Accuracy evaluation of two different intraoral scanners in implant prosthodontics. A comparative in vitro study

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ABSTRACT

Aim To test differences in term of accuracy among two Intraoral Scanners used in implant fixed prosthodontics.

Materials and methods A reference stone model was prepared, representing a partially edentulous maxilla on area #23 and from #14 to #16, with three implant analogues and polyether-ether-ketone (PEEK) scanbody screwed on to represent the situation of a single crown on implant (SB) and a implant-supported partial prosthesis (2SB). The model was digitized with a laboratory scanner (Aadva lab scanner, GC, Tokyo, Japan) used as a reference, and with two intraoral scanners (Trios 3; 3Shape A/S; I700, Medit). Ten scans were performed using the two different intraoral scanner. Scanning and processing time as well as the number of images were reordered for each scanner. All datasets were loaded into reverse-engineering software (Geomagic Control X 2018), where digital impressions were superimposed on the reference model to evaluate trueness in the full arch, in the SB area (#23) and in the2SB areas(#14 and #16).Therefore, all the scans of the same group were superimposed onto the cast that recorded the best result of trueness whose trueness corresponded to the actual reference value for precision. Mann-Whitney U-test test was performed to analyze differences between the groups ($P<0,05$) (SPSS software Version 26,IBM).

Results Statistically significative differences where found between Medit i700 and TRIOS 3 regarding trueness and precision in the full arch , with Trios 3 showing better results than Medit I700. Trios 3 performed statistically better also in the 2SB area regarding precision. No statistically significative differences were found regarding trueness and precision in the other areas.

Conclusions Trios 3 performed statistically significative better than Medit I700 in acquiring scanbody position when the full arch model was analyzed. Both the tested Intraoral scanners reordered good values in line with the previous literature.

INTRODUCTION

Digital devices such as intraoral scanners (IOS) and processing software together with a new wide range of materials and powerful manufacturing devices are changing dentistry, in particular the prosthetic field(1,2).

Intraoral scanners are able to collect optical impressions of jaws thanks to a beam or light grid that captures through a high-resolution camera the distortion that such a beam or grid undergoes when it hits structures like teeth(3). Then, different softwares processes the collected pieces of information and reconstruct the 3D dimensional model(4). Digital impression has been used for different applications in prosthodontics, such as study cast, for an impression of natural abutments, and for rehabilitation of single and multiple implants too(5,6).

The digital workflow for implant-supported restorations begins with intraoral direct digitizations of soft tissue and implants' position and proceeds with the laboratory steps of computer-assisted design (CAD) and computer-assisted manufacturing (CAM). The final prosthesis can be realized in a monolithic design from zirconia, lithium disilicate, or hybrid ceramic materials(7). Passive fit between prosthetic structures and supporting implants is considered a key factor in preventing subsequential mechanical and biological complications. Screw loosening or fracture, prosthetic breakage, and even implant fracture can in fact be caused by tension and compression due to a poor passive fit(8,9).

Fit of the restorations depends on the accuracy of implant impression taking, which may be realized using long-term established conventional techniques or more recently introduced digital techniques(10).

Traditionally the master model is realized in gypsum from a polyether (PE) or polyvinylsiloxane (PVS) impression that can be performed using the pickup or transfer technique. The final outcome is strongly affected by dimensional changes of both impression materials and gypsum, due to variations in temperature, time elapsed between impression making and pouring, surface wettability of the gypsum, and disinfection procedures (11,12). In the digital workflow, one of the key factors is the accuracy of the intraoral scanner used to capture the position of implants. As reported in the glossary of digital terms, the accuracy of a digital scanner is the closeness of agreement between a measured result and a reference value(13). It is described by precision and trueness. Trueness is the closeness between the test object and the reference object, whereas precision is the variability of repeated measurements of the object(14,15). The accuracy of a digital scan can be affected by clinical circumstances such as ambient light, scanning protocol, limited spacing between abutments and adjacent teeth, and edentulous span length (16-20). Currently, there is a wide range of intraoral scanners on the market and new software and hardware versions are constantly released by the manufacturers that claim improved scanning accuracy. The aim of these in vitro studies is to compare the accuracy of two different intraoral scanners in the impression-making of single and multiple implant restoration.

Null hypothesis: there is no statistically significant difference in the accuracy between Trios 3 Shape and Medit i700.

MATERIALS AND METHODS

A model representing a partially edentulous maxilla (PEM), with implant analogs in position #23 (to imitate the situation of an implant-supported single crown) and in positions #14 and #16 (to simulate the situation of an implant-supported partial prosthesis), was prepared. Three high-precision non-reflective polyether-ether-ketone (PEEK) scanbodies (SBs) were screwed on the implant analogs.

Two intraoral scanners (Trios 3, 3 Shape, Copenhagen, Denmark, and I700 Medit, Seul, South Korea) as well as a powerful reference scanner (Aadva Lab Scanner 2, GC) were used in the present study.

The scans proceeded in the following order. First, the model was scanned with the reference scanner three times. The three .stl files were imported into powerful reverse-engineering software (Geomagic, Morrisville, NC, USA) and superimposed on each other, in order to validate the manufacturer's data and one dataset was then selected as the reference model (RM). Secondly, an operator initiated the process of acquiring model scans using each of the two intraoral scanners involved in the study. For each IOS, the operator performed 10 scans of the entire arch focusing on the area with 2 scanbody #14 and #26 (2SBs) and on the area with a single scan body #23 (SB), resulting in a total of 20 scans. The operator began the scanning process from the right vestibular posterior sector, proceeding to the incisal vestibular area, and subsequently the left vestibular area. The operator then continued scanning the right occlusal area, followed by the left occlusal area, without placing the scanner's handle down. Finally, the palatal section was scanned. All scans were conducted under consistent environmental conditions, in a room with moderate sunlight and a temperature of 22 °C. The time taken by each scanner to register the impression, the number of images captured, and the scan processing time were recorded for each device. All the .stl files (RM as well as all .stl files obtained with the 2 different intraoral scanners) were imported into the reverse-engineering software (Geomagic, Morrisville, NC, USA). Here, small artifacts identified as independent polygons were automatically removed, and models were cut/trimmed to remove all unnecessary information, using the "cut with planes" function. A preformed template was adopted to cut files in the most uniform manner: with this, uniform files were obtained and saved in specific folders. Then, it was possible to proceed with the superimposition for the evaluation of the trueness. All the stl files obtained from each intraoral scanner were superimposed to the corresponding RM, using the "three-point registration" function as shown in Figure 1. The three points were easily identified on the surface of the implant scan bodies. After this first rough alignment, the "best fit" alignment function was used for the final registration. Then, the root mean square (RMS) was calculated based on all cloud points of dRT by using the following formula:

FIG. 2

$$RMS = \frac{1}{\sqrt{n}} \cdot \sqrt{\sum\nolimits_{i=1}^{n} \left(X_{1,i} - X_{2,i}\right)^{2}},$$

where $X_{1,i}$ indicates a measurement point at it in RM and $X_{2,i}$ indicates a measurement point at it in each stl of the intraoral scanner. "n" is the number of all points evaluated. Therefore, the RMS value is the absolute average distance of all cloud points and means the degree of agreement between RM and each stl IOS file. For each experimental group, the trueness was calculated considering the RMS value resulting from the superimposition of each stl file and the RM. The precision was evaluated by taking as a reference model the .stl file that recorded the best trueness value for each group. Therefore, all the scans of the same group were superimposed onto this selected cast, whose trueness corresponded to the actual reference value for precision. RMS values were recorded for the whole model surface as well as for the area of the single scan body (SB) and two scan bodies (2SB) as shown in Figure 3 with different colors.

Therefore, the distances between corresponding areas of RM and all superimposed models were color-coded on the superimposed models to analyze the result, using the "3D deviation" function. A color map was generated, where the distances between specific points of interest were quantified, overall and in all three planes of space. All deviations were therefore visualized and calculated. The color maps indicated inward (blue) or outward (red) displacement between overlaid structures. An absence of change was indicated by a green color. The collected data then underwent statistical analysis (SPSS software Version 26 IBM).

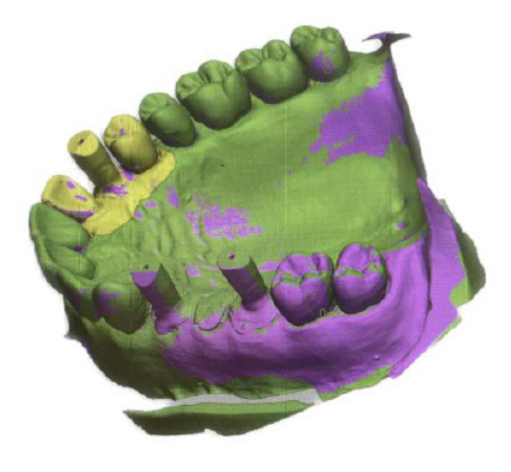

FIG 1 The .stl file obtained with the IOS in superimposed on the RM reference model.

RESULTS

For trueness, Trios 3 performed statistically better than I700 in the full arch acquisition while no statistically significant differences were found in the 2 Scan abutments and 1 Scan abutment sections. Regarding precision Trios 3 performed statistically significative better than I700 in the full arch and in the 2 scan abutments area. No statistically significant difference was found in the section of 1 Scan abutment. The scanning performances of the two scanners are reported in Table 3. Statistically significative differeces were found between Trios 3 and I700 regarding scanning time and processing time. Regarding the number of images, a statistical difference was found since I700 acquired more than double of images of Trios 3 in the same scanning time.

DISCUSSION

It is many years since the long-term success of implants was confirmed by Branemark et al.(21). Since then, new surgical and prosthetic techniques have added enhancements to improve the clinical outcomes of implant treatments. About that, one of the biggest improvements has been guaranteed by digital impressions(22-25). In fact, with the advent of IOSs, it's possible to scan the patient's mouth and register the position of implants in a few minutes with no need for impression trays and materials(26-29). Obviously, a high impression accuracy of the IOSs is needed to realize a digital cast for implant-supported prostheses even if no impression technique can achieve an absolute passive fit(30,31). The aim of this in vitro study was to assess the trueness and precision of two different intraoral scanners (TRIOS 3 SHAPE and Medit i700) in capturing impressions of a single scan body or two scan bodies. Statistically significant differences between the two tested Intraoral scanners were reported thus the null hypothesis was rejected. When trueness was taken into consideration, Trios 3 performed statistically better than Medit I700 in the full arch scan, but when the area of 1 scan body and 2 scan body was taken into consideration the values for accuracy were comparable. These results are similar to the one obtained in a previous study by Imburgia et al. and Chew and al. where a discrepancy of trueness around 50-60 μm was found in scanning two implants for a partial prosthesis(32,33). In research by Mangano et al., the discrepancy reported was much lower and they put 30 μm as a threshold for trueness(34). Anyway, previous clinical studies have shown that the biological and technical complications increased when a misfit of 30 to 150 μm was found between the prosthetic framework and the implant abutments(35). Mangano reported better accuracy of IOSs in scanning the position of a single implant, but it must be noticed that the whole surface of the model was analyzed while in this study the discrepancy was calculated also in the restricted area of the single scan body(33).

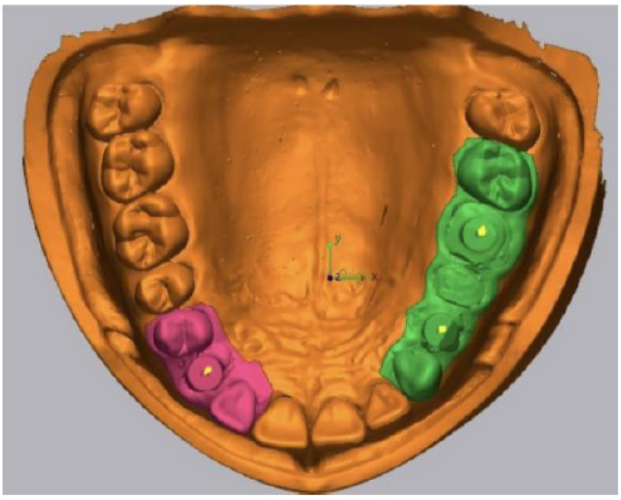

FIG. 3 Different areas of the model where the RMS value was evaluated: the full model surface is highlighted in orange, the single Sb and the 2SB areas were highlighted respectively in pink and green.

Regarding precision, Trios 3 performed statistically better in the full arch scan and in the 2 scanbodies area but in the single scan body area did not report any difference. When the precision was analyzed in the single scan body area lower values were reported for both scanners compering to the precision in the two scan body areas and full model.

It should be noted that the same intraoral scanner, Trios 3, performed in a different manner in different articles(31,33). This can be correlated with different reference models used or scan bodies. Scanbody plays an important role in digital implant impressions as recently reported by Mizumoto and Yilmaz(36). Regarding scanning time, no statistically significant difference was found, but the number of images acquired by I700 was more than double the ones acquired by Trios 3. It can be speculated that the higher number of images acquired by I700 caused the differences in processing time between the two IOSs with Trios 3 being much faster than I700. Anyway it should be noticed that I700 allows the operator to take new scans and proceed with a new case during the processing time of each scan so the longer processing time does not interfere with the workflow schedule or chair time.

This is an in vitro study and the findings may not fully reflect the trueness and precision of IOS in real-life clinical scenarios. Conditions detectable in vivo could be the presence of blood and saliva, as well as technical problems during intraoral scanning and patient movements, that can significantly affect the quality of scans(37).

Scanner	Full arch	2SB	1SB
Trios 3	29.8±4.05	55.2±3.47	44.1±15.12
I700	40.9±7.18*	52.4±4.34	40.4±15.97

TABLE 1 Trueness values (μm)for the two tested IOSs.

Scanner	Full arch	2SB	1SB
Trios 3	35.5±7.19	28.2±12.26	17.7±5.39
I700	60.2±7.08*	50.9±19.85*	16.8±6.38

TABLE 2 Precisions values (μm) for the two tested IOSs.

Scanner	Scanning Time	Processing Time	Number of Images
Trios 3	202.30±10.00	34.53±1.81	3798.50±252.20
I700	201.40±10.86	206.70±17.68*	8374.90±474.29*

TABLE 3 Scanning performances for the two tested IOSs.

CONCLUSIONS

Within the limit of the present in vitro study, statistically different results were found in the full arch scan with Trios 3 showing better results than Medit I700. Concerning the scan abutment areas no statistically significant differences were found between the two tested Intraoral scanners except for precision in the 2 Scan abutment where Trios 3 performed statistically better than Medit I700. Both the tested Integral scanners obtained accuracy results in line with the standard values reported in the literature.

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