Accuracy and efficiency of digitally fabricated all-ceramic crowns from conventional impressions and intraoral scans: A single-blind clinical randomized controlled trial

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Abstract

Purpose: To evaluate the accuracy of intraoral scanners by comparing the marginal fit of 70 all-ceramic crowns fabricated from both conventional impressions and intraoral scans. Materials and Methods: A total of 70 posterior teeth requiring single-crown restorations randomly underwent either intraoral scanning or conventional impression-taking followed by laboratory scanning of the casts in a parallel-group RCT. Subsequently, 70 monolithic all-ceramic crowns were CAD/CAM fabricated; only the impression technique differed. Marginal fit, internal fit, adjustment time required for insertion and occlusal contacts, and visual analog scale (VAS) scores assessing dentists’ satisfaction with all of the crowns were clinically evaluated by a blinded and calibrated examiner. Data were analyzed using independent-samples t test and likelihood ratio test or Fisher exact test. All tests were performed with $\alpha = .05$. Results: The mean marginal fit with intraoral scanning ($57.94 \pm 22.51 \mu m$) was better than with diagnostic cast scanning ($82.98 \pm 21.72 \mu m$). The difference was statistically significant ($P = .000$). The differences in internal fit, adjustment time for crown insertion and occlusal contacts, and VAS scores were also significant, and the secondary outcomes were in favor of intraoral scanning. Conclusion: Within the limitations of this clinical trial, CAD/CAM–fabricated single-tooth restorations in the posterior region produced by an intraoral scanning technique using TRIOS was found to be a more accurate and efficient alternative to restorations based on conventional
impressions in combination with the laboratory scanning technique. *Int J Prosthodont* 2022. doi: 10.11607/ijp.8143

**Introduction**

Making impressions is a critical step in the production of definitive indirect restorations and critically influence marginal fit, accuracy of occlusal contacts, and other clinical parameters. Conventional impression materials such as vinyl polysiloxane (VPS) and polyether are widely used in clinical practice. Such materials show adequate precision and stability. On the other hand, many intraoral scanning systems have been developed recently. Some scholars have compared clinical performances and proved that intraoral scanning has some potential clinical advantages. However, previous clinical studies had two limitations: first, the number of clinical trials comparing conventional impression-making techniques with intraoral scanning remained limited and the in vivo findings were controversial; second limitation was the lack of comprehensive outcomes in previous clinical studies. Some studies only compared the accuracy of clinical prosthesis in terms of marginal fit and internal fit; while other studies only compared efficiency indicators such as clinical operation time. Clinical studies that compare both accuracy and efficiency of impression making techniques are scarce. In general, if an impression technique achieves high accuracy, but the clinical operation is time-consuming, or vice versa, or both achieve high accuracy and save clinical operation time, our evaluation of these three situations will be quite different. Therefore, clinical studies with comprehensive clinical outcomes are urgently needed.

The marginal fit of the crown is one of the main factors determining the longevity of the crowns. An inadequate marginal fit can lead to plaque accumulation, microleakage, development of periodontitis, secondary caries, and even tooth loss. Some in vivo studies
have compared the marginal fit between intraoral scanning techniques and conventional impression-making. Bosniac et al. \(^1^1\) reported that the marginal fit obtained with intraoral scanning (88.95 ± 54.46 μm) was better than that obtained using conventional impressions (143.29 ± 100.71 μm), with statistically significant difference. Berrendero et al. \(^1^2\) also reported that the intraoral scanning technique (106.6 ± 69.6 μm) was better than conventional impressions (119.9 ± 59.9 μm), but their study did not identify a statistically significant difference. In contrast, Rodiger et al. and Sakornwimon et al. showed that conventional impressions (82.17 ± 75.17 μm and 56.29 ± 38.08 μm, respectively) were better than intraoral scanning (87.40 ± 91.21 μm and 61.52 ± 32.16 μm, respectively), although the difference was not statistically significant. \(^1^3\) Thus, in vivo studies comparing the marginal fit between the intraoral scanning technique and conventional impressions are limited in scope with contradictory findings.

Therefore, the present single-blind randomized controlled trial study was set to evaluate comprehensive clinical outcomes of two different impression techniques. The primary aim was to compare the marginal fit of 70 monolithic all-ceramic crowns fabricated using conventional impressions or intraoral scans. The secondary outcomes, including internal fit, adjustment time for setting the crowns and occlusal contacts, and visual analogue scale (VAS) scores assessing dentists’ satisfaction, were also compared in this trial. The marginal adaptation detected using dental probe according to the FDI criteria was used for supplementary analysis. \(^1^4,^1^5\) The tested null hypothesis was that no significant difference would be found in the marginal fit detected using silicone replicas between crowns fabricated from both conventional impressions and intraoral scanning techniques.

**Materials and methods**

This single-blind randomized controlled trial was conducted at the Department of
Prosthodontics of ***. This study followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guidelines. 16 A total of 70 posterior teeth in 68 patients (34 females and 34 males; age, 24 to 65 years) were included in this study. The inclusion criteria were indication for an all-ceramic crown restoration; completed root canal therapy; and an asymptomatic posterior tooth; age between 18 and 65 years; and ability to revisit for follow-up assessments. Exclusion criteria included severe periodontal disease (grade 2 or higher mobility, bleeding index ≥ 3), bruxism, a short clinical crown (< 4 mm), incomplete root canal therapy, and absence of adjacent or antagonist teeth to the abutment tooth. All included participants provided written consent after being informed of the aims and the procedure of the study. This trial was previously registered in ***.

The 70 teeth randomly received either intraoral scanning with TRIOS (Trios intraoral scanner; 3Shape, Copenhagen, Denmark) (test group, n = 35) or a conventional impression with VPS (control group, n = 35) through a random number sealed in an opaque envelope. A consort flowchart showing the enrolment, intervention allocation, follow-up, and data analysis is presented in Fig. 1. The protocol was previously approved by the local ethics committee (***)) and the study was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice.

Forty-four molars and 26 premolars, 43 in the maxilla and 27 in the mandible, were treated. All patients underwent the same clinical protocol, which was conducted by three experienced prosthodontists. Before the study, the three prosthodontists were calibrated and separately completed the preparation of three teeth on simulation casts. The results of tooth preparations were scored automatically by the computer, and the intraclass correlation (ICC) value of the results was 0.823.

The abutment preparation consisted of a chamfer finish line and a circumferential reduction
of the tooth substance between 1 and 1.5 mm using diamond burs (TR13/62C/SO20, MANI). Occlusal reduction was approximately 1.0–1.5 mm (TF22, MANI, Japan). All internal edges were rounded and polished with fine diamond burs (Diatech 881-012-8F, Coltene, Switzerland). The margin was placed at the level of the gingiva, while some were subgingival.

Impressions were made immediately after tooth preparation. A cordless gingival retraction material (Expasyl, Acteon, France) was injected into the sulcus and left in place for 2 minutes for all patients, after which it was removed with air-water spray. Four abutments with a wide or deep (0.6–1.5 mm subgingival) shoulder due to the original tooth defect were used with the retraction cord technique (Ultrapack 00®, Ultradent, South Jordan).

Digital impressions were made using the intraoral scanner TRIOS (Standard Cart Cast T12A, with Software build 1.4.6.5, 3Shape, Denmark) according to the manufacturer’s scanning protocol. The intraoral scanner was calibrated every morning. Scanning was started from the occlusal direction. Subsequently, the buccal and lingual surfaces were scanned. The quadrants containing the prepared tooth, the antagonist arch, and the occlusion in maximum intercuspation buccally were optically scanned. The captured data were checked for the definition of the finish line and distribution of occlusal contact.

For conventional impressions, a VPS material was used in a two-step impression technique (Silagum-Putty as tray and Silagum-Light as wash material; DMG, Germany) using a stock metal impression tray. The antagonist arch impression was made with irreversible hydrocolloid impression material (ALGINOPLAST, Kulzer, Netherlands). Once removed, the impressions were disinfected and poured 1 hour later with type IV stone (Fuji Rock; GC Corp, Japan). The conventional casts were digitized by a trained dental technician using an automated laboratory scanner (D700; 3Shape, Denmark).

After tooth preparation and impression making, a provisional restoration was made
chairside using a temporary acrylic-based material (Luxatemp, DMG, Germany) and finally cemented with a non-eugenol temporary cement (Provicol, Voco, Germany).

Direct and indirect digital impressions were sent to a trained dental technician, at a laboratory, for design and manufacturing of 56 the full-contour zirconia crowns and 14 lithium disilicate glass ceramic crowns (IPS e.max CAD LT; Ivoclar Vivadent, Schaan, Liechtenstein). The design software was dental system 2017. The design parameters were set at 30 μm for the cement gap, 60 μm for the overall layer thickness, and 60 μm for the edge reinforcement. The drill radius compensation was 0.66 mm. The nesting software was Ceramill Mind. All the crowns were milled by means of a 5-axis milling machine (Ceramill Motion 2, AMANN GIRRBACH, Austria).

The marginal fit of all-ceramic crowns was the primary outcome of the study and was determined by means of the replica technique. After removing the provisional crown, the abutment teeth were thoroughly cleaned. The crowns were tried in, a fit-checker was used, and proximal contacts were adjusted using a fine diamond bur (25 μm grain size) as needed to the best fit. Then the replica technique was performed, the crowns were filled with a low-viscosity silicone (Silagum-Light; DMG, Germany), seated on the preparation, and held in place with maximum finger pressure for 5 seconds, simulating the clinical cementation of the crown. After a setting time of 2.5 minutes, the crown and the silicone were removed from the tooth carefully. If the thin layer of silicone tore during removal, the procedure was repeated. Subsequently, the lumen of the crown was filled with another low-viscosity silicone (Virtua; Ivoclar vivadent, Schaan, Liechtenstein) to stabilize the first layer. After the silicone had set, the replica was carefully removed from the crowns and sectioned. Using a sharp razor blade, one cut was made mesiodistally, and the other was made buccolingually, resulting in four
sections. The measurements were made using a digital microscope (stereomicroscope system szx16, Olympus, Japan) at 20× and 40× magnification. Image analysis software was used to measure the marginal discrepancy (the shortest distance from the margin of the coping to the abutment surface closest to the finish line), which was performed in accordance with the procedure described by Bosniac et al.\textsuperscript{11}(Fig. 2). The measurements were recorded in microns and exported to an Excel sheet.

All the replicas were prepared and all the measurements were made by the same calibrated operator, who was not involved in insertion of the restorations and was blinded to grouping. To evaluate the precision of the measurements, the intraclass correlation coefficient (ICC) values were calculated for one section of the silicone replica. Ten groups of images selected randomly were renamed by random numbers three weeks later and sent back to the same dentist for the second measurement.

The internal fit of the crowns was measured as the secondary outcome. Three measurement points were selected for each section cut off from the silicone replica: axial (A), crest (C), and occlusal (O) according to Berrendero et al. (Fig. 2).\textsuperscript{12,17,18} The following evaluation parameters were also the secondary outcomes of the study: the adjustment time required for crown seating and occlusal contact, and the dentist’s overall satisfaction rated using VAS (range, 0–10). The dentists were trained to perform the insertion and adjustment of the crowns according a standard operating procedure. After crown cementation, the marginal adaption was assessed with a probe according to the FDI criteria. All the crowns were evaluated by the same blinded examiner.

Based on the data provided by Bosniac et al.,\textsuperscript{11} a sample size of 70 teeth was used for achieving a power of 80%. The statistical analysis was performed using SPSS 22 (IBM Statistics, Armonk). The level of significance was set at $\alpha = 0.05$. The independent-samples t-test and the likelihood ratio test or Fisher's exact test were used. The mean values and standard
deviations were reported.

Results

A total of 70 monolithic all-ceramic crowns from 68 patients were evaluated in the present study. Distribution and basic information of restorations are presented in Table 1. The marginal fit obtained with intraoral scanning (57.94 ± 22.51 µm) was better than with diagnostic cast scanning (82.98 ± 21.72 µm), and the difference was statistically significant (P < 0.001) (Fig. 3). The marginal fit was (71.3 ± 26.9) µm for zirconia and (67.0± 18.3) µm for lithium disilicate (p=0.633).

The differences in internal fit, adjustment time for crown setting and occlusal contact, and VAS scores for dentist satisfaction were significant. The parameters from intraoral scanning were also better than those from diagnostic cast scanning (Table 2). The median of seating time and occlusal adjustment time of crowns made by conventional impression were 4 times higher than that of crowns made by intraoral scanning, revealing that intraoral scanning has higher efficiency. The marginal fit assessed with dental probe according to the FDI criteria were not significant.

Ten groups of images and eight points of each group (total 80 points) were remeasured for calculating ICC; the values ranged from 0.817 to 0.994.

Discussion

The mean marginal fit obtained in the present clinical trial was 57.94 µm for intraoral scanning and 82.98 µm for diagnostic cast scanning. Though the results are within 100 µm, proposed as clinically acceptable in literature, \(^{19,20}\) the differences between the two methods were significant (p < 0.05), so the null hypothesis was rejected.

In similar clinical trials, the mean marginal fit obtained was 49–141.5 µm with intraoral scanning and 56.29–143.29 µm with conventional impressions.\(^{6,12,13,17,18,21–28}\) Therefore, the
outcome we obtained for the marginal fit was good and comparable. Furthermore, five previous clinical studies reported that the marginal fit obtained with intraoral scanning was better than that with conventional impressions and that the difference was significant.\textsuperscript{11,17,18,24,27} Though two other previous clinical studies had also reported that the marginal fit obtained with intraoral scanning was better than that with conventional impressions, the differences identified in those in vivo studies were not significant.\textsuperscript{12,22} In contrast, three previous clinical studies showed that conventional impressions were better than intraoral scanning, although the difference was not significant.\textsuperscript{13,21,23} Several factors can affect the marginal discrepancy, such as different equipment, parameters setting, software versions,\textsuperscript{29} and the accessibility of the intraoral scanner.\textsuperscript{30} The differences in these factors may have resulted in the different values of marginal fit obtained by digital workflow in these clinical trials. However, the full-digital workflow eliminated the step of master cast fabrication that reduced a potential source of error, and thereby resulted in a trend of higher accuracy. Moreover, Bosniac et al.\textsuperscript{11} reported that while the intraoral scanning technique appears to be undergoing continual improvements, the method utilizing conventional impression followed by laboratory scanning appears to have reached its limit in the clinical environment.

The 3shape D700 lab scanner was used in our study and other similar clinical trials.\textsuperscript{11, 28,31} It has comparable accuracy with 3shape TRIOS intraoral scanner. However, the use of D700 makes people wonder whether the comparison results of two impression techniques revealed in our clinical trial will be still the same if an updated scanner used.

An in vitro study with a similar methodology has been published, although 3shape TRIOS 3 intraoral scanner and 3shape D2000 lab scanner were used.\textsuperscript{32} According to the manufacturer's documents, the ISO accuracy of the two scanner is 6.9 μm and 5 μm respectively. They reported the marginal gap of zirconia crowns was (106 ± 87) μm for the PVS group and (53 ±56) μm for
the TRIOS 3 group (P<.05). The intraoral scanning has better marginal fit, which is consistent with our trial. Interestingly, a parallel group of “PVS A” was set up in their study. In this group, the zirconia crowns were seated on the stone die instead of seated on the typodont tooth, so the marginal gap value was (34 ± 49) μm. The marginal fit has been significantly improved compared with PVS group. The difference between “PVS A” group and “PVS” group was that the steps of making conventional impression and poured with stone were eliminated. To some extent, this was similar to the difference between cast and the clinical situation in vivo study. Using metal tray, PVS impression material and type IV stone, the dimensional change of conventional impression can be minimized. However, it is still unable to control all variables (eg. dimensional change affected by thermal changes33) and human errors. 32 The study by Carrilho et al. revealed these factors accounted for a considerable proportion in the final deviation of marginal gap. Moreover, these uncontrollable variables and human errors can’t be eliminate by improving the accuracy of dental scanner.

The marginal fit was evaluated using a silicone replica and probes in the present clinical trial. Replica techniques have been used in many studies. They are reliable, quantitative, and allow non-invasive detection of in vivo adaptation of the crown-to-tooth surface.11,27,34,35 However, these methods have inherent errors and limitations.36,37 One of the main problems is the difficulty in identifying overhanging margins and steps.26 In contrast, probes can easily reveal them.15 Therefore, a combination of replicas and probes would be more reliable for evaluating marginal fit.

An excellent marginal fit depends on good gingival sulcus opening and hemostasis at the finish line of the abutments. The gingiva may bleed due to injury during tooth preparation, and this can badly affect impression quality. Hence, Rodiger et al. made impressions after a minimum waiting time of seven days to allow complete healing of the soft tissues.21 However,
this protocol necessitates more patient visits and prevents restorations from being created in a single visit, which is the unique advantage of chairside CAD/CAM. In our study, Expasyl, a cordless gingival retraction paste, was used to achieve immediate gingival hemostasis and good gingival sulcus opening. Rayyan et al. compared four cordless gingival displacement pastes in vivo and found that Expasyl produced the best vertical displacement (200–300 µm) and sufficient gingival sulcus opening (375–550 µm). Chandra et al. also found that Expasyl could yield a sufficiently large sulcal width and facilitate immediate hemostasis. However, the cord system showed a greater amount of displacement than the cordless system. Therefore, in this study, in four abutments with a wide or deep finish line (subgingival, 0.6–1.5 mm) because of original tooth defect, retraction cord technique with Ultrapack prior to Expasyl application was used to achieve greater gingival displacement than with the cordless paste alone. For deep subgingival finish lines, some trials have suggested performing surgical crown lengthening prior to impression making.11

The mean value of internal fit reported in other clinical studies ranged from 96.65 µm to 190.55 µm for the conventional impression technique and from 111.40 µm to 228.48 µm for intraoral scanning.12,17,18,21–24 The corresponding values obtained in the study were 125.44 µm and 106.89 µm (p<0.05). The findings of the present study were in the lower range of the previously published values. This may be partly due to the use of different milling unites. The type of milling machines could affect the result of internal fit.40 Restorations fabricated with 5-axial mill device have a higher accuracy than those milled with 4-axial mill device.41 This trend is consistent with the results of marginal fitness and supported the finding of the higher accuracy with intraoral scanning.

The present study reported that the mean adjustment time for crown setting was 51.69 seconds with the intraoral scanning technique and 120.37 seconds with conventional
impressions. This time was mainly spent for adjusting the proximal contacts. There are few clinical studies regarding this. In a study by Sakornwimon et al.\textsuperscript{13} the average time spent in adjusting the proximal contacts was 216 seconds for the conventional impression group and 138 seconds for the digital impression group. The digital impression group required less time, like the trend observed in our study. The mean adjustment time of occlusal contacts was 80.11 seconds for intraoral scanning and 223.00 seconds for conventional impressions. In a previous study, the adjustment duration for occlusal contact was 216 seconds for digital impressions and 522 seconds for conventional impressions.\textsuperscript{13} Gjelvold et al.\textsuperscript{42} verified the “occlusal contacts” with occlusion foil, and the results showed a better result for the digital technique. The trend seen in the above studies are consistent with that of the present study. However, two other studies that had also investigated occlusal contacts by using occlusion foil showed no significant differences between conventional and digital impressions.\textsuperscript{27,28} The intraoral scanning technique showed better results in VAS assessments of dentist satisfaction, which was consistent with the results reported by Gjelvold et al.\textsuperscript{42}

Intraoral scanning technology greatly improves the clinical efficiency of single crowns. The reasons why necessary adjustment is still needed in clinic is mainly the accumulated dimensional deformation along the process chain, including the accuracy of intraoral scanner, the parameters set in the CAD process,\textsuperscript{43} the complex shape of restorations and the accuracy of milling devices. There are also dimensional changes caused by necessary manual polishing, glazing and staining after the restoration was milled. Due to the continuous technological improve in the full digital workflow, the potential sources of dimensional change are expected to be reduced.

Wostmann et al.\textsuperscript{44} investigated the marginal gap with different VPS impression techniques in vivo. They found the two-step technique to be slightly superior to the one-step technique
particularly for infragingival margins. Therefore, the two-step technique with VPS impression was used in this present trial and few other studies.\textsuperscript{12,24,27}

Two kinds of restoration material (zirconia and lithium disilicate glass ceramic) were involved in the present trial. Previous studies had demonstrated there were no significant differences in marginal fit between the two restoration materials.\textsuperscript{35,45–47} It is reasonable that the adaption of a CAD/CAM restoration depends on the accuracy of the milling unit rather than on the material itself.

This present trial supported the finding that intraoral scanning is a better choice with improved accuracy for processing of dental crowns. However, there were some clinical limitations associated with the indications for intraoral scanning. First, the accuracy of digital impressions could be influenced by the scanning range. The TRIOS system tested in the present study has been demonstrated to have acceptable accuracy up to a scanning range of half an arch.\textsuperscript{48} When the scope of intraoral scanning is extended to the full-arch, the results may be different from the present study.\textsuperscript{49} Second, previous studies have shown significant differences in marginal and internal accuracy among different intraoral scanning devices,\textsuperscript{50} so care should be taken when extrapolating the results of this study to other oral scanning devices. Third, three experienced prosthodontists were involved in teeth preparation. Although we tried to calibrate them on simulation casts before the start of the trial, tooth preparation in vivo is after all different from in vitro. Further analysis should be carried out in the future. Finally, long-term clinical observations are still needed to determine whether the improvement in the prosthetic performance brought about by intraoral scanning technology will provide long-term benefits to the abutment teeth.

**Conclusions**
Within the limitations of this clinical trial, though both techniques offered clinically acceptable results, monolithic CAD/CAM-fabricated single crowns in the posterior region produced by an intraoral scanning technique using Ultrafast Optical Sectioning™ technology offer a more accurate and efficient alternative to restorations based on conventional impressions in combination with laboratory scanning technique.

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Conflict of interest declaration
No conflict of interest exits in the submission of this manuscript, and manuscript is approved by all authors for publication. We declare that the work described was original research that has not been published previously, and not under consideration for publication elsewhere, in whole or in part. All the authors listed have approved the manuscript that is enclosed.

Ethical approval: All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study protocol was approved by the Ethical Committee of the ***, and registered at the ***.

Informed consent: Informed consent was obtained from all individual participants included in the study.
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doi:10.1016/j.prosdent.2014.05.012


### TABLES

**Table 1.** Distribution and basic information of restorations in the test (intraoral scanning [IOS]) and control (cast scanning) groups.

<table>
<thead>
<tr>
<th></th>
<th>Intraoral scanning</th>
<th>Cast scanning</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crowns(n)</td>
<td>35</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Ages (years)</td>
<td>40.80 ±11.93</td>
<td>36.26 ±8.69</td>
<td>0.073</td>
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<tr>
<td>Gender (n)</td>
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<tr>
<td>Male</td>
<td>18</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>17</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Tooth (n)</td>
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<td></td>
<td>0.522</td>
</tr>
<tr>
<td>Maxillary</td>
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<td>9</td>
<td></td>
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<td>premolar</td>
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<td></td>
<td></td>
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<tr>
<td>Maxillary</td>
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<td>14</td>
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<td>Mandibular</td>
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<td></td>
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<tr>
<td>premolar</td>
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<td></td>
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<tr>
<td>Material (n)</td>
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<td></td>
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<tr>
<td>-------------</td>
<td>-------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zirconia</td>
<td>27</td>
<td></td>
<td></td>
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<tr>
<td>Lithium</td>
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<tr>
<td>disilicate glass</td>
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<tr>
<td>Location of finish line (n)</td>
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<tr>
<td>Supragingival</td>
<td>21</td>
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<tr>
<td>Subgingival</td>
<td>14</td>
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</table>

Mandibular molar

This peer-reviewed, accepted manuscript will undergo final editing and production prior to publication in IJP.

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Table 2. Comparison of the internal fit (µm), procedure duration (seconds, mean value ± SD), visual analogue scale (VAS, mean value ± SD) and marginal adaption according to the FDI criteria results

<table>
<thead>
<tr>
<th></th>
<th>Intraoral scanning</th>
<th>Conventional Impression</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal fit (µm)</td>
<td>106.89 ±34.29</td>
<td>125.44 ±36.20</td>
<td>0.0311*</td>
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<td>Adjustment time of crown insertion (second); (median)</td>
<td>51.69 (15)</td>
<td>120.37 (67)</td>
<td>0.0</td>
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<tr>
<td>Adjustment time of occlusal contact (second)</td>
<td>80.11 (36)</td>
<td>223.00 (170)</td>
<td>0.0</td>
</tr>
<tr>
<td>VAS of dentist's assessment</td>
<td>8.95 ±1.27</td>
<td>7.95 ±1.59</td>
<td>0.0048*</td>
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<tr>
<td>Marginal adaption</td>
<td>34 (97.1%)</td>
<td>34 (97.1%)</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

* denotes a significant difference (p < 0.05).
FIGURES

**Fig. 1.** Flow chart showing study protocol.

```
Assessed for eligibility (n=70)
  Patients excluded (n=0)
Random Treatment Order (n=70)
  Allocated to intervention (n=35)
    Crowns from intraoral scanning (n=35)
  Allocated to intervention (n=35)
    Crowns from silicone impression (n=35)

Lost to follow-up (n=0)  Lost to follow-up (n=0)

Analysis (n=35)
  Excluded from analysis (n=0)
  Excluded from analysis (n=0)
```

**Fig. 2.** Title: Graph of two-layered silicone replica.

Cross-section of replica with locations of measurement points. blue=abutment, orange=marginal/internal gap.
**Fig. 3.** Title: Box plot diagram of marginal fit of different impression methods. Significant differences are connected by the horizontal lines, P< 0.001.