Effects of Training on the Execution of Complete-Arch Scans. Part 2: Scanning Accuracy

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Purpose: To investigate the effect of training on scanning accuracy of complete arch scans (CAS) performed by first-time users, with a distinction made between specific training (repeated performance of CAS) and nonspecific training (simple use of an intraoral optical scanner for a sextant scan in the context of a CAD/CAM teaching module).

Materials and Methods: A total of 36 students with no experience in intraoral scanning were randomized into three groups (n = 12 per group) according to the number of CAS sessions: three sessions (3S), two sessions (2S), and one session (1S). Each student had to perform 10 CAS per scanning session. Sessions were scheduled at T0, T1, and T2 for group 3S; at T0 and T2 for group 2S; and at T2 for group 1S. Before the final scanning session in each group (ie, the first scanning session in group 1S), the students completed a CAD/CAM teaching module, which included fabrication of a monolithic crown in a fully digital chairside workflow. Results: In all groups, repeated CAS resulted in improved scanning accuracy. Participation in the CAD/CAM module had a positive effect on initial accuracy for CAS. Mean absolute deviations in cross-arch distance were 84 µm (T0), 68 µm (T1), and 63 µm (T2) for group 3S; 79 µm (T0) and 61 µm (T2) for group 2S; and 67 µm (T2) for group 1S. Conclusion: To perform CAS with the best possible accuracy, specific training is highly recommended. In addition, nonspecific training leads to an improvement in initial scanning accuracy. Int J Prosthodont 2021;34:27–36. doi: 10.11607/ijp.6940

As in other areas of medicine, use of digital technology in dentistry is increasing. In prosthodontics, for example, this is reflected in the increasing use of CAD/CAM technology for the fabrication of indirect restorations. However, this requires an accurate 3D model of the patient’s oral situation as a starting point. Direct generation of a 3D model without the need for a physical model based on an analog impression offers considerable potential for increased workflow efficiency. Direct digitization of the dental arches is achieved by use of intraoral scanners, which optically capture the conditions inside a patient’s mouth. In general, the position and geometry of all relevant teeth are recorded in a series of partial images/scans, which are successively aligned to generate a complete 3D dataset. Such datasets are already being used for diagnostic and planning purposes, as well as for routine fabrication of inlays, tooth- or implant-retained single crowns, and short-span fixed partial dentures (FPDs). Based on both sextant and quadrant scanning, the restoration fit and scanning accuracy of digital impressions are comparable or even superior to those of analog impressions.
Current intraoral scanning systems use several different principles of data capture: optical triangulation, confocal data acquisition, and wavefront sampling. In optical triangulation, light strips are projected onto a 3D object and recorded by use of a camera system. Confocal microscopy is an optical range finder comparable to a single-lens reflex camera. Objects in front of and behind the focus plane are displayed in an unfocused manner and are therefore not detected. The wavefront sampling principle is basically a modification of spatial vision. The surface of an object is recorded from several perspectives by differently oriented cameras. The difficulty of this method is identifying identical points in the different perspectives. This scanning system therefore requires a light application of powder on the surface of the object. Then, the software can search the recorded images for characteristic patterns and superimpose them according to these patterns.

With regard to the most accurate reproduction of the complete arch, however, analog impressions are still considered superior to digital impressions. Intraoral scanning accuracy can be negatively affected by the following: reflections on metallic, shiny, or moist surfaces; shadowing at sharp transitions, steep preparations, and areas that are difficult to access (approximal areas or preparation margins close to the marginal gingiva); poor accessibility of the scanning area (due to restricted mouth opening or unfavorable soft tissue conditions); a lack of hardware recalibration; errors in the alignment of partial scans; failure to observe scanning paths; and edentulous areas. However, further development of scanning software, particularly the alignment algorithm, may increase the accuracy of digital impressions.

The extent to which the operator’s routine in digital impression-taking affects the accuracy of a scan has not yet been fully clarified. There is evidence that operator experience and repeated scanning of the same region may increase accuracy, although this primarily appears to be true for older and technology-sensitive systems. However, on the basis of most studies investigating the effect of the practitioner’s level of experience, it must be assumed that, due to the small number of participants per group in these studies, the dominance of individual variables is likely to overshadow general trends. In addition, it is unknown whether specific training (in the form of repeated digitization of the same situation) improves impression accuracy or if unspecific training (in the form of general handling of the scanner) is sufficient to achieve this.

The aim of this study was therefore to investigate the effect of training (specific compared to unspecific) on the accuracy of complete-arch scans (CAS) performed by students. The null hypothesis was that training would have no effect on the accuracy of a CAS.

MATERIALS AND METHODS

This study was approved by the Ethics Committee of the Medical Faculty of the University of Heidelberg (ethics vote no. S-670/2018) and conducted in compliance with the Declaration of Helsinki. All participants gave their written informed consent to participate in the study and for their data to be collected and evaluated.

The test model (Fig 1) simulated the condition of a mandibular arch with preparations for a full crown–retained FPD for replacement of the left second premolar and for an inlay on the right second premolar. An implant scan abutment was in the position of the right second molar. All preparation margins were supragingival. Three stainless steel precision balls (diameter = 3.175 mm; quality G3: shape deviation $t_{DWS}/V_{DWS} \leq 0.08 \mu m$, mean roughness value $R_a \leq 0.010 \mu m$, variation of ball diameter $V_{Dwl} \leq 0.13 \mu m$) were welded to the metal model on the left second molar (center of the precision ball: $P_1$), the right first molar ($P_2$), and between the central incisors ($P_3$) (Fig 1).

Before this welding process, all prepared teeth were measured with high precision to create a digital reference dataset for each tooth (µscan with CF4 sensor, NanoFocus; resolution approximately 1 µm in the x- and y-directions and approximately 0.02 µm in the z-direction). To determine the spatial positioning of the welded precision balls, measurements were taken using a coordinate-measuring machine (MarVision 222, Mahr; accuracy 3 µm, SD ± 1.5 µm). The distances between the centers of the precision balls were as follows: 40.338 mm between $P_1$ and $P_2$, 35.916 mm between $P_1$ and $P_3$, and 31.927 mm between $P_2$ and $P_3$.

In the present study, a distinction was made between two forms of training: specific and unspecific training. Specific training was defined as the execution of CAS of the model described above. Nonspecific training was defined as the use of an intraoral scanning device to perform a sextant scan in the context of a student CAD/CAM course in which a monolithic crown was fabricated in a fully digital chairside workflow.

A total of 36 volunteer students from the preclinical course with no experience in intraoral scanning were recruited for the study. The only exclusion criterion was the presence of diagnosed epilepsy, in accordance with the recommendations of the intraoral optical scanner manufacturer. The students were randomly divided into three groups (n = 12 each) according to the number of specific training sessions (S) carried out: group 3S, group 2S, and group 1S.

After a theoretical introduction to intraoral scanning with a special focus on CAS, the students were expected to (1) know the functional principles of intraoral devices; (2) be aware of the current literature on the topic of CAS;
and (3), as a principal objective, theoretically be able to perform a CAS independently. Each student performed 10 CAS of the test model per scanning session. Scanning sessions were scheduled at baseline (T0), T1 (2 weeks after T0), and T2 (4 weeks after T0) for group 3S; at T0 and T2 for group 2S; and at T2 for group 1S. Before the final scanning session in each group (ie, the first scanning session in group 1S), all students participated in a CAD/CAM teaching module (3 weeks after T0), during which each of them fabricated a monolithic zirconia crown in a completely digital chairside workflow (Fig 2).

At the start of the scanning sessions, each participant demonstrated that they were familiar with the CAS strategy by orally reproducing the scanning paths provided by the manufacturer, and, as part of the first scanning session, each participant conducted one trial scan using an inactive intraoral optical scanner. Errors were corrected by the study supervisors (M.W., C.T., W.B.).

The scanning device CEREC Omnicam was used (software: Sirona Connect version 4.5, Dentsply Sirona). The computer hardware settings were as follows: CPU, Intel CoreTM i7-5820K 3.30 GHz; RAM, 16.0 GB; display card, AMD Radeon R9 200 Series. Scans were performed in a windowless room with artificial ceiling lighting. All scans were conducted at 23°C ± 2°C and 45% ± 5% relative humidity. The reference model was placed on a green surgical drape at the edge of the table, and its position could not be changed by the participant. During the scanning process, care was taken by the study supervisor to ensure that the movement of the intraoral device corresponded to that in the oral cavity of a real patient. To reduce reflections, a thin coating of scan spray (CEREC Optispray, Dentsply Sirona) was applied to the model’s surface. After each scan, the coating was completely removed using a steam cleaner, and the coating was renewed.

A CAS was accepted as successful if the complete dental arch was captured, including at least 5 mm of the alveolar process, without flaws, missing data, or major reflections. Reflections and flaws in the scanning surface were removed by use of the cutting tool in the scanning software, and missing areas were added by re-scanning. This was repeated until both the participant and the supervisor agreed on the scan’s success.

If serious alignment errors resulted in obvious disruption of the continuity of the acquired scan, the scan was deleted and a new one was started.

The scans were exported in standard tessellation language (STL) file format for further evaluation. First, the positions of the centers of the three balls (with nominal diameter \(d = 3.175\) mm) were determined by means of optimization (method of least squares; squared deviations at the triangle corner points were weighted with the proportionate surface area using Matlab version R2015a, MathWorks), and deviations of distances between ball centers \(\Delta P_1P_2\) (cross-arch distance), \(\Delta P_1P_3\) (first scan quadrant), and \(\Delta P_2P_3\) (second scan quadrant) were calculated in relation to the reference distances. For changes in distance, results were analyzed using both signed and unsigned values. According to ISO 5725-1,22 accuracy is composed of trueness and precision. To provide information on the accuracy of the individual surfaces of the prepared teeth within the preparation margin, the trueness (determined as the mean mesh
deviation between reference and scan) and precision (determined as the SD of the mesh deviations along the surface) of the scanners were analyzed. In this study, unsigned distances (ie, absolute values) were used for evaluation of trueness and precision.

The statistical evaluations in this study were purely explorative and served to generate hypotheses, which is why no adjustment of the significance level due to multiple testing was performed. Because the data in this study were not normally distributed, nonparametric tests were used to reveal differences between scanning sessions for different scanning groups (Mann-Whitney U test) and between different scanning sessions within the same scanning group (Friedman test, Wilcoxon signed-rank test). Nonparametric tests were also used to analyze the effect of group allocation on the distance deviations for the final scanning sessions (Kruskal-Wallis with post hoc test, pairwise Mann-Whitney U test). Finally, whether specific training before the CAD/CAM module was superior to nonspecific training was examined. For this purpose, groups 3S and 2S at T0 were compared to group 1S at T2 using Mann-Whitney U test. Effect estimators and, if possible, confidence intervals were given for all comparisons, and the significance level was set to \( \alpha = .05 \).

RESULTS

Distance Deviations

The evaluation using signed values (Fig 3) showed that measured distances could be shorter or longer than reference distances, with no consistent pattern of over- or underestimation. For groups that participated in two or three scanning sessions, it was observed that the dispersion of values decreased from the first to the final scanning session.

The mean absolute distance deviations calculated for each student for all groups and scanning sessions are shown in Table 1 and depicted in Figs 4 to 6. Generally, it was found that the extent of deviation depended on the position of the distance in the scanning path. The largest deviations in distance occurred over the cross-arch distance \((\Delta P_1P_2)\), followed by the second scan quadrant \((\Delta P_2P_3)\) and then the first scan quadrant \((\Delta P_1P_3)\) of the scanning path. For groups that had more than one scanning session, it was observed that the deviations became smaller regardless of the position of the measured distance in the scanning path.

With regard to the specific training sessions, in group 3S, no statistically significant improvement was observed for the cross-arch distance \((\Delta P_1P_2)\) from T0 to T1 or T2. For the first scan quadrant \((\Delta P_1P_3)\), the distance deviations between T0 and T1 improved significantly \((P = .009)\), as did those between T0 and T3 \((P = .012)\). For the second scan quadrant \((\Delta P_2P_3)\), a significant improvement was observed with regard to the distance deviations between T0 and T2 \((P = .002)\) and between T0 and T2 \((P = .002)\).

In group 2S, a significant improvement \((P = .042)\) was observed for the first scan quadrant \((\Delta P_1P_3)\) between T0 and T2, but not for the cross-arch distance \((\Delta P_1P_2)\) or the second scan quadrant \((\Delta P_2P_3)\).

Comparison of groups 3S and 2S at T0 showed a significant difference over the second scan quadrant \((\Delta P_2P_3, P = .020)\). Group 2S achieved fewer scan deviations than group 3S. The other deviations were not statistically significant.

Comparison of all groups at T2 showed a significant difference over the first scan quadrant \((\Delta P_1P_3, P = .015)\). Group 3S achieved significantly fewer scan deviations than group 1S \((P = .009)\). The other distance deviations were not significantly affected by group allocation at T2.

With regard to the effect of nonspecific training on scanning accuracy, a significant difference was observed between group 3S at T1 and group 1S at T2 for the first scan quadrant \((\Delta P_1P_3, P = .039)\). Here, one-time specific training (group 3S at T1) was superior to nonspecific training only (group 1S at T2).
In addition, group 1S at T2 achieved fewer scan deviations for the second scan quadrant (ΔP2P3, P < .001) than group 3S at T0. Here, nonspecific training was superior to no training.

Figure 7 shows the floating mean value for all scans. The deviations from the reference distances decreased with each additional scan regardless of the location in the scanning path.

With regard to deviations of distances measured in the first scans over the cross arch (ΔP1P2), groups 3S and 2S started with greater distance deviations (group 3S = approximately 110 µm, and group 2S = approximately 90 µm, compared to group 1S = approximately 70 µm). The distance deviations of the final scans were similar in all groups (approximately 60 µm).

In the first quadrant of the scanning path, the first 10 scans of each group were in the same range, with distance deviations of approximately 15 µm. In group 3S, the distance deviations decreased slightly until the final scan (approximately 8 µm). In groups 2S and 1S, no change could be detected.

In the second quadrant of the scanning path, the initial distance deviations in group 3S (approximately 26 µm) were higher than those in groups 2S and 1S (almost 20 µm). In all groups, deviations in the final scans were similar (approximately 10 to 15 µm).

### Accuracy of Individual Abutment Tooth Surfaces

Trueness and precision (with SD) for the prepared teeth are listed in Table 2 and depicted in Figs 8 and 9.

<table>
<thead>
<tr>
<th>Scanning session</th>
<th>Distance deviation</th>
<th>Group 3S</th>
<th>Group 2S</th>
<th>Group 1S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ΔP1P2</td>
<td>Mean</td>
<td>SD</td>
<td>Median</td>
</tr>
<tr>
<td>T0</td>
<td></td>
<td>83.7</td>
<td>39.04</td>
<td>73.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20.8</td>
<td>10.15</td>
<td>18.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32.0</td>
<td>10.55</td>
<td>28</td>
</tr>
<tr>
<td>T1</td>
<td></td>
<td>67.8</td>
<td>26.71</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>13.1</td>
<td>6.72</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>21.6</td>
<td>8.29</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td></td>
<td>63.4</td>
<td>24.97</td>
<td>51.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.1</td>
<td>4.46</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16.9</td>
<td>7.56</td>
<td>16.8</td>
</tr>
</tbody>
</table>

Table 1: Mean Absolute Distance Deviations for Each Student (µm) at Each Scanning Session for All Groups

© 2021 BY QUINTESSENCE PUBLISHING CO, INC. PRINTING OF THIS DOCUMENT IS RESTRICTED TO PERSONAL USE ONLY. NO PART MAY BE REPRODUCED OR TRANSMITTED IN ANY FORM WITHOUT WRITTEN PERMISSION FROM THE PUBLISHER.
In group 3S, an improvement was observed between T0 and T1 for the first molar (crown preparation, P = .037). For the second premolar (inlay preparation), significant improvements were observed between T0 and T2 (P = .013) and between T1 and T2 (P = .019).

In group 2S, there was an improvement in trueness for the first molar (crown preparation, P = .003) between T0 and T2.

Comparison of groups 3S and 2S at T0 showed a significant difference for the second premolar (inlay preparation, P = .002).

At T2, group 3S achieved statistically significantly better trueness for the second premolar (inlay preparation) compared to group 2S (P = .005).

Nonspecific training resulted in greater trueness only for the first premolar (crown preparation) when comparing group 2S at T0 and group 1S at T2 (P = .012).

**Precision**

In group 3S, improved precision was observed between T0 and T2 for the first molar (crown preparation, P = .034).

In group 2S, precision increased for the second premolar (inlay preparation, P = .001) from T0 to T2.

Comparison of groups 3S and 2S at T2 revealed no significant differences in precision.

At T2, precision for the second premolar (inlay preparation) was significantly better for group 3S than for group 2S (P = .023).

With regard to the effect of nonspecific training on precision for prepared teeth, a significant difference was observed for the first molar (crown preparation) between group 3S at T0 and group 1S at T2 (P = .023). Here, nonspecific training (group 1S at T2) was superior to no training (group 3S at T2). Furthermore, with regard to the second premolar (inlay preparation), precision was significantly lower for group 1S at T2 than for group 2S at T0 (P = .002).

**DISCUSSION**

Based on the results of this study, the null hypothesis had to be rejected. Specific and unspecific training both had an effect on scanning accuracy of CAS.

For all groups and measured distances, a positive, but not always statistically significant, trend in favor of specific training was observed. Significant improvements were observed for both the first and second scan quadrants. Across the dental arch, deviations did not change to a statistically significant
extent. Because digital scans deviate from reality both positively and negatively, and because errors caused by the stitching process can either accumulate or cancel each other out,23,24 this might have superimposed the positive effects measured for the individual quadrants. Furthermore, a statistically highly significant difference was not to be expected when using an intraoral scanning device, which performs single-image recordings and their generation in a 3D dataset in a standardized way.

In agreement with the study by Lim et al.,16 the potential for improvement seems to depend on the ability of the user. In this study, it was not possible, even by means of randomization, to evenly divide the participants into groups of identical initial scanning ability; this resulted in statistically significantly higher deviations in group 3S than in group 2S in the second scan quadrant at T0. However, the ability of both groups was the same after their respective final scans. It can therefore be concluded...
that although scanning accuracy differs among users at the start, it can be improved to such an extent that the main variables affecting accuracy are the measurement accuracy of the system and the stitching algorithm. The effect of interindividual differences means that no recommendation can be given regarding the specific number of CAS needed before clinical use.

Analysis of the deviations of the chronologically increasing scans revealed that the effect of specific training directly depended on the position of the measured distance in the scanning path. The limiting variable for scan accuracy in the first scan quadrant, independent of group allocation, was the measurement accuracy of the intraoral camera of typically 5 to 15 µm. As the length of the scan path increased, the measurement accuracy of the optical system was no longer the only limiting variable. Over the cross-arch distance, an improvement of 33% to 50% could be achieved by specific training (group 3S and 2S).

The study results also indicate that scanning accuracy was improved not only by specific training in CAS, but also by nonspecific training (ie, handling of an intraoral scanner). For all measured distances it could be shown that in the group with nonspecific training only (group 1S at T2), distance deviations were similar to those in the groups after specific training (groups 3S and 2S at T2). Looking at the distance deviations for chronologically increasing scans (floating mean values), the effect of nonspecific training can be seen for the cross-arch distance only. The scanning results achieved by group 1S were 30% to 50% better than those achieved by groups 2S and 3S in their first scans. For the first and second scan quadrant, the scan results are limited by the measurement accuracy of the system used. It seems that nonspecific training results in an initial scanning accuracy that is almost solely limited by the measurement accuracy of the intraoral camera or the stitching algorithm of the software.

The accuracy of individual abutment tooth surfaces was assessed in terms of trueness and precision. In relation to the prepared teeth, satisfactory accuracy (ie, suitable for fabrication of fixed dental prostheses) was achieved by all groups. Irrespective of the type of preparation, no effect of training was observed between the individual scanning sessions. The fluctuations in trueness and precision are within the range of the scanning accuracy of the scanning system used. Any significant differences found can therefore be considered not clinically relevant. In agreement with the findings of Park et al, scanning accuracy is directly dependent on both the type of preparation and the measurement accuracy of the system used.25 The sharp preparation margins of an inlay are, to some extent, rounded during digitization. The largest deviations between the reference dataset and the test scan occur at these margins. This rounding also occurs for teeth prepared for conventional crowns but is not as significant here as it is for inlay preparations.

Table 2  Mean ± SD for Trueness and Precision (µm) Based on Mean Absolute Distance Measurements for Each Student

<table>
<thead>
<tr>
<th>Scanning session</th>
<th>Tooth</th>
<th>Group</th>
<th>3S</th>
<th>2S</th>
<th>1S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trueness</td>
<td>Precision</td>
<td>Trueness</td>
<td>Precision</td>
<td>Trueness</td>
</tr>
<tr>
<td>T₀</td>
<td>First molar</td>
<td>12.1 ± 1.5</td>
<td>11.7 ± 1.4</td>
<td>12.9 ± 1.4</td>
<td>10.6 ± 1.1</td>
</tr>
<tr>
<td></td>
<td>First premolar</td>
<td>12.0 ± 1.4</td>
<td>9.4 ± 1.1</td>
<td>14.2 ± 1.4</td>
<td>9.8 ± 2.3</td>
</tr>
<tr>
<td></td>
<td>Second premolar</td>
<td>24.2 ± 2.8</td>
<td>23.9 ± 2.0</td>
<td>23.9 ± 2.0</td>
<td>17.7 ± 2.5</td>
</tr>
<tr>
<td>T₁</td>
<td>First molar</td>
<td>13.2 ± 1.8</td>
<td>11.2 ± 1.2</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>First premolar</td>
<td>12.4 ± 1.7</td>
<td>9.3 ± 0.9</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Second premolar</td>
<td>25.6 ± 4.0</td>
<td>24.7 ± 8.3</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>T₂</td>
<td>First molar</td>
<td>13.1 ± 2.3</td>
<td>10.7 ± 1.4</td>
<td>14.2 ± 1.5</td>
<td>11.1 ± 1.5</td>
</tr>
<tr>
<td></td>
<td>First premolar</td>
<td>11.8 ± 2.6</td>
<td>9.3 ± 1.5</td>
<td>13.3 ± 1.6</td>
<td>9.4 ± 1.0</td>
</tr>
<tr>
<td></td>
<td>Second premolar</td>
<td>21.7 ± 3.0</td>
<td>21.0 ± 4.3</td>
<td>25.0 ± 2.4</td>
<td>25.2 ± 4.4</td>
</tr>
</tbody>
</table>

The first molar and first premolar received full crown preparations, and the second premolar received an inlay preparation.
To determine, as clearly as possible, the effect of training on scanning accuracy, students without any experience with intraoral scanners were selected as participants. Students were also chosen to prevent a possibly negative opinion of digital impressions from affecting the study results. This is because assessment of digital and conventional impressions in terms of effectiveness and application preference seems to depend on the user's clinical routine in addition to the scanner system used. In contrast to students, experienced dentists taking an impression of a single-tooth implant in 2013 regarded conventional impression-taking to be more effective than digital impressions and therefore preferred to use the conventional technique.26 In a similar study 4 years later, in which a more modern scanner system was used, both dentists and students considered digital impression-taking to be more efficient. Nonetheless, experienced clinicians still preferred to take a conventional impression.27 Despite improvements in scanner systems, it seems that new treatment procedures and practices are being met with greater resistance by the dentist and dental team. This includes a reluctance to use digital instead of analog impressions.

A limitation of the present study was that the model was positioned on a table and could not be moved. Unlike in a clinical setting, the scans were not impeded by any soft tissues such as the tongue or cheek. Furthermore, the positioning of the intraoral scanner was not affected by the limited accessibility of the oral cavity. To better simulate in vivo conditions, the model could have been placed inside a phantom head. The in vitro setting was nevertheless regarded as adequate because no reference data (recorded with a much more accurate device than the one used for the tests in the present study) would have been available in vivo to validate scanning accuracy, especially for CAS.

This study was conducted on a test model. Therefore, in terms of the applicability of these results to clinical practice, the distance deviations measured can only be used as a guide. Clinically, it should be assumed that scanning accuracy will be lower in vivo than in vitro.15 With regard to technique-sensitive scanning systems, it was shown that in vivo scanning accuracy decreases if scans are performed by practitioners without previous clinical experience. It seems that less experienced practitioners are less adept than experienced dentists at responding to patient movement, saliva, and soft tissues in combination with intraoral scanning.5

![Fig 8](image8.png) Trueness (µm) for prepared teeth.

![Fig 9](image9.png) Precision (µm) for prepared teeth.
CONCLUSIONS

Specific and unspecific training both had an effect on scanning accuracy for CAS. For all groups and measured distances, a positive trend in favor of specific training could be observed. Statistically significant improvements were observed mainly for the first scan quadrant but also for the second scan quadrant. Across the dental arch, deviations did not change to a statistically significant extent. In addition, unspecific training led to an improvement in initial scanning accuracy.

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