Effects of Training on the Execution of Complete-Arch Scans. Part 1: Scanning Time

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

Methods: Thirty-six students with no experience in intraoral scanning were randomized into three groups (n = 12 per group) according to the number of specific CAS training sessions: three sessions (3S), two sessions (2S), and one session (1S). Each student performed 10 CAS per scanning session. These 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), the students participated in a CAD/CAM course (3 weeks after T0) in which a monolithic crown was fabricated in a fully digital chairside workflow. The scanning time was measured as the time between the activation and termination of the scanning mode of the intraoral device. Data were analyzed using SPSS Statistics 25 (IBM). The level of significance was set to $\alpha = .05$.

Results: A continual decrease in scanning time was observed for all groups as experience in intraoral scanning increased. The mean scanning times were as follows: for group 3S, 305 seconds at T0, 246 seconds at T1, and 233 seconds at T2; for group 2S, 380 seconds at T0 and 303 seconds at T2; and for group 1S, 355 seconds at T2. When compared to group 1S after it had received nonspecific training only, the effect of a single specific training session in groups 3S and 2S was not significant ($P = .4428$). However, two specific training sessions had a significant effect on scanning time compared to nonspecific training only ($P = .0005$).

Conclusion: Training does affect the scanning time required for CAS. To perform such scans in a time-efficient manner, dental practitioners should undertake training that comprises at least 12 CAS.


The future routine use of digital impressions in the dental profession will depend on five key areas: range of application, patient acceptance, user-friendliness, accuracy, and efficiency. The range of application of current intraoral devices ranges from diagnostics and planning to the fabrication of indirect restorations, such as temporary restorations, inlays, single crowns (SCs), and short-span fixed partial dentures (FPDs). The internal and marginal fit of such digitally based restorations is comparable to, or even better than, that of dental restorations made on the basis of an analog impression.

In addition to objective criteria such as restoration fit, patient-related outcome measures should be taken into account when choosing a dental impression method. In this context, it has been reported that patients associate digital impression techniques with less discomfort, less nausea, fewer mouth-opening and jaw-joint complaints, less
restriction of breathing, and less sensitivity in the area of the teeth and periodontium.\textsuperscript{10–12} It seems, however, that minimization of chair time is most important for patients. Closer analysis reveals that, although patients usually find digital impressions more comfortable, they are only preferable if they take less time than analog impressions.\textsuperscript{10–14}

In terms of practitioner preference, a distinction must be made between experienced practitioners and novice or student practitioners. When taking an impression of a single-tooth implant or single-crown/short-span partial denture, dentists find digital scans similarly difficult to\textsuperscript{15} or less difficult than analog impressions, whereas students learning both methods for the first time find digital impressions easier.\textsuperscript{15–17} Students regard digital impressions as more efficient and would ultimately prefer to use them. Possibly due to the further development of scanning systems, dentists found intraoral scanning more efficient in 2017 than they did in 2013 but would still prefer to use routine analog impressions.

Time efficiency has a substantial effect on whether digital impressions are met with acceptance. For dentists, the use of digital impressions only makes sense if they reliably produce accurately fitting restorations and take the same or less time than analog impressions. For single-implant SCs, conventional SCs, and FPDs, it has been shown that digital impressions can save time compared to high-precision analog impressions. On average, it was shown that quadrant scans save 5 minutes, and complete-arch scans (CAS) save 1.5 minutes.\textsuperscript{18} However, consideration must be given to the indication for which the CAS is being used. Compared to an alginate impression, each scan takes longer.\textsuperscript{19} The more precision required for an impression (in the case of FPDs, for example), the longer the scan takes: approximately an extra 60 seconds per additionally prepared tooth.\textsuperscript{16}

It is unclear whether a dentist’s scanning experience has a positive effect on the time taken to perform a complete dental arch scan. It is also unknown whether repeated, specific practice of CAS (ie, specific training) is required to reduce scanning time or if practice with the use of an intraoral scanner (ie, nonspecific training) would suffice.

The aim of this study was to investigate the effect of training (specific vs nonspecific) on the scanning time for a CAS performed by students under standardized conditions. The null hypothesis was that neither type of training would have an effect on the time taken to scan a complete dental arch.

**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. Undergraduate dental students were eligible to participate. Exclusion criteria were the prior use of an intraoral scanner and—based on the recommendations of the manufacturer of the intraoral device—the presence of diagnosed epilepsy.

The test model (Fig 1) simulated the conditions of a mandibular arch that had been prepared for (1) a full crown–retained FPD for replacement of the left second premolar and (2) an inlay on the right second premolar. An implant scan abutment was in the position of the right second molar. All preparation margins were located supragingivally. Stainless steel precision balls were welded onto the right second molar, the left first molar, and between the central incisors. The precision balls were used to analyze the accuracy of the scans (which was not the subject of this study). The base of the model was covered with resin (PMMA) to simulate the gingiva.

Specific training was defined as the execution of full-arch scans 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 undergraduate students with no experience in intraoral scanning were recruited for the study. The students were randomly assigned to three groups of 12 persons each according to the number of specific scanning sessions (S) they were to undertake: group 3S, group 2S, and group 1S.

All groups received a theoretical introduction to intraoral scanning with a special focus on CAS. After the seminar, the students were meant to know the functionality principles of intraoral scanners and the current literature on the topic of CAS, and, as a principal objective, to be able to perform a CAS independently.

Each student performed 10 CAS per scanning session. Scanning sessions were scheduled at baseline (T\textsubscript{0}), T\textsubscript{1} (2 weeks after T\textsubscript{0}), and T\textsubscript{2} (4 weeks after T\textsubscript{0}) for group 3S; at T\textsubscript{0} and T\textsubscript{2} for group 2S; and at T\textsubscript{2} for group 1S. Before each group’s final scanning session (ie, the first scanning session in group 1S), the students participated in a CAD/CAM course (3 weeks after T\textsubscript{0}; Fig 2).

At the start of each scanning session, each participant demonstrated their familiarity with the complete-arch scanning strategy by orally reproducing the scanning paths provided by the manufacturer.\textsuperscript{20} Errors were corrected. Furthermore, as part of the first scanning session, each participant conducted one trial scan with an inactive intraoral device to familiarize themselves with the procedure.

In this study, CEREC Omnicam (software: Sirona Connect version 4.5, Dentsply Sirona) was used to obtain the scans of the reference model. 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 under supervision in a windowless room with artificial ceiling lighting. All scans were conducted at 23°C ± 2°C and 45% ± 5% relative humidity. The test model was placed on a green surgical drape on the edge of the table, and its position could not be changed by the participants. During the scanning process, the supervisor (M.W., C.T., W.B.) ensured that the possible movements of the intraoral device reflected the limited accessibility of the real oral cavity. To reduce reflections, a thin coating of scan spray (CEREC OptiSpray, Dentsply Sirona) was applied to the model's surface. After each scan, a steam cleaner was used to fully remove the coating from the model, and the coating was then renewed.

A scan was accepted as successful if the complete dental arch was captured including at least 5 mm of the alveolar process, with no flaws, missing data, or major reflections. Reflections and flaws in the scan surface were removed by use of a cutting tool in the scanning software, and missing areas were added by re-scanning. This was repeated until both the participant and the supervisor were in agreement on the scan’s success.

Measurement of the scanning time began when the scanning mode of the intraoral device was activated by tapping the respective foot switch. Once a successful scan had been recorded in accordance with the above criteria, the time measurement was stopped when the participant clicked on the calculation button in the scanning software for further processing of the scan data. If a stitching error occurred in a scan, the scan was deleted and a new scan was started. The time measurement was also restarted.

The statistical evaluations in the study were solely explorative and were used to generate hypotheses, which is why no error adjustment for multiple pairwise testing was carried out. The target variable of the study was the time required to conduct a CAS. To verify the comparability of the three groups, their demographic data were analyzed descriptively. Mann-Whitney U test was also used to compare the groups to determine whether the scanning time differed between groups 3S and 2S at T0. Kruskal-Wallis test was used to test whether group allocation had an effect on the scanning time of the final scanning session, and post hoc pairwise Mann-Whitney U tests were used to reveal group differences. To test whether an improvement occurred between the individual scanning sessions, Wilcoxon signed-rank test was used for group 2S (T0 compared to T2), and Friedman test and Wilcoxon signed-rank test were used for group 3S (T0 compared to T1 compared to T2). Finally, the question of whether the specific training before the CAD/CAM module was superior to the nonspecific training was examined. For this purpose, Mann-Whitney U test was used to compare groups 3S and 2S at T0 to group 1S at T2. The significance level was set to $\alpha = .05$. Effect estimators and, if possible, confidence intervals are given for all comparisons.

RESULTS

Due to stitching errors, 8 of 720 scans had to be repeated.

The CAS scanning times during the different scanning sessions ($T_0$–$T_2$) are summarized in Table 1 and Fig 3. Irrespective of group, the scanning time decreased between the first and final scans (Fig 4).
For group 3S, a significant improvement in mean scanning time was observed between T₀ and T₁ (P = .001), but not between T₁ and T₂ (P = .569). A significant improvement in mean scanning time was also observed between T₀ and T₂ for group 2S (P = .009).

At T₀, group 3S performed significantly better than group 2S (P = .012). Furthermore, the scanning time at T₀ for groups 3S and 2S did not significantly differ from that at T₂ for group 1S.

Comparison of the scanning time of group 3S at T₁, with that of group 1S at T₃ shows that one specific training session had a significant effect on scanning time compared to nonspecific training only (P = .001). However, no significant difference was found between the scanning times of group 2S and group 1S at T₂ (P = .101).

At T₂, the difference between groups 3S and 2S (P = .012), and between groups 3S and 1S (P < .001), was significant. Comparison of group 2S to group 1S revealed no significant difference (P = .101).

**DISCUSSION**

This randomized in vitro study was designed to investigate the effect of training on the scanning time for CAS. A distinction was made between specific and nonspecific training.

The null hypothesis had to be rejected. Specific training had a positive effect, resulting in a reduction in scanning time, whereas unspecific training had no statistically significant effect on scanning time.

As a result of performing CAS repeatedly, the scanning time within each test group decreased continuously as the (chronologic) scan number increased (Fig 4). The first repetitions resulted in the greatest improvements, whereas the scanning procedure became only slightly more efficient from the 12th scan onward—any further time reductions were no greater than 30 seconds. It can be assumed that patients do not consciously perceive a time difference of 30 seconds during dental treatment. To ensure time-efficient dental scanning, it thus seems reasonable for practitioners to undergo CAS training at least 12 times. It should be noted here that the clinical conditions in routine dental practice will differ from those in the present study, as the effects of other variables (soft tissue, saliva, ...
and restricted access to the oral cavity) and the fact that a different oral cavity will usually be scanned each time will result in a flatter learning curve.

A single session of specific training (ie, 10 scans) was associated with the greatest reduction in scanning time. This effect was observed both for group 3S and group 2S (Fig 3 and Table 1). Although further reductions in scanning time were observed for repeated sessions of specific training, these time reductions were not statistically significant, and, as the time reductions did not exceed 30 seconds, were also not clinically relevant. Unfortunately, this study could not conclusively prove the effect of unspecific training on scanning time. When comparing nonspecific training (group 1S at T2) to specific training, a statistically significant difference was only observed if group 3S at T1 was used for comparison, but not if it was used for comparison with group 2S at T2, even though both groups had previously undergone specific training in the form of a CAS scanning session. This is probably due to the heterogenous composition (despite randomization) of groups 3S and 2S in terms of their scanning ability at T0, as indicated by the statistically significantly longer scanning times of group 2S.

It is well known that a dental practitioner’s choice of impression procedure is strongly affected by their previous experience with impression methods. Experienced practitioners, for example, would usually prefer to take an analog impression over performing a digital scan.\textsuperscript{15,17} To prevent bias against digital impressions, students were therefore used as the test subjects in this study. Furthermore, the students had no experience with intraoral scanning, thus ensuring that the maximum effect of training on scanning time could be observed.

The students performed the scans under standardized in vitro conditions. One major limitation of this study was that the test model was positioned on a table and could not be moved. For this reason, the limited accessibility of the oral cavity could not be simulated in this way. During the scanning process, therefore, care was taken to ensure that the students guided the intraoral camera at clinically realistic angles and trajectories only. To better simulate in vivo conditions, the test model could have been placed inside a phantom head.

Scanning times measured in vitro cannot be directly transferred to clinical practice. This is mainly due to the fact that clinical difficulties, such as limited accessibility of the oral cavity and interference from the tongue, cheek, and saliva, cannot be simulated in vitro. In addition, the extent to which frequent repetition of scans leads to an acclimatization effect in relation to the reference model must be viewed critically. The model used in this study reproduced a clinically realistic situation with different preparation geometries. In particular, the complex geometry of the inlay cavity did not represent a trivial form of preparation for optical impression-taking. Because this study did not cover a closed row of teeth, but instead tooth preparations and a scan abutment distributed throughout the arch, it can therefore be assumed that any possible acclimatization effect was very minor.

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REFERENCES

The purpose of this network meta-analysis was to identify to what extent the degree of efficacy of stabilization appliances in the management of painful TMDs arises from the placebo effect only or whether it arises chiefly from an actual effect. An electronic search was undertaken to identify randomized clinical trials published up to April 2020 comparing the efficacy of stabilization appliances in patients with painful TMDs to that of nonoccluding appliances (active placebo) and untreated controls (passive placebo). Outcome variables were pain intensity at follow-up, the proportion of participants reporting pain improvement, and the number needed to treat. The quality of evidence was rated per the Cochrane tool for assessing risk of bias. Mean difference was calculated via frequentist network meta-analysis using the STATA software program. Treatment with stabilization appliances showed a significant reduction in pain intensity when compared to the other groups, but the lower pain intensity at follow-ups in favor of stabilization appliances when compared to nonoccluding appliances was not statistically significant. However, a significantly higher number of participants reported pain improvement after treatment with stabilization appliances compared to those treated with nonoccluding appliances or to untreated participants. This network meta-analysis showed no significant difference in reported pain intensity at follow-ups between the treatment of painful TMDs with stabilization appliances or nonoccluding appliances (active placebo). However, a significant difference in participants reporting treatment satisfaction with reduced pain and a significantly lower number needed to treat in favor of stabilization appliances were found. Patient-reported treatment satisfaction probably included more domains than just pain intensity—such as improvements in physical functioning and psychosocial factors—and deserves further investigation. The authors concluded that stabilization appliance treatment efficacy is beyond the placebo effect.