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Comparing the Trueness of full arch scans captured by customized and original scan bodies: An in vitro study

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Abstract

Purpose:

To evaluate the trueness of full arch scans using customized metal and resin scan bodies and to compare them with splinted and non-splinted original scan bodies.

Materials and Methods

Four methods were utilized to capture the position of multi-unit abutments (i.e. implant positions) using different scan bodies. In group I, customized metal scan bodies were fabricated while in group II, customized resin scan bodies were fabricated then all customized scan bodies were scanned. In group III, original scan bodies were scanned and in group IV, original scan bodies were splinted together then scanned. Trueness of the scans in each group was evaluated using a surface matching software (Geomagic control X) by measuring the deviation between the prosthetic screws. Statistical analysis was done using One -way ANOVA of Variance. The significance level was set at $p \leq 0.05$.

Results

The results show that minimum deviation of the prosthetics screws (multiunit abutment positions) was recorded in group I (0.027 ± 0.0051mm), while maximum deviation of the prosthetics screws was recorded in group II (0.0736 ± 0.0078mm). There was a statistically significant difference between all groups ($P \leq 0.05$).

Conclusion

Customized metal scan bodies enhanced the trueness of full arch scans when compared to customized resin as well as splinted and non-splinted original scan bodies.

Introduction

Digitization of various clinical and laboratory steps is the emerging approach in various disciplines of dentistry. Intraoral scans are done to instantly obtain digital dental models that represent the dental arches of the patient including implants, teeth and the oral mucosa. These scans exclude the use of trays and impression materials thus decrease clinical time, patient discomfort and exclude the possible waste of materials in case of repetitions. [1]

It has been well documented that digital scans represent an accurate alternative to conventional impressions in cases of partially edentulous arches. [2, 3] However, scanning a completely edentulous arch is more challenging than capturing an area of a limited extent, and thus the fabrication of a full-arch

prosthesis using a fully digital workflow is still being assessed. [4] In full-arch cases, the accuracy of scanning is affected by the absence of prominent structures in edentulous arches, the reflective and mobile nature of the oral mucosa, as well as the presence of saliva and blood. Moreover, the material, design, surface characteristics as well as the position and inclination of the intraoral scan bodies (ISBs) significantly affect the accuracy of scanning. [5, 6, 7]

It has been reported that the scanning range as well as the inter-implant distance affect the accuracy of intra oral scanning. Hence, several approaches were made to increase the accuracy of full-arch scans such as using auxiliary removable devices or connecting the scan bodies together by thermoplastic resin. [8, 9] It has also been recommended that scan bodies should be created with more characteristic designs rather than the available cylindrical ones to enhance scanning them with higher precision. A previous study concluded that the material and design significantly influenced the accuracy of complete-arch digital impressions as well as the scanning time. [10]

There is no evidence that customized scan bodies could improve the accuracy of scanning of full-arch cases. The aim of this study was to evaluate the trueness of scanning of full arch cases using customized metal and resin scan bodies and to compare them with splinted and non-splinted original scan bodies. The null hypothesis was that the trueness of the scans would not differ with customized and original scan bodies.

Materials and methods

This in vitro study was conducted on an edentulous mandibular printed model. The model was designed to receive four digital multiunit abutment analogues at the positions of the canines and the second premolars.

Four methods were utilized to capture the position of the multiunit abutments (i.e. implant positions). Thus, four groups were defined. In group I, customized metal (Cobalt chrome) scan bodies were designed and scanned using an intraoral scanner. In group II, customized resin scan bodies were designed and scanned using an intraoral scanner. In group III, original scan bodies were scanned and in group IV, original scan bodies were splinted together using flowable composite then scanned. (Fig. 1)

The sample size was calculated by G*Power software for Windows version 3.1.9.4. A sample size of 10 scans (n = 10) in each group was calculated to have 95% power, $\alpha = 0.05$,$1- \beta = 0.95$.

Reference scan:

Original scan bodies were screwed to the multiunit abutments, then the model was scanned using a desktop scanner (E series, 3 Shape, Denmark). The STL file of the scan was exported to be used as a reference for evaluation.

Group I and II:

The STL file of the original design of the scan bodies was modified using the 3D modelling software program Meshmixer (Autodesk, San Rafael, CA, USA) by adding one of the shapes from the library to extend from the shank of the scan body. [11] These steps were repeated for the four scan bodies by adding a different shape to each one. The selected shapes were stretched (extended) in a horizontal direction guided by the inter-implant distance creating four different customized scan bodies with different extension shapes.

The modified STL files in group I were imported to the Netfab software (Netfab software, Autodesk Media and Entertainment, USA) to add the support arms. Then the scan bodies were printed (Phrozen printer, Phrozen Tech Co. Ltd, Taiwan) using grey liquid resin (ANYCUBIC, Shenzhen, China)

In group II, the modified STL files were imported to the Materialize magics for nesting (Materialise magic,3D data and build preparation software, Belgium) then they were printed by M-150 (Riton M-150, China) using Cobalt chrome (CoCr)

In both groups I and II, the scan bodies were screwed to the multiunit abutments so that the added extensions were facing each other. Each customized scan body (with a specific shape) was screwed at the same position in the model in both groups.

Group III and IV:

In group III, original scan bodies (Flotechno, Italy) were screwed to multiunit abutments while in group IV, they were splinted together using flowable composite (Coltene, Swizerland) at the neck of the scan bodies. The scan bodies in these two groups were screwed at the same torque as the customized scan bodies in group I and II.

Scanning the model:

In each group, the model was scanned using the IOS (Medit i900, South Korea) starting from the occlusal surface of the most distal scan body followed by the buccal and lingual surfaces. Each scan was exported as an STL file. (Fig. 2)

Scanning was done by a single experienced operator under the same lighting conditions. It was repeated 10 times for each group. Calibration of the scanner was done before each scan.

Evaluation of the trueness of the scans:

The reference scan as well as the study scans of each group were imported to the Exocad designing software to align them with the virtual multiunit abutment-scan body in the library to detect the position of each implant. (Fig. 3) The orientations of the four prosthetic screws of the multiunit abutments in each scan were extracted and exported as a new STL file. The position of the prosthetic screws represents the position of the multiunit abutments in each scan. (Fig. 4)

Trueness of the scans in each group was evaluated using the surface matching software (Geomagic Control X, 3D systems, USA) by measuring the deviation between the prosthetic screws. The new STL file with the prosthetic screws of the reference model was marked as reference data while the STL file of the prosthetic screws of each evaluated scan was marked as measured data. Overall deviation between the reference and measured data was measured using the 3D compare tool. Color spectra were set to have a maximum critical value of ± 0.5 mm and a tolerance value of ± 0.1 mm. This was repeated for all scans in each group. (Fig. 5)

Statistical analysis was performed with IBM (IBM Corporation, NY, USA) SPSS (SPSS, Inc., an IBM Company) statistic Version 20 for Windows. One-way ANOVA of Variance was used to determine whether there was a difference between the four groups. Tukey comparison was used as a post hoc test in case of significance. The significance level was set at $p \leq 0.05$.

Results

Table 1
Mean, SD, P value and F value of one way Anova test for the comparison of surface deviations of the Multiunit abutment positions in the four study groups.

GROUPS	Group I (Customized metal)	Group II (Customized resin)	Group III (Original non-splinted)	Group IV (Original splinted)	P value	F value
Mean (mm)	0.027 a	0.0736 b	0.0394 c	0.0705 b	< .00001	124.56508
SD	0.0051	0.0078	0.0024	0.0088		

In this study, the multiunit abutment positions were captured using four different scan bodies and the accuracy of the scans were evaluated by comparing the position of the prosthetics screws. Table 1 shows that minimum deviation between the prosthetics screws (multiunit abutment positions) was recorded in group I (customized metal scan bodies) (0.027 ± 0.0051mm), followed by group III (original non-splinted scan bodies) (0.0394 ± 0.0024mm) then group IV (original splinted scan bodies) (0.0705 ± 0.0088mm). Maximum deviations between the prosthetics screws (multiunit abutment positions) were recorded in group II (customized resin scan bodies) (0.0736 ± 0.0078mm). One-way Anova test showed there was a statistically significant difference between all groups ($P \leq 0.05$).

The post hoc test (Tukey HSD**)** showed that there was a statistically significant difference between group I and all the other groups as well as between groups III and the other groups. However, there was a non-statistically significant difference between group II and IV.

Discussion

The accuracy of an impression directly influences the passive fit as well as the success of any restoration. It has been documented that the prognosis of full-arch prostheses designed and fabricated using intraoral scans were comparable to those fabricated using conventional impressions regarding rates of technical and biological complications, as well as marginal bone loss. In addition, clinical time is significantly reduced when intraoral scans are used. However, repetition of the scans is more common than those of conventional impressions especially in edentulous cases. [12, 13]

Scanning edentulous arches is quite challenging due to the limited number of reference points between the scan bodies. Thus, different techniques and scanning devices have been recently introduced to improve the accuracy of full arch scans. [13–15]

The “Continuous Scan Strategy” (CSS) was proposed for capturing accurate intraoral digital impressions to fabricate precise long-span implant-supported restorations. It is based on filling the areas between the scan bodies through splinting them to enhance the stitching process and to reduce the intrinsic scan errors. [9, 16]

Several studies showed that the material of fabrication as well as the shape of the scan bodies influence the overall accuracy of the digitized data. [10, 17, 18] Hence, in this study the shape of the original scan body was modified to bridge in the gap between the implants as well as to create different geometrical structures that can be easily captured by the scanner. Moreover, two materials were used to fabricate the customized scan bodies to evaluate the effect of the printed material on the accuracy of scanning. (Group I and II)

The results of this study showed that there was a significant difference in the trueness of the scans in all groups thus the null hypothesis was rejected. Group I (customized metal) showed the least surface deviation in multiunit abutment positions (implant positions) than all the other groups. This indicates that the customized metal scan bodies (group I) helped achieve more accurate scans than the original scan bodies (group III).

These results are similar to a previous study that reported that adding extensions to the scan bodies significantly improved scanning accuracy. [19] Another study confirmed that PEEK scan bodies with modified geometry resulted in more accurate scans with less scanning time, when compared to titanium scan bodies with simple cylindrical shape. [10] On the other hand, customized resin scan bodies in group III showed greater deviations in implant positions than the customized metal (group I) and original scan bodies (group III). This may be attributed to the imprecision of the printing process of resins as it has been reported that the layer thickness, exposure time, X-orientation as well as the post curing process all affect the dimensional accuracy of resin 3D printed objects. [20, 21]

In group IV, original scan-bodies were splinted using flowable composite to compare the splinting effect on the trueness of the scans. [22] The results showed that splinting the original scan bodies reduced the accuracy of scanning. This coincides with the results of other studies that stated that splinting scan

bodies with floss led to significantly more distance deviation of the implants particularly when crossing the midline of the arch. This was attributed to masking part of the scannable area of the scan bodies by the splinting material which may have interfered with the capability of the scanner to digitize the surface of the scan body. [23, 24] On the other hand, a study concluded that splinting the scan bodies intraorally did not affect the trueness or scan time of complete arch edentulous implant digital scans. [25]

Although there was a statistically significant difference between all the studied groups regarding the trueness of the scans, yet the surface deviations of the implant positions in all groups were within the clinically acceptable range mentioned in previous studies. [13, 15, 26]

The introduction of customized scan bodies that can be modified for each patient according to the number of implants as well as the inter-implant distances is a new economic approach to improve the trueness of full arch scans. However, further clinical studies should be conducted to verify the effectiveness of this approach due to limitations of the current study. Moreover, the influence of different intraoral scanners as well as other variables such as number and distance between the implants and scanning time should be evaluated.

Conclusion

Customized metal scan bodies enhanced the trueness of full arch scans when compared to customized resin as well as splinted and non-splinted original scan bodies.\

Abbreviations

ISB
Intraoral Scan Body
CoCr
Cobalt Chromium
STL
Standard Tessellation Language
IOS
Intraoral Scanner
ANOVA
Analysis of Variance
HSD Honestly
Significant Difference
PEEK
Polyether Ether Ketone
CSS
Continuous Scan Strategy

Declarations

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Consent for publication: Not applicable

Availability of data and materials: Available upon request from the corresponding author

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Author Contribution

T.M.A.E. conceptualized and designed the study, performed the clinical procedures, collected data, and drafted the main manuscript text. Y.G.T. supervised the methodology, performed the statistical analysis, and critically revised the manuscript. M.E.S. provided overall supervision, resources, and final project administration, and assisted in revising the manuscript text. All authors read and approved the final manuscript.Author Initials Key (for your reference):T.M.A.E.: Tarek Mohamed AL Sayed El SaaediY.G.T.: Yasmine Galaleldin ThabetM.E.S.: Marwa Ezzat Sabet

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Figures

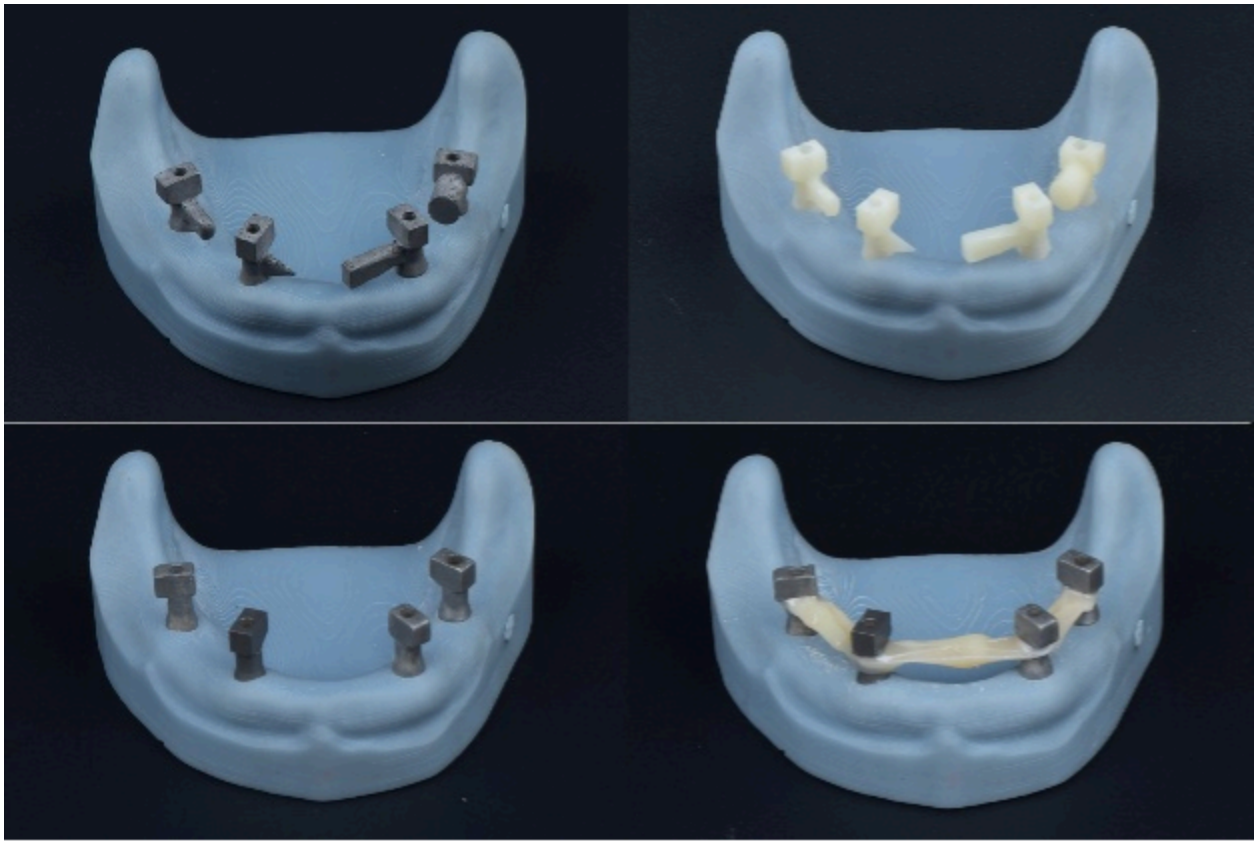


Figure 1

The models of the four groups of scan bodies.

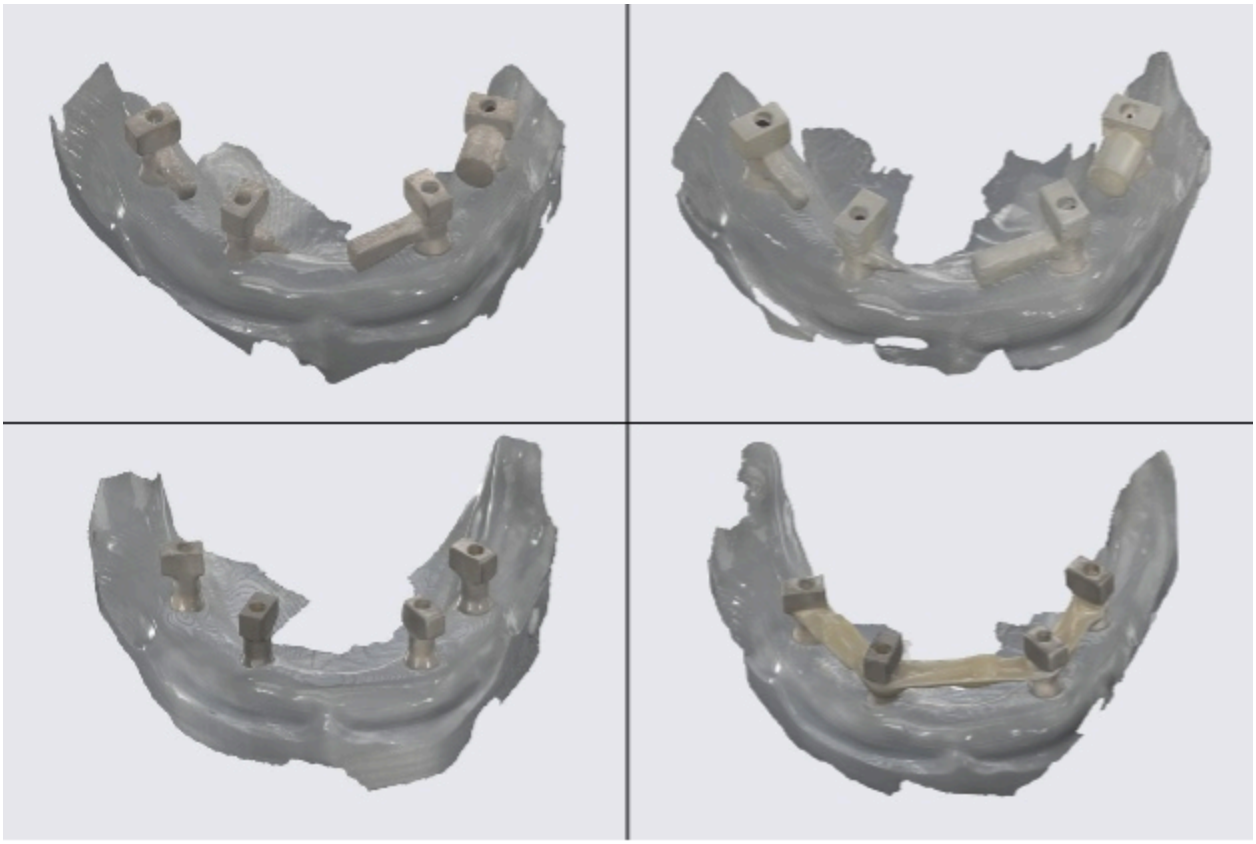


Figure 2

The scans of the four studied groups.



Figure 3

Identification of the positions of the scan bodies by the software.



Figure 4

Extraction of the screws from the scan bodies.



Figure 5

Evaluation of the captured position using the extracted screws.