Comparison of accuracy of single crowns generated from digital and conventional impressions: an in vivo controlled trial

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INTRODUCTION

Dental impression is a negative imprint of an oral structure used to produce a positive replica, used as a permanent record or in the production of a dental restoration or prosthesis. Thus, accuracy in the development of the impression is a determining factor to assure a successful fabrication and survival of both fixed and implant-retained prosthesis (1,2). Conversely, inadequacy in impression-making technique and/or in the manual steps of prosthesis fabrication may lead to several problems related to the misfit of the fixed dental prosthesis. These include luting agent dissolution (3), microleakage (4), caries hypersensitivity (5) and periodontal inflammation (6,7), but also issues concerning the retention of the crown which may affect prosthesis longevity (8).

Marginal and internal fitness (MG and IG, respectively) are important criteria for the success of fixed dental prostheses (FDPs). A high level of impression accuracy is important to assist the fabrication of a precise restoration (9).

According to the literature, the reported MG for the metal-ceramic crowns ranges from 26 to 138 μm (10) or 50 to 100 μm (11), depending on whether these are fabricated by traditional impression (TI) (10) or digital workflow (DI) (11), respectively. In fact, to date, TI using different impression materials and DI using intraoral scanners, represent two approaches by which impressions of dental arches may be accomplished. The implementation of the intraoral digital workflow has allowed the elimination of many procedures (12, 13). In comparison with TI, intraoral DI technique can save time and steps for both dentists and technicians. In particular, steps avoided at the dental office include tray selection, material dispensing/setting/disinfection and impression packaging and shipping; steps eliminated at the lab are plaster pouring, die cutting, trimming, articulation, and extraoral scanning (8-11, 14). Moreover, simplification of the protocols also resulted in greater patient comfort depending on...
time reduction in clinical treatments (15-17). However, different obstacles and deficiencies have to be addressed in intraoral impressions too; these are related to the digital workflow and include additional costs of purchasing an intraoral scanner, the learning curve and rate adjustment models and scanner displacement to assure scanning accuracy (15,16).

Several authors investigated different variables concerning the TI technique but few compared the accuracy of casts produced by TI versus DI techniques (18). Moreover, the results are discordant as some studies recorded better results from DI compared to TI (19,20,21), while others, considering the fit of single crowns, reported a comparable outcome for both techniques (22,23).

With the development of digital dentistry, more clinical investigations are needed to determine clinical accuracy of new DI techniques combined with CAD/CAM technology. According to our knowledge, only four studies evaluated the MG of crowns produced by means of TI versus DI techniques, with a replica in vivo (23-36); hence, the aim of this study was to compare the accuracy of the two approaches in realizing a single crown on natural tooth, measuring the MG through Scanning Electron Microscopy (SEM). The null hypothesis was that no significant differences would be found between TI and DI techniques.

**MATERIALS AND METHODS**

**Patients enrollment**

This study was performed in a private practice, in accordance with the Declaration of Helsinki and Good Clinical Practice (GCP).

A total of 30 adult patients were recruited from individuals who were previously considered for regular treatment with fixed prostheses. In particular, all patients needed single crowns in the posterior region. As Good Clinical Research Practice (GCRP) requires, patients were always asked to give full and informed consent before inclusion within any protocol. Hence, informed consent was provided by each participant before being enrolled in the study.

Regarding the inclusion criteria, these were: over 18 years of age; good general health; no local inflammation; good oral hygiene; posterior teeth (premolar or molar) planned for regular treatment with single fixed crown and no requirement for additional endodontic treatment. On the other hand, the exclusion criteria included: pregnancy and advanced periodontal disease with teeth mobility.

**Preparation technique**

The treatment was performed by the same specialist in prosthodontics according to a standardized protocol; in particular, the teeth needing treatment were prepared under local anaesthesia and providing a chamfer finish line (27). The chamfer finish line was carried out with a circumferential reduction of the tooth structure (range: 1.5-2 mm); all internal edges were rounded, and the preparation's convergence angle (approximately 6 degrees) was achieved through holding the chamfer tapered as straight as possible (24-27). Moreover, the margin was performed at the level of the gingiva and in any case without exceeding the subgingival depth beyond 1 mm (24-27). A provisional crown of polymethyl methacrylate acrylic (PMMA) (Luxatemp, DMG, Hamburg, Germany) was placed on the prepared tooth. Thereafter, the TI and the DI techniques were performed after a minimum waiting period of 4 weeks from the preparation to allow the healing of possible gingival injuries caused by the preparation procedure.

**Impression protocols: TI versus DI technique**

The provisional crowns were removed, and the abutment tooth was cleaned with pumice on a rotating brush. Double retraction cords (Ultrapak 000 and 00, Ultradent, South Jordan, USA) were plugged into the sulcus using the double cord technique; the same retraction cord technique was used for both the TI and DI. Sixty TI and 30 DI of the abutment tooth were realized. In particular, the DI was performed by using an intraoral digital scanner (Zfx Intrascan, Zfx GmbH, Zimmer Dental, Dachau, Germany) according to the manufacturer’s protocol. No powder was applied and intraoral scanner was calibrated prior to scanning the abutment tooth. The stereolithographic interface (STL) files were then sent electronically by Zfx DentalNet (Zfx GmbH, Zimmer Dental, Dachau, Germany) to the dental laboratory. After finishing the intraoral scans, the TI technique was performed.

Perforated metal stock trays were used for the TI. The trays were varnished with an adhesive for polyvinyl siloxane (PVS) 5–10 minutes before impression (VPS Tray Adhesive, 3M ESPE, Seefeld, Germany). PVS materials were used as material impression for each conventional impression (Express 2 Penta Putty/Express 2 Light Body Quick, 3M ESPE, Seefeld, Germany). The dental antagonist was taken using dental alginate (Aroma Fine; GC Corp, Tokyo, Japan). The registration of the bite was performed by Imprint Bite (3M ESPE, Seefeld, Germany). The impressions were then poured with type IV dental plaster (Shera Hard Rock) and sent to the same dental laboratory. The model was scanned by means of a laboratory scanner Zfx Evolution (Zfx GmbH, Zimmer Dental, Dachau, Germany). The digitalized data from the TI, as well as the DI, were transmitted to CAD software program (Exocad Dental CAD) which allowed for the design of the crowns using identical parameter settings for both; the STL files were then sent to centralized milling centre (Zfx, Gargazzone, Bolzano, Italy) for review and fabrication of Co-Cr copings. Three Co-Cr copings were fabricated for each...
of the 30 teeth. A total of 90 Co-Cr copings showing the same design (cement gap: 80 μm; layer thickness: 700 μm; edge reinforcement: 250 μm) were fabricated. In particular, two copings were made using the TI techniques (n=60) and one coping by means of DI technique (n=30). Thereafter, one of the two copings prepared by TI technique was randomly examined for both the MG and IG while the other one was conserved to be veneered with porcelain and finally cemented to the patients. The cementation stage was performed after ensuring the correct seating of the crowns on the abutments tooth by a tray-in stage.

Fit analysis
To analyse the IG between the internal surface of the coping and the abutment tooth, replica technique was applied in vivo. The copings were first filled with a low viscosity silicone (Xantropen VL, Heraeus Kulzer, Hanau, Germany) and then located on their corresponding abutment tooth. The copings were pressed in the correct position exerting maximum finger pressure in order to simulate the crown cementation. After 3 minutes, the copings were dragged off the abutment tooth with a partial conventional impression (Express 2 Penta Putty/Express 2 Light Body Quick, 3M ESPE, Seefeld, Germany) which was poured with a resin Exakto-Form (Bredent, Senden, Germany) to obtain a stump mimicking the abutment tooth. All copings were cemented on the respective abutment tooth made of resin, using a resin-reinforced glass-ionomer cement (GC Fuji PLUS, GC Europe) before being embedded in an epoxy resin (Araldite 2000; Huntsman corporation, Ternate Varese, Italy). After 24 hours, the copings, cemented in abutment tooth incorporated in the resin, were cut in 2-mm thick slices using a precision cutter (Isomet LSS Buehler; ITW Company Lake Bluff). Thereafter, the sections were polished with a Labopol-35 (Struers s.a.r.l., Milano, Italy) and metalized by means of a high-vacuum carbon evaporator (Emitech K950X) prior to being analyzed by SEM (CamScan MX 3000) (29) (Fig. 2). One section for each coping was randomly selected and analyzed by SEM to identify the distance between the internal surface of the coping and the abutment tooth surface close to the preparation finish line (MG) (24,27,30) (Fig. 3); as well as the distance from the coping to the abutment at the lowest point.

<table>
<thead>
<tr>
<th>Marginal Gap</th>
<th>Internal Gap</th>
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<tr>
<td>Traditional Impression</td>
<td>Digital Impression</td>
</tr>
<tr>
<td>Mean</td>
<td>75.04 μm*</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>13.12 μm</td>
</tr>
<tr>
<td>Min</td>
<td>53.17 μm</td>
</tr>
<tr>
<td>Max</td>
<td>97.49 μm</td>
</tr>
<tr>
<td>p-value*</td>
<td>0.001</td>
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</table>

Level of statistical significance was set as α = 0.05 and statistical power of 80%.
Fixed dental prostheses are routinely manufactured. CAD/CAM methods are used more often, allowing to overcome the limitations of the lost-wax technique which is time-intensive and also yields inconsistent results (32). A typical fixed restoration, manufactured using a dental CAD/CAM system needs a dental impression. Since the accuracy of the impression affects the accuracy of the definitive cast, an accurate impression is essential to fabricate a prosthesis with a good fit. Conversely, an inaccurate impression may result in failure to restore tooth anatomy leading to prosthesis misfit, and occurrence of mechanical and/or biological complications such as disturbed occlusal function and painful muscles (33).

As dental impressions represent an important step in all restorative treatments, to date, significant progress has been made in procedures for making impressions for fixed prosthodontics. Beside the TI techniques, DI techniques stands out. Hence, the aim of this study was to assess the accuracy of copy denture templates produced using DI versus TI techniques for fabricating cobalt-chromium copings veneered with porcelain. According to our data, a statistically significant difference was found between conventional impression group and digital impression group (p-value = 0.001). Specifically, the comparative statistical analysis showed that the copings of DI-group had a better fit than the copings of the TI-group.

DISCUSSION

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Revising the literature, there are few studies evaluating the accuracy of single crowns produced through the support of intraoral scanners (23,24,34); at first, we considered the MG (μm), but as in vivo measurement of the MG is not achievable, we used a replica technique (14,17,24,30,34); the purpose was to assess the misfit between the crown and the abutment tooth. In the literature, few studies measured the MG of crowns produced by means of intraoral scanning versus
conventional impressions, taking advantage of a replica (23-26). Among these, Boeddinghaus et al. (23) analyzed the marginal fit of dental crowns realized from three different intraoral digital impressions and one from conventional impression. The recorded mean values of MG were 88 μm (range: 68 – 136 μm), 112 μm (range: 94 – 149 μm) and 149 μm (range: 114 – 218 μm) for True Definition (3M ESPE, Seefeld, Germany), Cara Trios (3Shape, Copenhagen, Denmark) and OCAM (Sirona, Bensheim, Germany), respectively. As regards the conventional impression technique, the recorded MG value was 113 μm (range: 81 – 157 μm). Zarauz et al. (24) analyzed the marginal fit of dental crowns based on one intraoral digital system (Caredent-iTero, Align Technology, San Jose, USA) and one conventional impression. Mean IG and mean MG were 111.40 μm (SD=54.04)/80.29 μm (SD=26.24), respectively for the crowns of the intraoral DI group and 173.00 μm (SD=92.65)/133.51 μm (SD=48.78) for the TI group. Syrec et al. (25) found a MG of 49 μm for the DI group (Lava Cos, 3M ESPE, Seefeld, Germany) and 71 μm for the TI-group. Brawek et al. (26) measured the misfit of crowns generated by two intraoral digital scanners, without considering any conventional impression technique. The mean MGs for Lava Cos (3M ESPE, Seefeld, Germany) and CEREC AC (Sirona Dental Systems, Long Island City, NY) were 51 μm and 83 μm, respectively.

After comparing the results reported by other authors with the ones recorded by our analysis, it emerges that the mean MG we identified was slightly smaller than the results of Boeddinghaus et al. (23) and Zarauz et al. (24); conversely, it was similar to the values reported by Syrec et al. (25), Brawek et al. (26) and Scotti et al. (34). As Syrec et al. (25), we fabricated only copings, while Boeddinghaus et al. (23) and Zarauz et al. (24) veneered the crowns with porcelain. Thus, the addition of aesthetic ceramic might have some influence in the marginal fit (35).

To date, there is not a consensus on what is clinically acceptable in terms of maximum marginal gap width. However, according to the first study in literature (36), the reported value which can be considered as clinically acceptable is <120 μm. Noteworthy, all intraoral impression systems in the few published clinical studies reported a MG <100 μm.

CONCLUSION

Despite the limitations of this study, it can be concluded that the copings fabricated from the DI, produced MG and IG adaptation results overall better than copings fabricated from TI. However, both techniques assure the obtainment of clinically acceptable results. The technology of intraoral DI enables the clinician to produce accurate restorations without the unpleasant aspects of traditional impression materials and techniques.

REFERENCE


