. Digital impression systems using powder application and active wavefront sampling technology achieve the most accurate results in comparison to other intraoral scanning systems (DRKS-ID: DRKS00009360, German Clinical Trials Register).

1. Introduction

CAD/CAM (computer-aided design/computer-aided manufacturing) technology is very well-established in dentistry, particularly in the production of high resistance all-ceramic restorations. The conventional production of dentures uses elastomeric impression materials and the CAD/CAM production of dental restorations are incorporated by the digitization of plaster models using laboratory scanners (indirect digitization). Although indirect digitization is still the standard procedure in digital practice [1], it has all of the same deficiencies that conventional impression taking and model casting has. The possibility of scanning inaccuracies by the laboratory scanner is also of concern [2,3]. To avoid the errors of the conventional CAD/CAM-production workflow, performing the digitalization directly in the patient's mouth using intraoral scanners would be more practical.

The accuracy of intraoral scanners has recently been investigated in several studies. In terms of single tooth digital impressions, studies demonstrated equivalent or even better accuracy with intraoral scanners than for conventional impressions [3–6]. To our knowledge, the accuracy (trueness) of full arch scans, necessary for long span restorations, has not been investigated directly in patients due to lack of feasible measuring methods. Furthermore, the few laboratory studies available demonstrate contradictory results [7–13]. Presumably, intraoral

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conditions such as saliva, humidity, limited oral space, and patient movement are additionally suspected to influence scanning accuracy [14]. The goal of the present study is to assess the accuracy of a new intraoral measuring method for full arch impressions.

In-vitro studies include different analyzing procedures that are used to investigate the accuracy of full arch digital models. Measuring linear distance between fixed reference structures in a model [13] is a common practice. However, the most commonly employed procedure is three-dimensional analyses generated by superimposing the digital model with a reference model using best-fit algorithms and calculating the mean differences of the surface areas [8–11,15]. For this purpose, a reference model is scanned by high-precision optical or tactile laboratory scanners. In general two factors have been investigated: the "trueness" of the scans describes the scan's deviation from the original object. The "precision" is defined as the differences between repeated measurements [16].

Because the jaw of a patient cannot be assessed with tactile or other high-precision optical laboratory scanners, it is difficult to obtain an accurate reference data set (reference model). Few in-vivo studies concerning full arch intraoral scans use gypsum casts obtained from conventional impressions as a reference or they only measure the precision of the scans [14,16,17]. Therefore, no conclusion about the real deviation (trueness) of the scans can be drawn. The goal of the presented study was to develop a new measuring method by creating an intraoral reference using reference spheres attached to the teeth of test subjects. Next, this method was implemented to determine the trueness of three digital impression systems (Sirona CEREC Omnicam, 3M True Definition, Heraeus Cara TRIOS) and one conventional impression (Impregum Penta Soft) intraorally. The following null hypothesis was tested: There is no statistically significant difference ($p < 0.008$) between the four tested impressions systems regarding the determined parameters for dimensional accuracy.

2. Methods

Fifty volunteer subjects (25 m/25 f) with a complete lower dental arch (fully dentate or fixed restorations) were included in the study that was executed in the Department of Prosthodontics of the Justus-Liebig-University, Giessen, Germany. The subjects included in the study had a dental arch shape that allowed for the proper fixation of the reference spheres (s. below). The study was approved by the Ethics Committee of the Justus-Liebig-University Giessen (163/15) and registered in the German Clinical Trial Register (DRKS ID: DRKS00009360).

2.1. Placement of reference spheres

To generate a reference data set, geometrical structures on the teeth with known dimensions and spatial distances were required. Four steel spheres (diameter = 5 mm) were attached to the teeth using a flowable composite (Plurafill flow, Pluradent, Offenbach, Germany) without etching the teeth. Previously the spheres were sandblasted to minimize reflective issues during powder-free scanning and to enhance the retention of the spheres to the teeth. A metallic transfer aid (TA) was manufactured to fix the spheres in each subject consistently in the same predefined spatial relation and distance from each other (Fig. 1). The shape of the TA was based on an average sized lower dental arch [18], the four spheres formed the corners of a symmetrical trapezoid (Fig. 2A). The TA was cut out of a stainless steel blank using a wire eroding machine and thereafter fine-tuned with a 5 axis milling machine (Reinhard Bretthauer, Dillenburg, Germany). The spheres were fixed in four

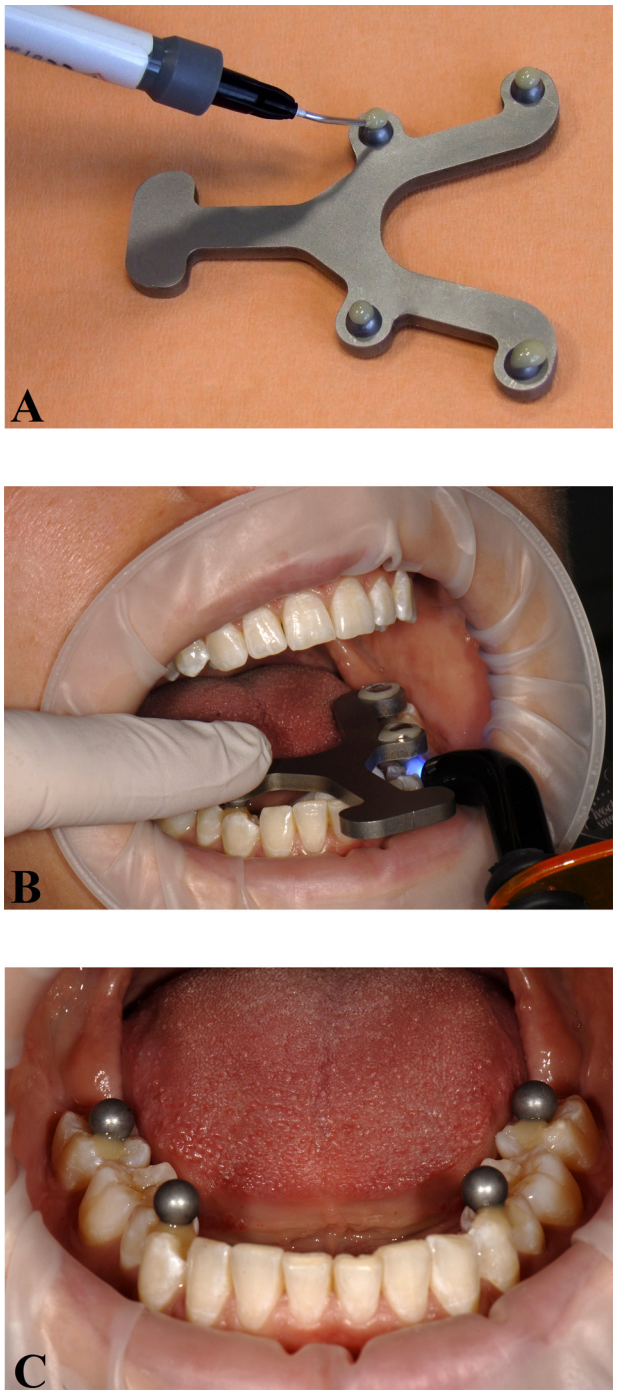

Fig. 1. (A) Transfer aid with spheres inserted. Application of composite on the spheres. (B) Placing the spheres on the teeth, light curing the composite, magnets are attached with composite to the upper side of the transfer aid. (C) Spheres fixed to the teeth.

round recesses on the underside of the TA by magnets without any movement range.

Prior to the attachment of the spheres, the lower teeth of the subjects were cleaned and completely dried from saliva. Composite was applied on the protruding parts of the spheres (Fig. 1A) and the TA with the spheres inserted was placed on the subject's dental arch (Fig. 1B). After light-curing the composite, the TA was carefully removed and the spheres remained on the teeth (Fig. 1C). To facilitate the procedure, Optragate (Ivoclar Vivadent, Schaan,