Evaluation of the Adaptation of Complete Dentures Fabricated Using Intraoral Scanning and Conventional Techniques

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ABSTRACT

Aim and objective: This study aimed to digitally analyze the 3-dimensional variations existing between conventional impressions and intraoral scans made in edentulous maxillae.

Materials and methods: Ten (n = 10) edentulous maxillae of patients seeking a maxillary complete denture were scanned using an intraoral scanner. The same participants were subject to the conventional impression procedure for the fabrication of maxillary complete dentures. The dentures' intaglio surfaces were scanned and superimposed over their corresponding IOS files with a 2-base best-fit alignment. Deviation analyses were calculated using the digital subtraction technique. Four anatomical regions were preselected to evaluate the deviations at these sites (posterior palatal seal, anterior border seal, the crest of the ridge, and palate).

Results: Based on the results and color maps of all selected regions, the overall difference between the two scans [IOS and denture intaglio surface scanning (DISSI)] was not significant. The IOS technique allowed for predictable outcomes of treatment compared to those observed with conventional impression. The palatal area seems to be the region with the least deviation, while the highest incidence of discrepancy was reported in the anterior border seal.

Conclusion: Within the limitations of this study, the IOS technique allowed the capturing of intraoral tissues and their immediate interpretation and transfer to a designing software making the impression procedure faster and easier.

Clinical significance: The computer-aided design (CAD)/computer-aided manufacturing (CAM) technologies can help overcome many limitations related to conventional impressions and therefore should be well investigated to improve the edentulous patient's quality of life.

Keywords: Adaptation, Complete denture base, Conventional impression, Intraoral scanning.

The Journal of Contemporary Dental Practice (2020): 10.5005/jp-journals-10024-2977

INTRODUCTION

Conventional removable prosthodontic remains the standard of care in treating edentulous patients. The multitude of clinical and laboratory steps needed for the fabrication of prosthetic devices can generate several errors related to the techniques or the materials.¹,² Patient discomfort is another disadvantage of a conventional impression as many patients experience gagging reflex triggered immediately after the material's placement in the oral cavity.³ A careful standardization of the clinical steps might decrease these complications but cannot omit them completely.

The use of computer-aided design and computer-aided manufacturing (CAD-CAM) technologies in the removable dentures confection open the door to a new era in digital removable prosthodontics adding several advantages to the conventional approach.⁴,⁵ The indirect method using an extraoral laboratory scanner implies scanning of the cast stone or the conventionally made impression to obtain a digital master cast. Then, the software is used to design the denture that will be milled or 3D printed accordingly.⁶

Currently, intraoral scanners (IOS) routinely used in fixed restorations have demonstrated high precision when compared to conventional methods.⁷ The use of IOS in removable prosthesis can offer several advantages such as dentures fabrication in a fully digital workflow, patients comfort, and reduction of errors related to materials distortion or technique sensitivity.⁸,⁹

The evidence related to the adaptation of complete dentures using intraoral digital scanners is scarce. The few published studies reported significantly better trueness of intraoral scanning compared to physical impressions for edentulous arches.⁹-¹¹ Although some reports confirmed comparable accuracy in registering hard tissues using either intraoral scans or conventional impressions,¹²,¹³ others established that scanning edentulous arches do not lead to the accurate results needed.¹⁴,¹⁵ Complete-arch scan accuracy was evaluated in the literature.¹⁶ The median value of trueness was reported in a study to be 54–180 μm in edentulous tissues while the precision was 109–215 μm.⁸ The accuracy of intraoral scans is deeply influenced by the scan pattern which can create a huge precision inconsistency.¹⁷ Furthermore, the type
of scanner is of big importance and might create a wide range of discrepancy among the machines used. This makes some laboratories more comfortable with converting the plaster stone cast issued from a conventional impression into a virtual one by the means of a highly accurate laboratory scanner.

This study aimed to digitally analyze the 3-dimensional variations existing between conventional impressions and intraoral scans made in edentulous maxillae.

The null hypothesis tested was that the accuracy of potential adaptation of the complete denture fabricated with the IOS is similar to the adaptation provided by the conventional impression.

**Materials and Methods**

Ten participants (45–70 years) with completely edentulous maxillary arches and seeking treatment to receive a complete denture at the department of prosthodontics, faculty of dental medicine, Lebanese University, were selected for the study. After the approval from the ethical committee, all-volunteer participants signed informed consent before the treatment. The inclusion criteria were to have good general health and the absence of any signs or symptoms of temporomandibular joint disorders and a well-formed edentulous maxilla. The exclusion criteria were dementia, malignant neoplasias, dependence on caregivers, excessive ridge resorption, and extensive bony undercuts.

**Intraoral Scanning**

The edentulous maxillary arch of each participant was scanned by means of an intraoral scanner (TRIOS 3; 3Shape) by the same trained prosthodontist (GM). To make the scanning procedure easier, a soft tissue retractor (OptraGate; Ivoclar Vivadent, Schaan, Liechtenstein) was used. The sequence of scanning the edentulous maxilla was initiated at the crest of the ridge then captured the palatal area followed by the buccal and labial mucosa. A virtual digital master cast was obtained for each scan (Fig. 1).

**Denture Intaglio Surface Scanning (DISS)**

The same participants were subject to the conventional impression procedure for the confection of their prostheses. The primary impression of the edentulous maxilla was made with an irreversible hydrocolloid material (Image Dust Free, Dux Dental, Germany) using a stock tray. The impression was poured and a maxillary custom tray was made in the laboratory using an autopolymerizing acrylic resin (Triad TruTray; Dentsply Sirona). Initially, the custom tray was tried in the mouth to remove any muscular interference, then the secondary impression followed. Border molding of the custom tray was made using a low-fusing modeling compound (Bite Compound, GC, Japan), and relining was then made using PVS (Imprint 3, 3M-ESPE, Seefeld, Germany). After an hour, the casts were poured using type IV dental stone (Kalrock-Kalabhia Karson India Pvt. Ltd., India). Maxillary complete dentures were obtained.

The intaglio surface of the obtained dentures was then scanned (Fig. 1) with an intraoral scanner (Trios 3, 3Shape). The datasets obtained were in the DM file format (a proprietary file format by 3Shape) and were exported to the CAD software (Orthoanalyzer).

**Superimposition**

3Shape proprietary DCM IOS files and the DISS files were superimposed with a 2-base best-fit alignment using a special software program (Ortho Analyzer 2019, 3Shape). Superimposition was done by identifying the same three points on both models. The software aligned the surfaces while using these three points as references. These points were selected to form a triangle (palatal, anterior, posterior) on unchanged landmarks of the palate and ridges.

The mean distance between the superimposed scans was measured at different points. Four anatomical regions were preselected to evaluate the deviations at these sites (posterior palatal seal, anterior border seal, the crest of the ridge and palate) (Fig. 2). The distance measurements were recorded and the deviations were extracted from the software as mean values and standard deviations. The collected data were represented in a color map highlighting the variations among the two techniques and were included in a report obtained from the software (Fig. 3).

**Statistical Analysis**

The overall and area-related variations in the adaptation of the conventionally made DIS over corresponding STL file were compared and data were analyzed using a statistical package (SPSS, v 24, USA). A one-way analysis of variance (ANOVA) was used followed by a post hoc test. Statistical significance was set to $p < 0.05$.

**Results**

Following the superimposition, the measurements were done by manually creating standardized planes at the four previously

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**Figs 1A and B:** The STL file of the scanned maxilla for the same patient: (A) IOS and (B) Denture intaglio surface scanning
described regions. For each region, the space between the two superimposed surfaces was measured in three different positions (left, center, and right). The mean and standard deviation for each of these locations were then calculated. The overall difference between the two scans was not significant (0.502 mm, \( p > 0.005 \)). The mean deviation for the IOS and DISS over the entire surface is represented in Table 1. The adaptation over different selected regions (posterior palatal seal, anterior border seal, the crest of the ridge, and palate) is reported in Table 2. Color maps of the surface-matching variations among the two tested surfaces are shown in Figure 3. Blue zones indicate a high adaptation of the denture over the corresponding edentulous arch. The degree of adaptation is proportional to the intensity of the color. Yellow to red zones indicate a spacing between the denture and the edentulous arch. However, the white color represents either a perfect adaptation (color scale = 0 mm) or a maximal discrepancy. This discrepancy can be considered either an overcompression (color scale = −3 mm) or an over spacing (color scale = 3 mm). Therefore, an entirely white map represents either the absence of any impression-related deformation and consequently a perfect adaptation of the denture over the edentulous maxilla or, on the opposite an increased discrepancy (impingement or spacing). Accurate measurement of the distance between the denture intaglio surface and the corresponding edentulous maxilla must be accomplished to determine the appropriate adaptation. As shown in Table 2, the palatal area seems the region with the least deviation (mean = 0.357 mm), while the highest incidence of discrepancy was reported in the anterior border seal (mean = 0.659 mm). Therefore, the digital evaluation of intraoral scans and conventional impressions made in edentulous maxillae highlighted the variation in adaptation among these different evaluated areas.

**Table 1: Mean and standard deviation of the overall evaluated surface**

| Overall surface | Mean (mm) | Standard deviation (mm) |
|-----------------|-----------|------------------------|
|                 | 0.502     | 0.035                  |

**Table 2: Mean and standard deviation of different selected regions**

| Region                        | Mean (mm) | Standard deviation (mm) |
|-------------------------------|-----------|-------------------------|
| Posterior palatal seal        | 0.447     | 0.089                   |
| Anterior border seal          | 0.659     | 0.099                   |
| Crest of ridge                | 0.579     | 0.092                   |
| Palatal area                  | 0.357     | 0.089                   |

**Discussion**

Based on the results of the current study, the null hypothesis tested that the accuracy and adaptation of the complete denture fabricated with the IOS are similar to the adaptation provided by the conventional impression was accepted. When compared with IOS, conventional impression with PVS proved a non-significant decrease of complete denture adaptation...
and exhibited a slightly larger interindividual variability with the highest SD for anterior border seal (mean = 0.659 mm, SD = 0.099 mm). The palatal area showed a relatively high SD (SD = 0.089 mm). The compressible nature of the palatal mucosa under the force exerted by the impression material might contribute to the observed differences. These results are in accordance with the study of Gan et al.,19 who compared the two impression techniques (IOS and CI) in the palatal mucosa of dentate patients. After digitally scanning the patients’ palatal soft tissue and comparing it to a scanned reference cast obtained from a PVS impression, they found trueness of 130.54 ± 33.95 µm and a precision of 55.26 ± 11.21 µm. The authors mentioned that this variation would be due to IOS being a mucostatic impression where the scanned objects’ flexibility does not interfere with the resultant impression, unlike the mucocompressive conventional impression.

Furthermore, anatomic variations could affect the accuracy of the impression technique. It should be well noted that the soft tissues have a varying degree of flexibility when compared to each other, and then will act differently and exhibit a different amount of movement under the same pressure exerted by the same conventional impression material. Picton and Wills20 mentioned that the contribution of mucosal resilience is related to the measured mean distance between IOS and DISS. In the present study, the different evaluated areas moved to a different extent when compared to each other. Consequently, the palatal area seems the region with the least deviation between the two impression techniques (mean = 0.357 mm), while the highest incidence of the discrepancy is detected in the anterior border seal (mean = 0.659 mm).

PVS impression and IOS resulted in a complete denture with a comparable adaptation (mean = 0.502 mm, SD = 0.035). Although the matching of IOS and DIS showed that some deviations in the measurements do exist between the different techniques and the largest differences are mainly detected at the borders (anterior border seal mean = 0.659 mm, SD = 0.099 mm). This impaired alignment and consequently variation in the accuracy of issued complete denture adaptation could be due to the absence of some peripheral regions in both files being hardly detectable. The clinical strategy followed to make the IOS and the conventional impression influenced these findings. During intraoral scanning, a stretching of the movable tissue was intended as a part of the procedure which made this technique unable to capture the tissue compression. The IOS is an impression technique of oral mucosa that is taken in its static state while in the CI the impression material applied some degree of pressure on it. The variation in the morphology of edentulous jaws also contributes to the obtained results since the pressure applied by the impression materials is differently conceived and therefore leads to various levels of tissue displacement in different regions.

Chebib et al.21 compared the trueness of impressions made with conventional impression materials or IOS in an edentulous maxilla. They concluded that edentulous arch impressions made with PVS, PVS modified with ZOE and IOS exhibited identical deviations and give clinically predictable outcomes. These results are in accordance with ours where digitizing maxillary edentulous jaw seemed a viable option for complete denture base fabrication. However, the drawback of this technique lies mainly at the periphery and the borders of the denture. During the scanning procedure, the recording of a functional border was not possible since the labial and the buccal mucosa had to be permanently retracted. These areas are of major importance for the retention of a complete denture. The borders must be near the tissues to restrict air and particles from going through.22

Establishing ideal, complete denture retention requires an understanding of the contribution of each anatomical area. Incorporation of these determinants into the prosthesis through adequate design and technique leads to a successful treatment.23 Maxillary complete dentures are prone to dislodgment due to their weight, physiological functions, adhesion of sticky food, and muscular interference.24 To remain in place, these prostheses must, therefore, exhibit sufficient retention and be appropriately sealed around the borders.25 The decreased adaptation of the IOS, when compared to CI in the anterior border seal, is in favor of increased retention of the conventionally fabricated denture bases. In the palatal region, the increased adaptation observed in both techniques has a favorable impact on the retention of the obtained denture base. However, special consideration should be made to the sensorimotor function and deglutition. Extensive coverage of the palate can decrease masticatory performance and impair sensations.26–28 Therefore, further improvement should be seriously considered in the field of digital scanning dentistry to incorporate accurately and functionally all the complete denture supporting tissues. Based on the current study’s results, the digital impression of edentulous ridges is a suitable technique to make complete dentures, especially for high ridges (i.e., class I and II)29 where the retention of the prosthesis is more dependent on the retentive forms of the ridge (i.e., undercuts) than on the peripheral seal.

A limitation is inherent to the current study’s design: being an in vitro study, it does not properly address the difference in soft tissue compressibility. The IOS is a mucostatic impression technique, when compared to the conventional mucocompressive impression technique, underlines the importance of conducting in vivo studies to obtain realistic and clinically applicable results. The difference in data input among the two techniques would contribute to the accumulation of errors. Thus, differences between the IOS and DIS using a lab scanner could be related to the different physics ruling the process of these techniques and not to any discrepancy in accuracy of one technique over the other. On the contrary, the only conventional impression material used in this study is the PVS. It would have been interesting to test and compare the performance of other impression materials that might prove better behavior in specific areas. Further evaluation of the patient preferences, comfort, gagging reflex, and nausea sensation between the two tested techniques would provide clinically relevant data related to the dentures’ performance.

**Conclusion**

Within the limitations of the current study, it may be concluded that intraoral scanning is a viable option for complete denture fabrication. It is noteworthy that the palatal area was the least deviated among the evaluated regions while the anterior border seal had the highest discrepancy.

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