European Journal of Musculoskeletal Diseases
ISSN 2038-4106 print - ISSN 2975-044X online

Article

READING DEPTH EVALUATION OF INTRAORAL SCANNERS. AN IN VITRO STUDY.

F. Ferrini*, G. Gastaldi, F. Cattoni, L. Colella and E. Gherlone

Dental School, Vita-Salute San Raffaele University, Milan, Italy.

**Correspondence to*:
Francesco Ferrini,
Dental School,
Vita-Salute San Raffaele University,
Via Olgettina 60,
20132 Milan, Italy.
e-mail: ferrini.francesco@hsr.it

ABSTRACT

The objective of this *in vitro* study is to measure and compare the detectable reading depth from different types of scanners with different acquisition technology, wireless* vs wired, and the newest technology on the market . Measurements were made by scanning a cubic-shaped reference solid with sulcus of different depths and widths in the 4 sides, in order to best simulate the possible scenarios found in clinical practice. Specifically, the anterior groove has dimensions of 1 mm in depth and 1 mm in width, the lateral grooves a width of 0.5 mm with depth varying antero-posteriorly from 1 to 4 mm, and finally, the posterior groove 1 mm in width and 5 mm in depth. For each type of scanner, 9 scans were taken, by the same operator under constant environmental conditions, in a time interval of 30 sec. For each reading, 12 measurements were taken, at 12 different points within the grooves traced in the solid. The results show, a possible overlap of values between wired and wireless scanners used, and a prevailing performance from the newest scanner. Based on the measurements and the subsequently calculated statistical values, it was found that there is no statistically significant difference, between the results acquired by the two intraoral scanners from the same series (i700), but a significant difference between series i700 and i900. Given the results obtained, it can be said that: the wireless scanner represents a future solution for evolution, the practicality of use and, the absence of data dispersion during acquisition, attests to its validity. Moreover, newest technologies aim on developing and new technologies aim to evolve and improve upon the limitations of previous models, thus providing breakthrough technologies day after day, leading on better results in everyday pratictice.

KEYWORDS: *Intra-oral scanner, wireless, wired, new technologies, reading depth, gingival sulcus*

INTRODUCTION

Intra-oral scanners (IOS) are 3D scanners that, through a scanning process, make it possible to start from a physical object and obtain a three-dimensional virtual replica of it (1). The acquisition process is made possible by the emission of a light beam, by the handpiece, which strikes the object of interest; the reflection is then captured by acquisition devices and transformed, by specific software, into three-dimensional coordinates (2). These consequently produce points that are transformed into triangles or meshes (3) (Fig.1).

Received: 11 November, 2024
Accepted: 23 January, 2025

ISSN 2038-4106 print
ISSN 2975-044X online

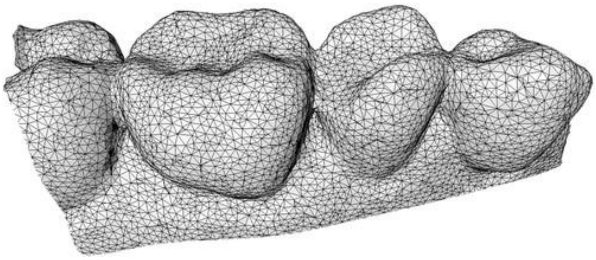

Fig. 1. *Points and meshes forming a 3D shape.*

IOS are now widely used, but nevertheless knowing their features and functionality is not so common, given the wide range of devices on the market. They are mainly distinguished into chairside intra-oral scanners and intra-oral scanners (4), which differ purely in the different workflows used, in that the former bypasses artifact production centers by providing the impression file directly to a CAD-CAM device, thus being able to deliver the artifact directly to the chairside (5). Moreover, considering this fundamental aspect, it is important to distinguish and evaluate them based on: accuracy, precision, resolution, speed, size, image quality, post-processing, cost and maintenance, and depth of reading understood as the ability to capture images at a certain distance from the emitting source; that is, a whole series of intrinsic and extrinsic variables (6) that the operator must consider, evaluate, and know, so that he or she can make the most of the instrument's capabilities (7).

In clinical practice there are countless situations where one may find oneself with grooves of different depths and widths (8).

As good practice, to make the registration more faithful (9). impression taking is used with the help of retractor wires (10) in order to have an opening in the depth and width of the gingival sulcus (11) always adapting the size of the wire to the gingival biotype and the size of the sulcus (12). Equally important for proper registration, it is necessary for the field to be clear and clean, this is possible with the help of mouth openers, retractors, aspirators, etc. (13,14).

The purpose of this study is to compare intra-oral scanners with different acquisition techniques including wireless, wired and newest technologies. In particular, it aimed to test the reading perception (15) of these scanners in depth (16), since one of the main challenges and difficulties in digital impression taking, is the registration of the gingival sulcus (17,18).

MATERIALS AND METHODS

Development

For this study, a resin reference solid model was made in the shape of a cube with grooves of different widths and depths (Fig.2).

The shape of the solid was designed to be able to standardize the acquisition and realize several different clinical conditions in the same scan. Specifically, the anterior groove has dimensions of 1 mm in depth and 1 mm in width, the lateral grooves have a width of 0.5 mm with depth varying antero-posteriorly from 1 to 4 mm, and finally, the posterior groove is 1 mm in width and 5 mm in depth (Fig.3).

Fig. 2. *Photo of the cast that was used.*

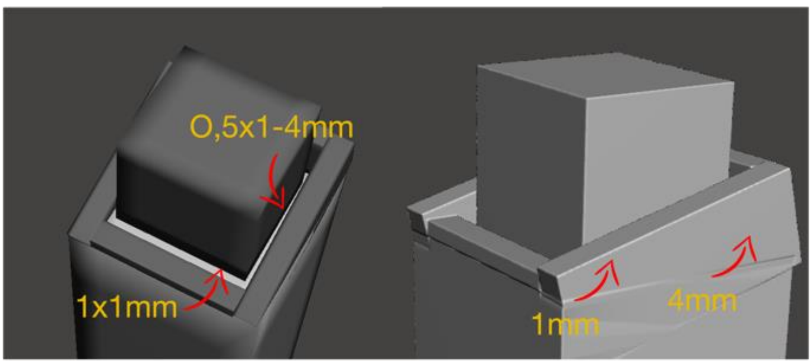

Fig. 3. *Project of the grooves.*

The creation of the solid was achieved by a digital design using a 3D designing software (PreForm vers. 3.27.1, FormLabs, Somerville, Massachusetts, USA) and three-dimensional molding with a 3D laser printer model (Form 2, FormLabs). The intraoral scanners used were: Medit i700 (Medit corp, Seongbuk-gu, Seoul, Korea) (Fig.4), Medit® i700 Wireless and Medit i900 (Fig.5,6). The results were divided into Group 1, Group 2 and Group 3 respectively.

Fig. 4. *Medit i700.*

Fig. 5. *Medit i700 wireless.*

Fig. 6. *Medit i900.*

To standardize the study and reduce possible variables, the taking of the scans was done under stable environmental conditions, in an impression time of 30 seconds, and by the same operator; in addition, for the second device, the distance of the Bluetooth base from the impression-reading handpiece was always 50 cm.

For each scanner, nine scans were carried out according to the previous arrangements. In order to perform accurate measurements, a reference grid was created on the occlusal face that could serve as a guide for the measurements taken successively within the grooves (Fig.7).

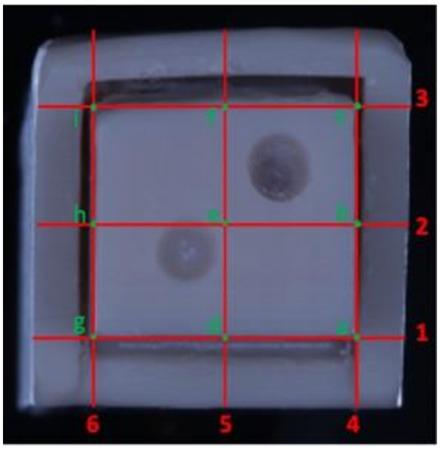

Fig. 7. *Grid for measurements designed on the cast.*

Statistical analysis

All measurements were performed on each scan of the cast with Medit Link Compare software (ML Subgroup, vers. 3.0.0, Seoul, Korea), sectioning the scan along the grooves, so that it could be possible to see the depth reached by each of the scans taken. Every measurement was recorded on an Excel page and three groups were created for the three scanners used. Nine scans were taken with each scanner and Mean (M) and Standard Deviation (SD) were calculated in order to perform a t-test calculation method to distinguish and evaluate a significant variance between the two IOS used.

RESULTS

The results obtained show an overlap of values between scanners used in groups 1, 2, and 3 in the anterior groove (1x1 mm), leading to exclude this value due to the low relevance of this result for this study, as every scanner used performed an excellent reading of this groove.

Groups 1, 2, and 3 were compared, as seen in Table I, in the lateral groves (0,5 x 1-4 mm) and the posterior groove (1x 5mm) (Table I).

Table I. *Mean and Standard Deviation in reading lateral grooves and posterior groove for each group*.

		GROUP 1	GROUP 2	GROUP 3
M	TOTAL	1,99	1,97	2,51
SD		0,827	0,871	1,135
M	0,5 x 1-4mm	2,101	2,266	2,793
SD		0,618	0,798	1,092
M	1 x 5 mm	1,699	2,388	2,485
SD		0,299	0,762	0,893

Mean and Standard Deviation calculations were made for the furrows of different width and depth detected by the three groups, and the values found were compared. Respectively for lateral furrows, with width 0.5 mm and depth varying from 1 to 4 mm, Group 1 results in both the standard deviation and mean collected lower values, compared to Group 2, and a deeper reading in Group 3. Then, in grooves with widths of 0.5 mm and depth of 4 mm, the result of mean and standard deviation was similar in group 1 and 2, with a better performance for Group 3, reaching 33% more than the other 2 Groups. In conclusion, for furrows of 1 mm width and 5 mm depth, the devices used for Group 1 and 3 performed deeper measurements than the device used for Group 2. Based on the measurements and the subsequently calculated statistical values, it was found that there was no statistically significant difference (p value < 0.05), between the results acquired by the two intraoral scanners used in Group 1 and 2. On the other hand the device used in Group 3 demonstrated a deeper reading, especially in narrow and deeper grooves, resulting in reading around 33% more than the other 2 scanners.

DISCUSSION

This study focused on the capacity of reading of two intra-oral scanners, with different acquisition techniques, to detect furrows of different width and depth.

As seen in various studies, but particularly in the study done by Kan Laohverapanich (16), intraoral scanners have very good furrow reading capabilities in comparison with traditional analog techniques. This *in vitro* study showed that the subgingival depth of an implant significantly influenced the accuracy of the 3D implant position, regardless of impression techniques. The final evaluations showed that the E3 laboratory scanner had the highest precision, and all the IOSs, except the DWIO scanner, showed better precision than the conventional impression technique.

A study conducted by Ferrari Cagidiaco (18) on the other hand, based on the results of this clinical trial, the null hypothesis, that there was no difference in the capability of the IOS independent of the vertical position of the prepared finish line, was rejected ($p < 0.005$). It was pointed out that the deeper into the sulcus the position of the margin is, the more of the part of the prepared root will be lost during the digital impression. Several clinical parameters were kept under control to ensure uniformity in order to reduce the risk of bias in this RCT. All the soft tissues around preparation margins were in similarly healthy condition; the operator was a long-time experienced user of IOS and each patient received detailed instructions before performing the digital impression. The accuracy of digital impression systems has been extensively studied in recent years. However, the wide majority of studies were performed *in vitro* and designed to detect differences among different scanners.

A recent literature review carried out by Garcia-Gil (14) was designed to evaluate the accuracy and efficiency of IOS for dental implant impression (DI) taking, compared with different impression materials (CI), and to assess the economic feasibility of introducing digital techniques, most of the studies analyzed obtained results indicating sufficient accuracy, precision or trueness to guarantee adequate passive fit; especially on partially edentulous models. Several authors concluded that dental implant angulation and depth did not influence outcomes in terms of passive fit. Regarding the economic feasibility of DI, in comparisons between DI and CI, only a single in vivo study found that DI allowed a more efficient workflow than CI.

As for studies involving comparisons between IOSs with different acquisition techniques, there are no studies comparing them for accuracy and precision. Wireless devices were found to be practical in use and, in this case, not depending on Wi-Fi transmission of data, but instead using Bluetooth transmission, the data line is not interrupted, and the speed and transmission of data does not depend on bandwidth or internet line. Wireless IOS offers clinicians a cord-free, comfortable scanning experience with the same power and capabilities as standard plug-in intraoral scanners. With a scan area of 15 mm by 13 mm, MEDIT i700 wireless can capture up to 70 frames per second for a smooth and quick intra-oral visualization. It utilizes powerful batteries in its i700 wireless, along with an intelligent power management function that switches the device to sleep mode when not in use, to save energy and enable up to 1 hour of continuous scanning. When the batteries are drained, just plug-in and charge the scanner overnight for a fresh start the next day.

The results in this study show a possible overlap of values between the two scanners from the same series (i700) but a significant difference between series i700 and i900.

With three scanners compared to each other in this study, it is appropriate to say that similar clinical studies with a wider number of IOS are desirable to assess the results acquired from this study.

CONCLUSIONS

A good knowledge of the technology of IOS systems is the basis for being able to understand their operation and the resulting image creation mechanisms.

There are many factors that can guide the clinician in choosing between one IOS and another, but primary in importance is the integration or integrability with production devices and 3D file processing applications. Based on this concept and the results obtained in the study, and the lack of statistical significance of the data, it can be affirmed that Group 2 scanner represents a future solution for the evolution of IOS technologies, with this leading to develop the newest scanner used in Group 3. Regarding the interest of this study, i.e., the evaluation of reading ability within the gingival grooves, it can be affirmed that Group 1 and 2 devices have good reading proficiency even in clinical conditions known to be difficult for the clinician, and Group 3 devices represent the great ability in developing new technologies in aid to evolution and improving. Moreover, regarding the ease of use and the absence of data leakage during acquisition, these further attest to the validity of IOSs.

Conflict of interest
The authors declare that they have no conflict of interest.

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