IN VITRO COMPARATIVE STUDY BETWEEN FULL-ARCH CONVENTIONAL IMPLANT IMPRESSIONS AND FULL-ARCH DIGITAL IMPLANT IMPRESSIONS WITH SNAP-ON SCAN BODIES

BY

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ABSTRACT

Statement of Problem: Digital impression techniques are widely used in everyday cases. There is sufficient evidence to support this technique in partially edentulous patients but the evidence supporting the use of intraoral scanners (IOS) in restorative digital workflows for edentulous patients is still limited.

Purpose: The aim of the present in vitro study was to measure and compare the accuracy of full-arch conventional implant impressions with open and closed-trays, full-arch digital implant impressions with intraoral scanners (IOS), and three-dimensional (3D) printed casts from the full-arch digital implant impressions.

Material and methods: Six implants were placed into a mandibular model. Snap-on scan bodies were inserted into the implants and scanned with a high-resolution reference scanner and exported in standard tessellation language (.STL) format (Group Control). Splinted open-tray impressions (Group 1, n=5) and closed-tray impressions (Group 2, n=5) were made and stone casts were fabricated. Digital impressions (Group 3, n=5) were made with an intra-oral scanner and the .STL files were exported to fabricate 3D printed casts. Snap-on scan bodies were inserted into analogs in Groups 1, 2, and 3 and scanned with the reference scanner. Using a 3D inspection software, impression techniques were compared to the control. Root mean square (RMS) values were calculated from the control and superimposed digitized casts from different impression techniques.

Results: Group 3 had the lowest mean dimensional difference when superimposed with Group Control, then Groups 4, 1, and 2. Significant differences were found in RMS values between Group Control and digitized models fabricated from different techniques ($P<0.05$). Post Hoc

(Tukey) test revealed that Group 3 ($P<0.001$) was significantly different from other groups while no significant difference was found between Groups 1, 2, and 4 ($P>0.001$).

Conclusions: 3D printed models from full-arch digital impression of Snap-on scan bodies seem to be as accurate as stone models fabricated from full-arch conventional impression techniques. Closed-tray full-arch impression technique using dual-functioning Snap-on scan bodies seem to be as accurate as the splinted open-tray full-arch technique.

REVIEW OF LITERATURE

Edentulism is defined as the state of being edentulous; without natural teeth.[1] Edentulism is the endpoint in any dental disease including caries, periodontal diseases, or oral cancer.[2] Health organizations have consider this condition a disability as complete edentulism not only affects the masticatory and speech functions, but also the social and psychological health.[3,4] While the global trend in edentulism has been declining,[5] according to the National Center for Health Statistics, 36 million Americans are still estimated to be completely edentulous.[6] With this condition affecting approximately 10% of the American population, the need for treating edentulous patients remains.

Treatment options for edentulism includes removable prostheses or fixed prostheses. A removable prosthesis or complete denture can be retained by the seal and the adherence to the underlying tissue.[7] Alternatively, the removable prosthesis can be retained by implants with ball attachments or bar attachement.[8] Whether retained by tissue adherence or implant attachments, a removable prosthesis can be removed for oral hygiene. A fixed prosthesis is supported by implants and cannot be removed by the patient.[1] While the removable complete denture without implants is the most traditional and cost effective treatment for rehabilitating edentulous patients,[9] the removable treatment option retained solely by tissue adherence cannot prevent the body's biological response to edentulism: residual ridge resorption.[10] This bone resorption process in the oral cavity, which happens as a sequelae to edentulism, can result in ill-fitting dentures resulting in traumatic ulcers, denture stomatitis, candida infection, angular cheilitis, or soft tissue hyperplasia.[11] Therefore, when indicated, using implants to retain or support a prosthesis is considered to be the preferred option for edentulous patients.

Restoring implants, as opposed to restoring teeth, is different due to implants lacking periodontal ligament.[12] One of the many characteristics of the periodontal ligament is that it supports a tooth like a “suspension bridge.” In other words, the periodontal ligament has physiologic-functional adaptive capability able to deflect load through movement (axial mobility 8 to 20 times greater than implants) and absorb shock by distributing stress.[13] Because implants lack periodontal ligament, excess occlusal forces or stress from a non-passive prosthesis may result in biological and prosthetic complications.[14,15] While an absolute passive fit does not exist, minimizing the misfit between implant-abutment interface and maximizing passivity are important concepts in implant restorations. To minimize misfit in the prosthesis and the implant, an accurate cast is required, and to fabricate an accurate cast, an accurate impression is necessary.[16]

There are three types of implant impression techniques for the edentulous arch: the closed-tray, the open-tray, and the digital impression techniques. The closed-tray impression technique involves placing impression copings into the implants and making an impression with a tray. Once the impression is set and removed, the impression copings then can be retrieved from the patient. The impression copings are then transferred into the impression tray. The splinted open-tray impression technique involves connecting impression copings with polymethylmethacrylate, dental floss, metal, composite resin, or the combination of all four.[17,18] Before an impression is made, the tray is modified with access holes for the impression copings to come through. Once the impression material is set, the impression copings are unscrewed and removed with the tray. The impression can then be poured, and a cast is fabricated. Although the open-tray technique has been shown to be superior, regardless of the impression technique, a verification jig is recommended to verify the accuracy of the master cast and to ensure clinical passivity for the fabrication of the definitive prosthesis.[19,20] While the accuracy of the conventional full arch implant impression techniques have been validated, the conventional workflow involves multiple materials and laboratory production steps, which are not only labor intensive but may also introduce errors.[20,21]

As an alternative to the conventional impression technique, digital impression using intraoral scanners (IOS) has been gaining popularity due to its efficiency. From a clinical perspective, digital impressions using IOS eliminates the need for impression material and tray selection. Additionally, from a practice management perspective, digital impressions can be stored electronically and shared with laboratories more efficiently.

After a digital implant impression is made with IOS, Standard Tessellation Language (.STL) files can be generated and exported. For full-arch implant fixed dental prosthesis, two digital workflows exist using .STL files: model free and printed model. For the model free pathway, the .STL files can be used to directly design and fabricate a monolithic prototype and a definitive prosthesis.[22,23] However, due to the limited evidence validating complete digital workflow for full arch implant rehabilitation, some studies recommend using a verification device to ensure passivity before fabricating the final prosthesis.[24,25] For the printed model approach, .STL files can be materialized into 3D printed casts, which then can be articulated for the fabrication of a prototype and a definitive prosthesis with ceramic application.[26] While studies have shown the accuracy of the virtual casts created from digital full-arch implant impressions, the evidence is limited on the accuracy of 3D casts from digital impressions.[23,24]

With the understanding of the importance of passivity in implant fixed dental prosthesis and the increase in digitization of restorative workflows in implant dentistry, there is a need to assess the clinical reliability of all aspects of digital workflow from digital impressions to 3D printed casts.

As such, in this study, the accuracy of conventional versus digital full-arch implant impression techniques was evaluated. Secondarily, the accuracy of 3D printed models was evaluated.

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INTRODUCTION

Advancements in digital technology have increased digitization of restorative workflows in implant dentistry. Implementation of intraoral scanners (IOS) in restorative digital workflows can minimize potential errors that can occur with conventional impressions, which involve multiple materials and steps.[1] Evidence supports digital implant impression technique as a clinically acceptable alternative to conventional implant impression technique for implant-supported single crowns and short-span fixed dental prosthesis.[2,3] As for edentulous patients, conventional splinted open-tray implant impression technique is recommended.[4,5] Still, there is growing evidence that has shown promising results that support digital impressions with IOS as an alternative to conventional implant impression techniques for edentulous patients.[5,6] Once digital impressions are made with an IOS, Standard Tessellation Language (.STL) files can be generated and exported for fabrication of implant-supported prosthesis in two different restorative pathways. First, the .STL files can be used to directly design and fabricate a monolithic prototype and definitive prosthesis in a model-free approach.[7] Alternatively, the .STL files can be materialized into 3D printed casts which then can be articulated for fabrication of a prototype and definitive prosthesis with ceramic application.[8] Regardless of the accuracy of the virtual casts created from digital implant impressions,[9] printing 3D casts from digital impressions for clinical application may introduce errors, which will likely result in inaccurate definitive casts. Passive fit of the definitive implant-supported prosthesis is directly dependent on the accuracy of the definitive cast.[10] While some degree of misfit is considered acceptable in implant-supported fixed dental prostheses (FDP),[11,12] maximizing passive fit can minimize mechanical and biological complications, such as prosthetic screw loosening or fracture, periimplant bone loss, and prosthetic fracture.[13,14] As such, more evidence is needed to evaluate the accuracy of 3D printed casts from full-arch digital implant impressions to validate their clinical application.

The purpose of the present in vitro study was to measure and compare the accuracy of full-arch conventional implant impressions with open and closed-trays, full-arch digital implant impressions with IOS, and 3D printed casts from the full-arch digital implant impressions. Accuracy was defined as mean dimensional difference between the superimposed digitized control model and digitized models from different impression techniques. The null hypothesis was that no difference would be found in the root mean square (RMS) values from the superimposed control model and digitized models between different impression techniques (open-tray, closed-tray, digital impression) and 3D printed casts from the digital impressions.

MATERIALS AND METHODS

Following the surgical protocol by the manufacturer, 6 implants (Tapered Internal Plus, 3.5 mm Platform Implant, BioHorizons) were placed with adequate antero-posterior (AP) spread into a type 2 density edentulous mandibular model (Fig 1). All 6 implants were placed parallel to each other. Dual functioning Snap-on scan bodies (Snap Scan Body, BioHorizons) were inserted into the implants (Fig 2), scanned with a high-resolution reference scanner (inEos X5, Dentsply Sirona), and exported as a .STL file (Fig 3). This file served as the control (Group Control).

2 conventional impression techniques and 1 digital impression technique were performed: splinted open-tray impression (Group 1, n=5), closed-tray impression (Group 2, n=5), and digital impression (Group 3, n=5). For the splinted open-tray impression technique, 6 open-tray impression copings were hand tightened (Direct Coping, BioHorizons) into the implants (Fig 4-5). Autopolymerizing acrylic resin (Pattern Resin LS, GC Intl) and dental floss were used to splint the impression copings (Fig 6). The acrylic resin was then sectioned and reconnected. 5 impressions were made using printed custom trays (Fig 7-8) and polyvinyl siloxane impression material (Aquasil, Dentsply Sirona). For the closed-tray impression technique, 6 dual functioning Snap-on scan bodies (Snap Scan Body, BioHorizons) were inserted into implants (Fig 9) and 5 impressions were made using pediatric stock trays (Fig 10) and polyvinyl siloxane impression material (Aquasil, Dentsply Sirona). All conventional implant impressions were poured with vacuum mixed type IV dental die stone (Fujirock, GC). Digital impressions (Group 3, n=5) were made with an intra-oral scanner (Primescan, Dentsply Sirona) by the same operator (Fig 11) from the control group and the .STL files were then exported and sent to Vulcan Custom Dental, where the .STL files were printed as resin models (Med690, VeroDentPlus, Group 4, n=5) from a 3D printer (Objet260 Connex3, Stratasys). All casts were digitized using the same protocol as

follows. Snap-on scan bodies (Snap Scan Body, BioHorizons) were inserted into the analogs of the casts from conventional and digital impressions (Fig 12) and scanned with the reference scanner (inEos X5, Dentsply Sirona) used for Group Control. The .STL files were exported to a 3D inspection software (Geomagic, 3D Systems) (Fig 13), where the .STL files of the digitized models from the different impression techniques were superimposed with the .STL file of the control using the fixed points of the scan bodies (Fig 14). RMS values were calculated from the superimposed files (Fig 15). A final scan of the control model was obtained and was compared with the initial control model, both .STL files were imported into CloudCompare and were merged by aligning common points between both files. (Fig 16)

Statistical analyses were performed by a software program (SigmStat, Systat Software, Inc). The description data of the RMS values (means and SD) were calculated for all 4 groups. The Shapiro-Wilk test was used to assess normality of the data. Levene's test was used to assess homogeneity of variance. The analysis of variance (ANOVA) was first used to assess significant differences in RMS values for all 4 groups. The level of significance was set at 0.05. Tukey's honest significant difference (HSD) for post hoc comparisons was used to compare each group to others. The level of significance was set at 0.001.

Results

The data of the RMS values (means and SD) were calculated and displayed for each test group in Table 1 and Figure 17. Of the four groups (open-tray, closed-tray, digital impression, printed models from digital impression), superimposed files of the control scan and the closed-tray impressions showed the highest RMS value (Group 2, 0.75268), followed by the open-tray impressions (Group 1, 0.708) and the printed models from digital impressions (Group 4, 0.5749). The superimposed files of the control scan and the digital impressions showed the lowest RMS value (Group 3, 0.2833).

Statistical analysis revealed normal variance and power value of 1.0. There was a significant difference found in the RMS values from the superimposed control model and digitized models between different impression techniques ($P<0.05$). Post Hoc (Tukey) test revealed that Group 3, the super imposed files of the control scan and digital impressions, was significantly different from other groups ($P<0.001$). There was no significant difference found for Groups 1, 2, and 4 ($P>0.001$).

DISCUSSION

The present study was designed to evaluate the accuracy of full-arch digital implant impression technique and printed casts from the digital implant impressions in comparison to conventional impression techniques. Based on the results of this study, the null hypothesis that no difference would be found in the RMS values from the superimposed control model and digitized models between different impression techniques was rejected.

Regarding the accuracy of full-arch digital implant impression technique in comparison to conventional implant impression techniques, the data from the current study supports existing evidence.[5,9] The digital impression group was significantly different from the conventional impression technique groups. Studies have shown that closed-tray implant impression technique has inferior in vitro and clinical accuracy compared to splinted open-tray implant impression technique for edentulous patients.[6,15,16] The findings of the current study showed that closed-tray impressions using dual-functioning Snap-On scan bodies resulted in similar accuracy to the splinted open-tray impressions.

Studies comparing the accuracy of 3D printed implant casts versus stone implant casts are limiting and conflicting.[17,18,19,20] A partially edentulous arch study by Balaski et al[17] and Alshawaf et al[18] reported that casts fabricated from conventional impression techniques were significantly more accurate than 3D printed casts from digital impression technique, while a study by Bohner et al[19] found no statistically significant differences. One in vitro study compared the accuracy of 3D printed casts from full-arch digital implant impression to the master cast and reported significant differences.[20] However, there was no comparison between 3D printed casts from digital impression and casts fabricated from conventional impression. In the present study, no significant difference was found between 3D printed casts and stone casts.

This study had a few limitations. Implants were placed with sufficient torque and supracrestally to ensure proper seating of all impression copings and Snap-On scan bodies. However, given the nature of any in vitro studies, the conditions for obtaining conventional and digital impression were easily controlled. In clinical situations, the presence of saliva, blood, and soft tissue can influence the results. To minimize errors, conventional impression techniques were performed following standard of care protocol using splinted impression copings in the open-tray group and using polyvinyl siloxane impression material. Impression trays were standardized by using printed custom trays from a single .STL file of the custom tray and a set of same stock pediatric impression trays was used for making closed-tray impressions. The same reference for the control group was used to digitize all casts. Another limitation to the study was investigating one scenario: number of implants, position, and angulation with one IOS system and one 3D printer system. Different scanners and printers may produce different results and may affect the accuracy of the impression thereby affecting the accuracy of 3D printed casts.

Based on current findings, while a fully digital workflow for edentulous patients may not be clinically viable, the combination of conventional and digital workflow may be an alternative to fully conventional workflow for rehabilitating edentulous patients with implant supported FDPs. Furthermore, closed-tray impression may be a clinically acceptable alternative to splinted-open-tray impression when dual functioning Snap-On scan bodies are used. Either workflows, the combination or conventional only (closed-tray impressions), would minimize the chairside time. The use of dual functioning Snap-On scan bodies would negate the need to splint impression copings and provide more comfort to the patients. Based on the results from the current study, for full-arch implant-supported prosthetic workflow requiring a definitive cast, there is still a need to use verification jigs to ensure the accuracy of the model, whether printed or poured, before proceeding to the definitive prosthesis.

With limited evidence in assessing the accuracy of 3D printed models for clinical application, more studies are needed for this topic. Fabrication of an implant framework or verification jig on the edentulous mandibular model and assessment of the actual fit of the framework or verification jig on printed casts could further validate the clinical acceptance and integration of the printed models in digital workflow.

CONCLUSION

The hypothesis that no difference would be found in the RMS values from the superimposed control model and digitized models between different impression techniques was rejected. Under the limitations for the present study, digital impressions and use of 3D printed models may be an adequate replacement for conventional impression techniques and stone models in full-arch implant cases. 3D printed models from full-arch digital impression of Snap-on scan bodies seem to be as accurate as stone models fabricated from conventional full-arch impression techniques. Closed-tray full-arch impression technique using dual-functioning Snap-on scan bodies seem to be as accurate as splinted open-tray full arch impression technique.

FIGURES AND TABLES

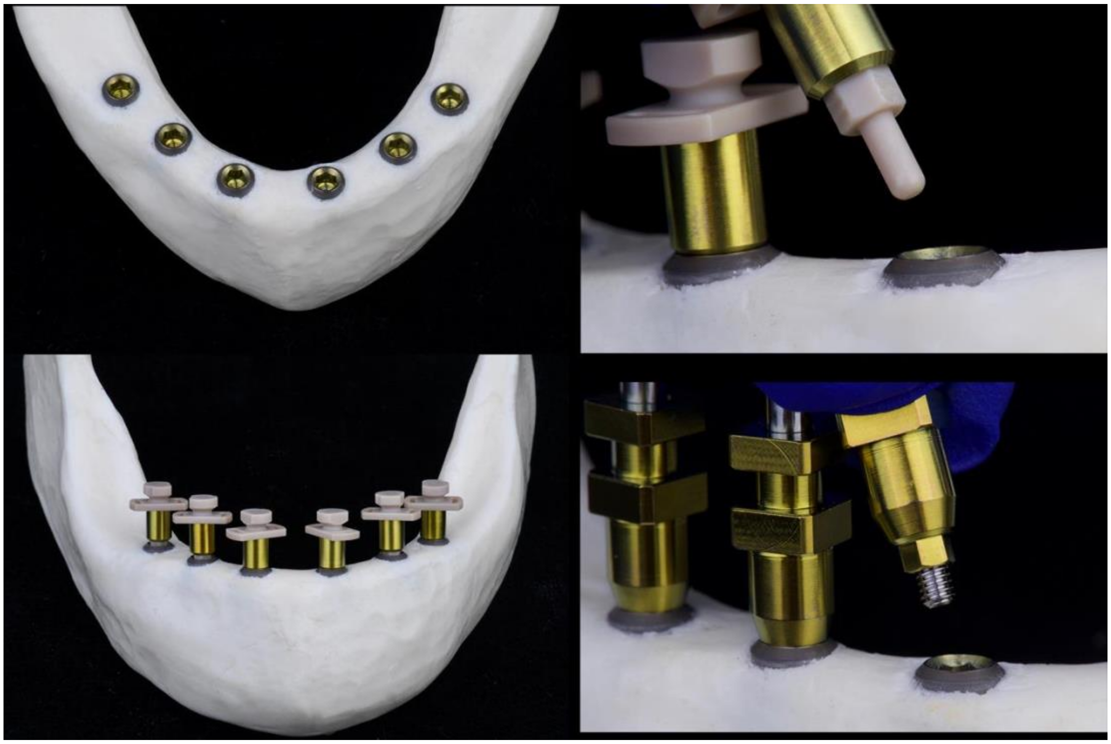

Fig 1

Six implants were placed into a type 2 density edentulous mandibular model.

Fig 2

Snap-On scan bodies were inserted into the implants.

Fig 3

A high-resolution reference scanner was used, and the .STL file obtained served as the control.

Fig 4

Open-tray impression copings were hand tightened into the implants.

Fig 5

Six open-tray impression copings in mandibular model prior to splinting.

Fig 6

Autopolymerizing acrylic resin and dental floss were used to splint the impression copings. Fig 7

The acrylic resin was then sectioned and reconnected.

Fig 8

Impressions were made using printed custom trays and polyvinyl siloxane impression material.

Fig 9

6 dual functioning snap-on scan bodies were inserted into implants.

Fig 10

Impressions were made using pediatric stock trays and polyvinyl siloxane impression material.

Fig 11

Digital impressions were made with an intra-oral scanner by the same operator.

Fig 12

Snap-On scan bodies inserted, and printed models rescanned with a high-resolution reference scanner.

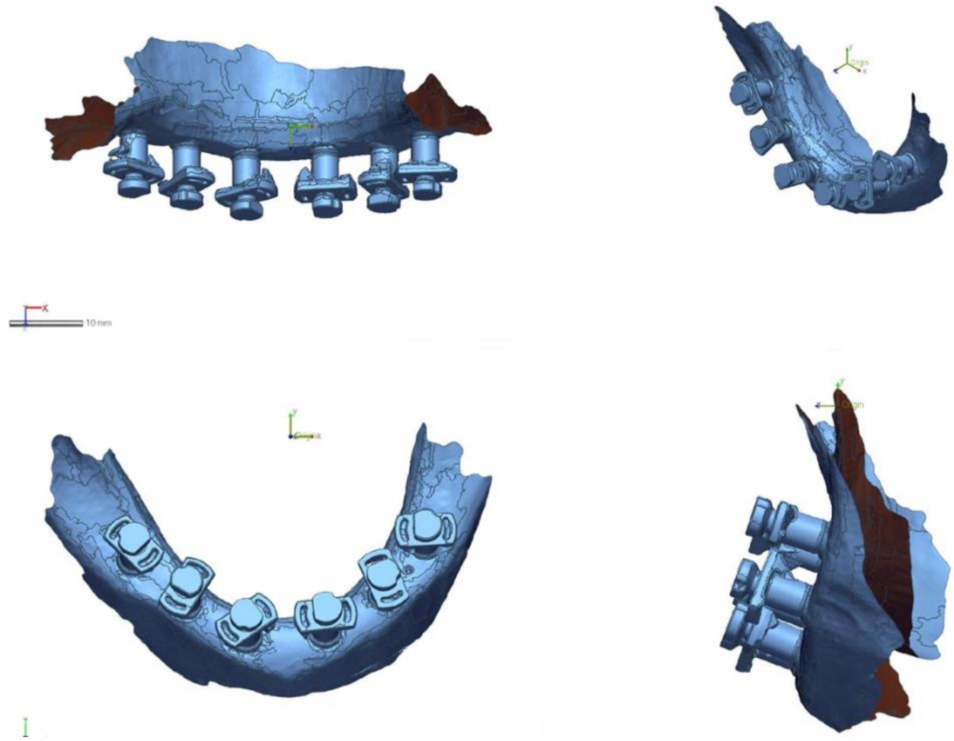

Fig 13

STL image from the reference file used as a control.

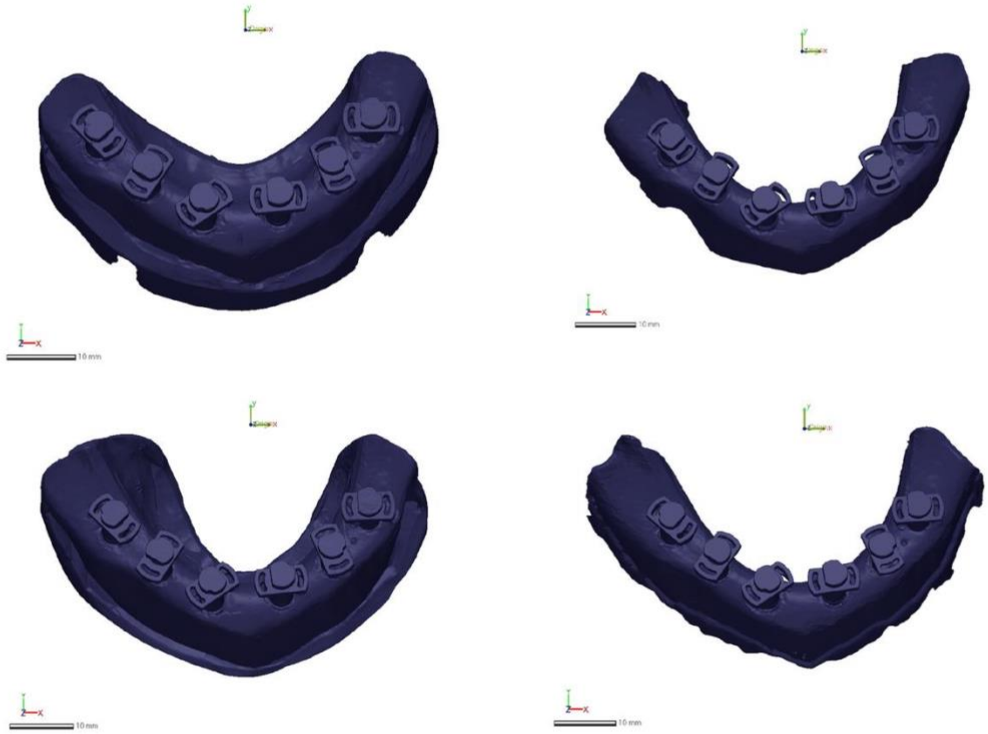

Fig 14

STL images from each group.

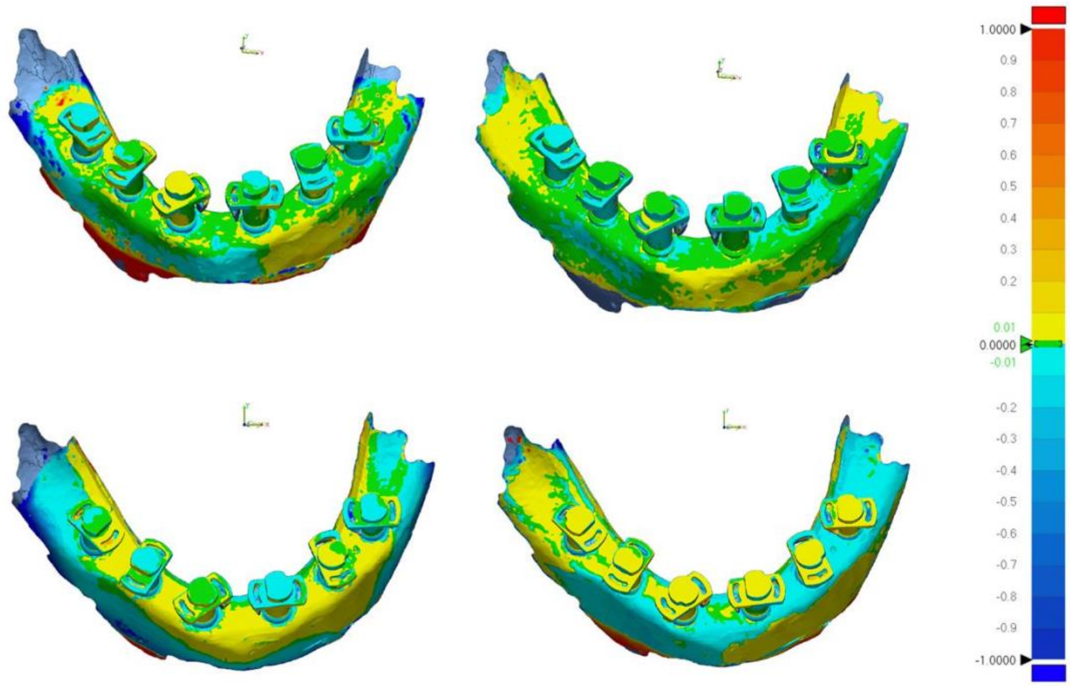

Fig 15

Graphical representation of 3D comparison between control STL and experimental STL for each group.

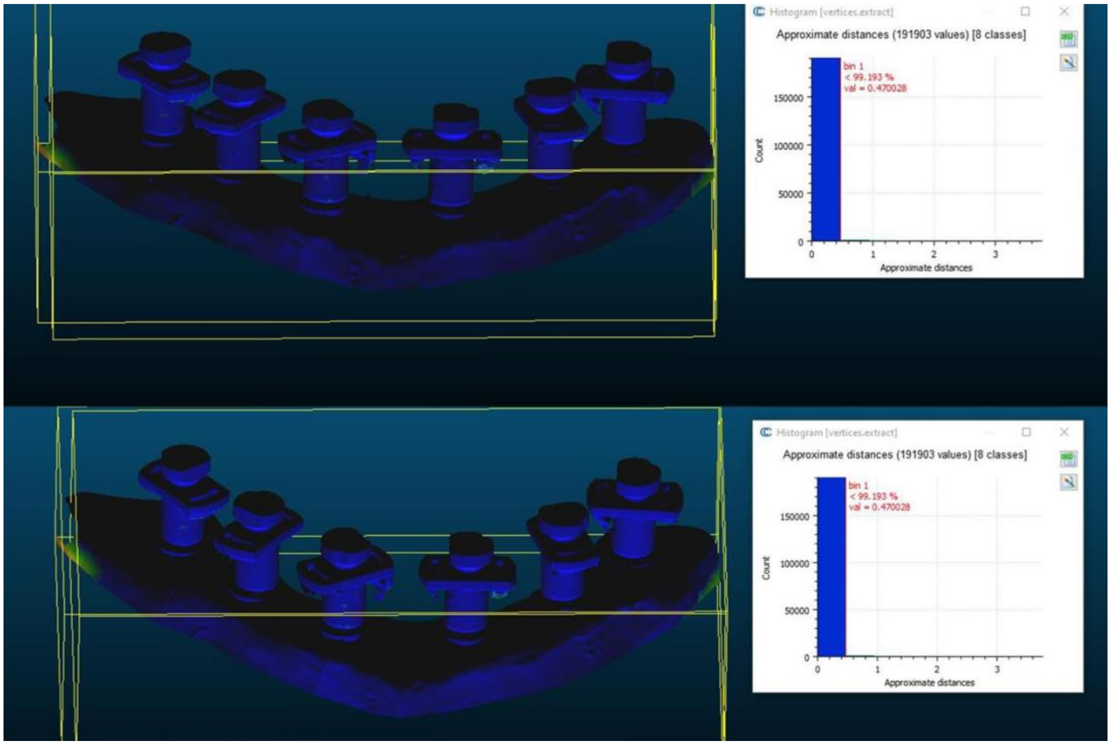

Fig 16

Comparison from the final and the initial control .STL files.

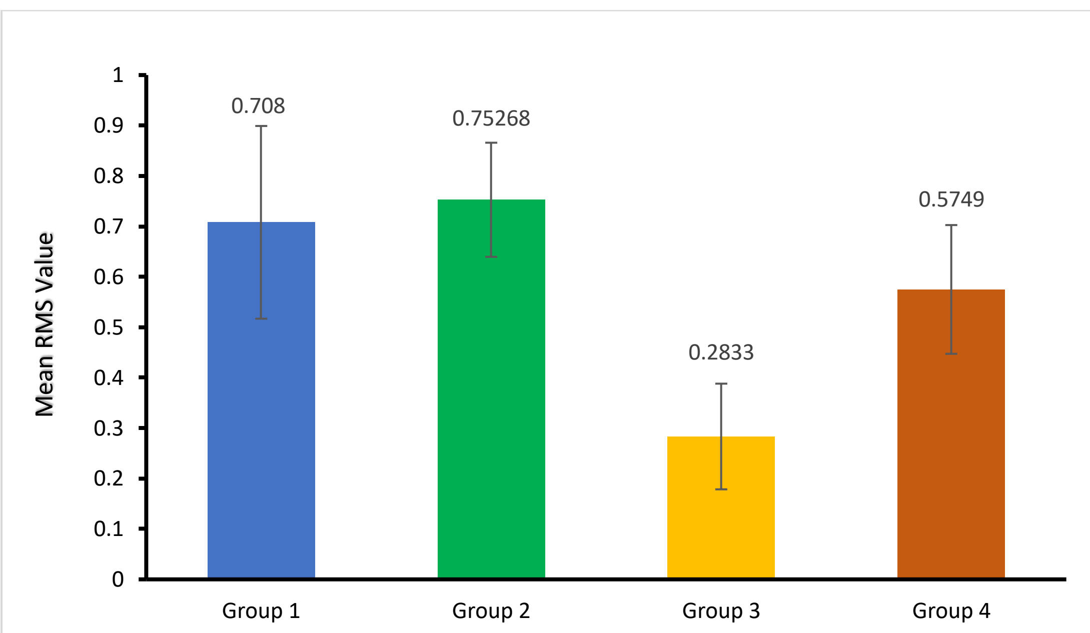

Figure 17

Mean RMS Value per group.

Group	Mean RMS Value	Standard Deviation	ANOVA P-Value
1 (n=5)	0.708 A	0.191073	<0.05
2 (n=5)	0.75268 B	0.10478208	<0.05
3 (n=5)	0.2833 A	0.11315355	<0.05
4 (n=5)	0.5749 B	0.12765204	<0.05

Table 1

Mean RMS Values for each group, Different uppercase letters represent means that differ from each other.

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