The mobility of implants is 10-fold lower than natural teeth; thus, implant prosthodontics require an extremely high transfer accuracy of the 3D implant position from the patient’s mouth to a digital or conventional model to warrant a passive fit of the final restoration.1–4 There are numerous known possible errors in conventional implant impressions. Many investigations have shown an influence of the impression material (polyether, polyvinylsiloxane), as well as the impression method (open or closed).5 Furthermore, transfer errors may also be related to fabrication of the model (plaster expansion, precision of the laboratory analogs). Overall transfer accuracies in the range of 25 µm to over 300 µm were reported.6–9 The use of intraoral scanners may seem to minimize possible errors in the impression and model-building process compared to conventional impression-taking (eg, no shrinkage of the impression material or plaster expansion). However, the nature of digital procedures involves other typical sources of errors.10 Numerous studies demonstrated that different factors influenced the accuracy of intraoral scans (ISc). The intraoral

The Influence of Using Different Types of Scan Bodies on the Transfer Accuracy of Implant Position: An In Vitro Study

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Purpose: To assess the absolute linear distances of three different intraoral scan bodies (ISBs) using an intraoral scanner compared to a conventional impression in a common clinical model setup with a gap and a free-end situation in the maxilla. Materials and Methods: An implant master model with a reference cube was digitized using x-ray computed tomography and served as the reference file. Digital impressions (TRIOS, 3Shape) were taken using three different ISB manufacturers: NT Trading, Kulzer, and Medentika (n = 10 per group). Conventional implant impressions were taken for comparison (n = 10). The conventional models were digitized, and all models (digital and conventional) were superimposed with the reference file to obtain the 3D deviations for the implant-abutment-interface points (IAIPs). Results for linear deviation (trueness and precision) were analyzed using pairwise comparisons (P < .05; SPSS version 25). For precision, a two-way factorial mixed ANOVA was used. Results: The deviations for trueness (mean ± precision (SD) of the IAIPs ranged as follows: FDI region 14 = 0.106 ± 0.050 mm (Medentika) to 0.134 ± 0.026 mm (NT Trading); region 16 = 0.108 ± 0.046 mm (conventional) to 0.164 ± 0.032 mm (NT Trading); region 24 = 0.111 ± 0.050 mm (conventional) to 0.191 ± 0.052 mm (Medentika); region 26 = 0.086 ± 0.040 mm (conventional) to 0.199 ± 0.066 mm (Kulzer). There were significant differences for trueness between all digital and conventional impression techniques. For precision, only two significant differences in two implant regions (14, 24) were observed. Conclusion: Longer scanning paths resulted in higher deviations of the implant position in digital impressions. Due to algorithms implemented in the software, errors resulting from the different scan bodies may be reduced during the alignment process of the IOS in clinical practice. Int J Prosthodont 2021;34:254–260. doi: 10.11607/ijp.6796
scanner (IOS) itself, the scanning path\textsuperscript{11,12}, the software version\textsuperscript{13}, the lack of calibration\textsuperscript{14}, and the users\textsuperscript{15} were identified as influential. Although scan bodies for the ISc are supposed to be influential\textsuperscript{16}, studies on intraoral scan bodies (ISBs) are rare\textsuperscript{17–19}. This scarcity is especially alarming because errors and inaccuracies in the point cloud primarily generated by the IOS may be amplified during the meshing process\textsuperscript{20}. Therefore, the present study investigated the transfer accuracy (trueness and precision) of three different ISBs using an IOS compared to a conventional impression.

Many studies of scanning and impression accuracy rely on surface comparisons only\textsuperscript{21–23}. However, this method tends to hide the real differences\textsuperscript{24}. Therefore, the present study introduces a reference system to assess the absolute linear distances and 3D deviations.

The following null hypothesis was tested: There are no differences in the transfer accuracy of different ISBs and a conventional implant impression.

MATERIALS AND METHODS

A model of a partially edentulous maxilla served as the implant master model (IMM) of a patient situation. The model consisted of a stainless steel baseplate (100 × 100 mm) on which four steel tubes were fixed for implant placement. Two tubes in the positions of the first molars (FDI 16 and 26) were placed in a straight position of 0 degrees and parallel to each other. The other two tubes were positioned in the regions of the first premolars (FDI 14 and 24) with a 15-degree angulation in the buccal direction (Fig 1).

Four implants (T3 Non-Platform Switched Certain Tapered Implants, Zimmer Biomet) were luted into the tubes (4.1-mm diameter, 11.5-mm length; AGC Cem adhesive, Wieland Dental). A perpendicularly placed cuboid served as a reference point in the center of the palate. This setup was integrated into a model of a partially edentulous maxilla made of PalaXpress (Kulzer; Fig 1).

To determine the implant-abutment interface points (IAIPs) for each of the four implants, the IMM was digitized using a multisensor coordinate measuring machine and x-ray computed tomography (Werth TomoScope S, Messtechnik; measurement parameters: 225 kV, 100 ms, 60 µm voxel size, 1-mm tin filter, 2,200 sections, surface resolution < 6 µm, linear accuracy < 4 µm). The IAIPs were defined by construction of the center of a plane on the surface of the implant shoulder (Fig 2).

For computing and analyzing the standard tessellation language (STL) output obtained from the TomoScope S, the software WinWerth (Werth Messtechnik) was used. Based on the reference cube on the IMM, a reference coordinate system was defined. The scan data were exported into an STL file format and served as a reference file.

For the digital impressions, four ISBs from three manufacturers (3D Guide, H-Series, NT Trading; cara H10/20, Kulzer; H1410, Medentika) were tightened in the implants (15 Ncm) of the IMM. The 3D Guide ISB consisted

Fig 1 (right) Implant master model with four steel tubes (angulation 0 and 15 degrees). Reference cube (left) and final setup with fixed NT Trading scan bodies (right).

Fig 2 (below) X-ray computed implant-abutment-interface points (IAIPs) on the top part of the implant. The red dots indicate highly magnified IAIPs (left) and detailed magnification (right).
of a titanium base and a polyether ether ketone (PEEK) superstructure with a cylindrical design, two opposite planes, a half cylinder, and a rounded cuboid in the upper part. The cara ISB consisted of a titanium base, a PEEK superstructure with a three-sided prism form, and three flattened planes. The H1410 ISB was completely made of PEEK with a cylindrical form and one flattened plane in the maxillary part. The ISBs are depicted in Fig 3.

Scans were performed using the IOS Trios 3 (3Shape, software version 1.4.7.4.), which is based on confocal laser scanning microscopy. One trained investigator (J.W. B.) performed 10 full-arch scans for each scan body using the calibrated scanner and following the scanning paths as follows, as recommended by the manufacturer: The path started at the occlusal-palatal surfaces of the maxillary right molar (including the reference cube), moved toward the left side of the arch (always including the palatal surfaces), the reference cube again, and the occlusal surfaces, and then returned on the buccal side.

All scan data were exported in a standard STL file format for analyses.

For the conventional impressions, a custom tray (C-Plast, Candulor) with a thickness of 3 mm and a similar tubular design around the impression copings, including the reference cube, was fabricated. The open tray technique was used. For the conventional impression, four impression copings (III IC41, Zimmer Biomet) were tightened onto the implants (15 Ncm). The impression material (Impregum Penta, 3M ESPE) was allowed to set for 10 minutes (to compensate for the laboratory conditions, 23 ± 1°C, 50% ± 10% relative humidity). Thereafter, the screws in the impression post were subsequently loosened, and the impression was removed from the IMM. A total of 10 impressions were made. Laboratory analogs were exactly repositioned in the hexagon (H series, NT trading) and tightened (15 Ncm). Plaster casts were made using Fujifrock EP (GC) and stored under laboratory conditions for 7 days.

For measuring the digital impressions, the STL files obtained were imported into GOM Inspect 2018 and aligned with the reference file by creating intersection planes on the reference cube, though it was possible to overlie the respective coordinate system within the digital impressions. For the measurement, first the distances of the IAIpS to the reference cuboid in the IMM were measured. These distances were also calculated in the conventional and digital models. Then the linear displacement (ΔR) of the two IAIpS per implant position from the reference data set and the impression was calculated using the equation: ΔR= 2 √(x₂–x₁)² + (y₂–y₁)² + (z₂–z₁)².

The result of the calculation is schematically depicted in Fig 4.

For measurement of the IAIpS of the gypsum models, four scan bodies (3D Guide, H series, NT Trading) were tightened onto the implants (15 Ncm) and measured using a coordinate measurement machine (CMM RAPID, Thome; precision: 2.2 µm) to evaluate the linear distances between the IAIpS and the reference cube. To increase the precision of the measurements and avoid errors resulting from even minimal vibrations of the CMM caused by manual manipulation, the following measures were taken. The scan bodies used for measurement of the conventional model were exactly measured using x-ray tomography (Tomoscope S) and a program for the CMM to automate and standardize the measurement process for all of the casts created in the CMM software (Metrolog X4, Metrologic Group). The program comprised a sequence of predefined measurement commands (PLANE, CYLINDER, TURNING POINT, etc) for the CMM with the final data evaluation.
Statistical analysis was performed using SPSS version 25 (IBM). Shapiro-Wilk and Levene tests were used for verification of normal distribution. The results for linear deviation (trueness and precision) were analyzed using pairwise comparisons ($P < .05$). The mean deviation describes the trueness, and the SD depicts the precision. For precision, a two-way factorial mixed analysis of variance (ANOVA) with Šidák correction was used. For a better overview, the results are presented in box plot format.

### RESULTS

The results for the implant regions for each scan body and the conventional impressions are presented in Fig 5 and Table 1, according to ISO 5725. Furthermore, the results for the digital impressions and each implant position are presented in Table 2.

The values of transfer accuracy for digital impressions within one quadrant were similar to the values of conventional impressions. In addition, it is noticeable that...
the longer the scan path, the greater the deviations in the digital impressions. There were significant differences for trueness between the different implant positions. In contrast, the conventional impression showed constant deviations over the entire arch. Likewise, the longer the scanning path, the higher the deviations. With regard to precision, no significant differences could be found. Therefore, the null hypothesis has to be rejected.

With regard to the digital impressions and the different scan bodies, no significant differences could be found in terms of trueness. For the precision, only in the implant position 14 (NT trading/Medentika) and in position 24 (NT trading/Kulzer) could significant differences be found.

**DISCUSSION**

There were significant differences between all of the digital and conventional impression techniques; therefore, the null hypothesis must be rejected. The present study simulated a typical problem with angulated implants in daily dental practice using four implants in the maxilla. For digital impressions, common ISBs for the implant system chosen were used. Even though there are different techniques for conventional implant impressions, polyether with an open-tray technique was used for comparisons because this technique has been frequently used in previous investigations and showed the highest transfer accuracies.6,25,27

The exact dimensions of the ISBs were examined in a previous investigation.16 Measuring errors were avoided by using previous measurements and a single investigator (J.W.B.). Furthermore, a scanning path as recommended by the manufacturer was used to obtain utmost accuracy.11 One strength of the present study was the use of the reference system, which allowed determination of the exact x-, y-, and z-deviations from the IMM. In contrast to the implications of the best-fit method, this technique allowed for exact 3D interpretations of the results. However, this approach requires the presence of a reference structure (cube), which is only possible in an in vitro setup, and this requirement is a clear limitation of the present study.

With regard to the analysis of accuracy, trueness and precision were assessed according to ISO 5725-1. Though the method for describing trueness is generally agreed upon, different approaches for the assessment of precision have been reported.28,29 It was decided to use the ISO approach as a standardized method, which the present authors consider helpful for a later comparison of these results with future studies.30

The advantage of using an IOS for direct digitization of the implant position allows for elimination of the classical model and the associated inaccuracies. However, this introduces other sources of error. Most previous studies that used ISBs for digital impressions compared conventional to digital impression methods, and most examiners used only one ISB6,31 and did not consider its influence. To the present authors’ knowledge, there is only one other study investigating different ISBs in combination with an IOS in a one-model setup.32 However, no additional reference structure was integrated into the model in both studies. Only one study investigated two different ISBs using a laboratory scanner.33

The present results showed significant differences between the conventional and digital impression techniques. Regarding the conventional impression, the individual implant regions did not affect the accuracy. This is consistent with previous studies.34,35

**Table 2** Comparison ($P$) of Mean Deviations for the Different Scan Bodies and Implant Positions

<table>
<thead>
<tr>
<th>Implant position</th>
<th>Scan body</th>
<th>Mean (trueness) ± SD (precision), mm</th>
<th>NT Trading</th>
<th>Kulzer</th>
<th>Medentika</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>NT Trading</td>
<td>0.134 ± 0.026</td>
<td>–</td>
<td>.981</td>
<td>.744</td>
</tr>
<tr>
<td></td>
<td>Kulzer</td>
<td>0.114 ± 0.037</td>
<td>.397</td>
<td>–</td>
<td>&gt; .999</td>
</tr>
<tr>
<td></td>
<td>Medentika</td>
<td>0.106 ± 0.050</td>
<td>.035</td>
<td>.217</td>
<td>–</td>
</tr>
<tr>
<td>16</td>
<td>NT Trading</td>
<td>0.164 ± 0.032</td>
<td>–</td>
<td>&gt; .999</td>
<td>.279</td>
</tr>
<tr>
<td></td>
<td>Kulzer</td>
<td>0.161 ± 0.045</td>
<td>.304</td>
<td>–</td>
<td>.730</td>
</tr>
<tr>
<td></td>
<td>Medentika</td>
<td>0.123 ± 0.041</td>
<td>.169</td>
<td>.973</td>
<td>–</td>
</tr>
<tr>
<td>24</td>
<td>NT Trading</td>
<td>0.180 ± 0.034</td>
<td>–</td>
<td>&gt; .999</td>
<td>&gt; .999</td>
</tr>
<tr>
<td></td>
<td>Kulzer</td>
<td>0.175 ± 0.075</td>
<td>.044</td>
<td>–</td>
<td>.999</td>
</tr>
<tr>
<td></td>
<td>Medentika</td>
<td>0.191 ± 0.052</td>
<td>.199</td>
<td>.298</td>
<td>–</td>
</tr>
<tr>
<td>26</td>
<td>NT Trading</td>
<td>0.183 ± 0.038</td>
<td>–</td>
<td>.998</td>
<td>.998</td>
</tr>
<tr>
<td></td>
<td>Kulzer</td>
<td>0.199 ± 0.066</td>
<td>.107</td>
<td>–</td>
<td>&gt; .999</td>
</tr>
<tr>
<td></td>
<td>Medentika</td>
<td>0.197 ± 0.052</td>
<td>.513</td>
<td>.367</td>
<td>–</td>
</tr>
</tbody>
</table>

Statistical analysis for trueness and precision according to ISO 5725. Significant differences ($P < .05$) are highlighted in bold type.
Significant results only in terms of precision were observed in two implant positions (14 and 24). No general superiority of titanium-based ISBs could be noted. However, when compared to other studies using other types of scan bodies, it has to be noted that overall ISBs may have an influence on the transfer accuracy.

Additionally, for daily clinical work, it must be noted that the data obtained from an IOS are not directly used, but first processed into a digital model using a model builder software. During this process—and dependent on the algorithms implemented in the software—errors resulting from the different scan bodies may be reduced during the alignment process of the CAD data from the scanbody (taken from the software library of the model builder) to the STL dataset from the scanner. Thus, in clinical reality, the resulting error may be smaller, as the present results and those of others suggest.

However, there were significant differences in the digital impressions between the individual positions of the implants. It was clearly noticeable that the inaccuracies increased with progression of the scan path. It is hypothesized that the continuous increase in the inaccuracies from implant position 14 (start of scan path) to 26 (end of scan path) were related to the addition of errors from the imperfect superimposition of the scan images. These results are consistent with previous studies, but contrast another where no increase in errors with progress of the scan path was observed. However, this difference may be due to the camouflage effect of the best-fit algorithm that was used in this study.

Although a direct statement on the transfer of the results is limited due to the missing reference point in vivo, a long scan path may also be present in patient situations. Therefore, it is recommended to limit the digital impression of implants to single-tooth restorations and a maximum length of the scans within a quadrant.

Therefore, in summary, the null hypothesis was partially rejected because no significant differences between the different ISBs were found. However, there was a clear difference between the digital and conventional impressions, especially with increasing scan path length.

CONCLUSIONS

Overall, the following conclusions can be drawn:

- All ISBs examined are suitable for the transfer of the implant position onto the digital model.
- If the scanning path remains within a quadrant, digital and conventional techniques show similar transfer accuracy.
- Longer scanning paths result in higher deviations of the implant position with digital impressions.

ACKNOWLEDGMENTS

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REFERENCES

Does Chlorhexidine Prevent Complications in Extractive, Periodontal, and Implant Surgery? A Systematic Review and Meta-analysis with Trial Sequential Analysis

This systematic review aimed to assess the effect of chlorhexidine (CHX) in preventing complications after extractive, implant, or periodontal surgery. The PICO question set for this systematic review was: Is the use of chlorhexidine formulations able to prevent complications (safety) in patients undergoing procedures of either oral surgery, dental implantology, or periodontology compared to treatment procedures in patients without a chlorhexidine prescription? Once inclusion and exclusion criteria were established, a search was carried out independently by two researchers in the PubMed/MEDLINE, Scopus, and Web of Science databases. The primary outcomes investigated were the rate of alveolar osteitis and bacteremia after surgical procedures in oral surgery. Meta-analysis and trial sequential analysis (TSA) were performed in order to evaluate the findings. A total of 32 studies fully met the eligibility criteria and were included in this systematic review. A meta-analysis was only possible for data obtained from studies related to extractive surgery. Meta-analysis and TSA showed a statistically significant decrease in the rate of alveolar osteitis after tooth extraction when CHX was employed compared to placebo treatments or treatments not using CHX (RR = 0.49, 95% CI: 0.40, 0.60, P < 0.001; I² = 8%). Focusing on the rate of bacteremia, meta-analysis and TSA showed that employment of CHX (RR = 0.87, 95% CI: 0.79, 0.96; P = 0.004; I² = 4%) decreased the rate of bacteremia after extractive surgery. Data from the literature seem to lack in the evaluation of CHX use for the reduction of complications between a conventional and two different intraloral injection techniques. Int J Prosthodont 2018;31:107–113.


