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Comparative Study

COMPARATIVE ANALYSIS BETWEEN INTRAORAL SCANNERS AND EXTRAORAL SCANNER: EVALUATION OF CLINICAL ASPECTS AND PRECISION

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ABSTRACT

Nowadays, digital technology is part of our daily clinical practice. Digital models have some advantages compared to traditional plaster models, and they can be obtained with intraoral and extraoral scanners. The aim of this study is to compare four types of scanners, three of which are intraoral (3Shape Trios, 3M True Definition, Carestream CS3500), and one is extraoral (ZFX Evolution). Digital dental impressions were taken to 8 patients with every intraoral scanner tested, and a scan of traditional models was performed with the extraoral scanner to create digital models. After each scan, the time required was calculated, and the patient and the operator answered a questionnaire. Six linear measurements were detected in every digital model to investigate the scanner's accuracy, both in the upper and lower arch. The scanners have good reliability, showing no significant differences between the first and the second measurements taken by the operator (with a distance of 7 days between them). The scanners tested are very accurate since there are no significative statistical differences between the measurement, except for one parameter (distance between the lower canine and the lower first molar on the right side). The Trios scanner has a reduced scan time, followed by the True Definition. Based on the questionnaires, patients prefer the 3Shape Trios in terms of ergonomics, versatility and ease of use, while the operators prefer the 3M True Definition, thanks to its lightness, speed and versatility. The digital models obtained with the three intraoral scanners tested are all good and accurate, but there are differences in comfort and scan time.

KEYWORDS: *intraoral, scanner, extraoral scanner, digital model*

INTRODUCTION

Nowadays, digital systems are becoming part of clinical practice to obtain more predictable results and contrast

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aspects that can lead to unsuccessful achievements (1-4). For instance, with digital cameras, digital x-rays and even digital models, we can simplify complex procedures, as Maino et al. (2) developed a 3-dimensional surgical guide to provide a safe and reliable palatal miniscrew insertion (2).

Using a digital model can produce some advantages, such as electronic archiving, which does not require space, simple classification and rapid transmission of information; furthermore, the models do not break or get damaged, and the use of software to calculate specific measurements is allowed. On the other hand, traditional models need storage space, can break and cost money (5-12).

In the literature, it was said that digital models have an accuracy comparable to traditional models (13-15). In addition, it seems that patients prefer digital acquisition of the models due to the shorter time required for the dental impression (16, 17).

A digital model can be obtained by both a direct and an indirect method. The direct method consists of an intraoral scan, reducing time and materials. The scan starts from the distal part of each arch and requires continuous movements. The upper and lower arches are scanned separately and then in occlusion. The 3D model is created by superimposing multiple images. The indirect method consists in scanning the traditional model with an extraoral scan: the upper plaster cast is inserted into the scanner, followed by the lower one; then, the two parts are scanned in occlusion. LED technology is used for the light, and digital cameras record the anatomy.

Regardless of the method, the final result is a 3D digital model of the patient's mouth in .stl format. Some authors have argued that extraoral scanners are more accurate than intraoral ones (18).

The aim of this study is to do a comparative analysis of four types of scanners, three of which are intraoral and one extraoral. In particular, there are four main parts under investigation:

- Evaluation of .stl files: linear measurements obtained with the scanners are compared in order to examine if the scanners are accurate;
- Comparison of the times required for each scan;
- Evaluation of the opinion expressed by patients after each scan;
- Evaluation of the opinion expressed by operators after each scan.

MATERIALS AND METHODS

The study was performed on 8 subjects (5 males and 3 females). The inclusion criteria were the age between 14 and 65 years, the presence of all dental elements (except the third molars) or a single missing tooth, and the absence of severe malocclusions and prosthetic elements.

Digital dental impressions were taken to each patient with every intraoral scanner tested (3Shape Trios, 3M True Definition and Carestream CS3500). Titanium dioxide powder in the patient's mouth, kept as dry as possible, was required to use the 3M True Definition scanner.

In order to obtain the digital model with the extraoral ZFX scanner, traditional PVS (Aquasil Dentsply) impressions were taken using a two-step technique with putty and light material. After that, the traditional dental plaster casts (Velmix Stone type IV) were produced. The ZFX Evolution scanner was then used to scan the plaster cast and obtain a digital model.

The scanners were used and tested in a different order. Each scanner has software with correction tools that can be used after the acquisition of the scans. After each scan, both patient and the operator answered a questionnaire. The questionnaire submitted to the patients was meant to evaluate their satisfaction, and the questionnaire submitted to the operators aimed to analyse the scanners from a clinical point of view. All the answers were rendered with the VAS scale (0-10).

The patient's questionnaire was structured as follows:

- Preferred method: traditional – scanner
- Scanner speed: slow – fast
- Ergonomics and comfort: non-ergonomic – ergonomic
- Aesthetics of the scanner: non-aesthetic – aesthetic
- Discomfort caused by the powder (when 3M True Definition is used): not at all – a lot

The questionnaire for operators was structured as follows:

- Ease of the software to start the acquisition process: difficult – easy;
- Weight: heavy – light;
- Ergonomics, in particular, the possibility to access the distal surfaces of the teeth: not ergonomic – very ergonomic;
- Ease and speed of the acquisition: difficult and slow – easy and fast;
- Problems detected from the end of the acquisition to the achievement of the .stl file: yes - no:
- Aesthetics of the scanner: non-aesthetic – aesthetic.

Moreover, the time required for each scan was calculated. All the models were inserted into Orthoanalyzer software (3Shape), and 6 linear measurements were detected, both in the upper and lower arches, to evaluate the accuracy in the three dimensions of the space (x, y, z).

The 6 measurements for each arch were (15):

- 3-3: intercanine distance, using as reference points the canines' cusps;
- 6-6: intermolar distance, using as reference points the mesio-buccal cusps of the first molars;
- 3-6 right side: distance between right canine and right first molar;
- 3-6 left side: distance between left canine and first left molar;
- 3 right side: height of the right canine's clinical crown;
- 3 left side: height of the left canine's clinical crown.

Every measurement was taken twice by the same operator, with a distance of 7 days between the repetition of the measurement, to assess the operator's reliability (Fig. 1).

Statistical analysis

The SPSS-22 application (IBM SPSS Statistics, v 22.0 for Windows; IBM Corp. Released 2013. Armonk. NY. USA) was used. A first test verified the reliability of the measurements and compared the means of the first and second measurements for each value. If there is a difference between the two averages, the operator has made an error. Therefore, a 95% confidence level was selected. For both measures of each variable, the relationship between them was estimated using the intraclass correlation coefficient; when this correlation is close to unity and has a high value, the measures are similar.

Another test compared the measurements obtained in the .stl files, derived from the models obtained with the four different scanners for each patient. The mean, the median and the standard deviation were calculated. In addition, a

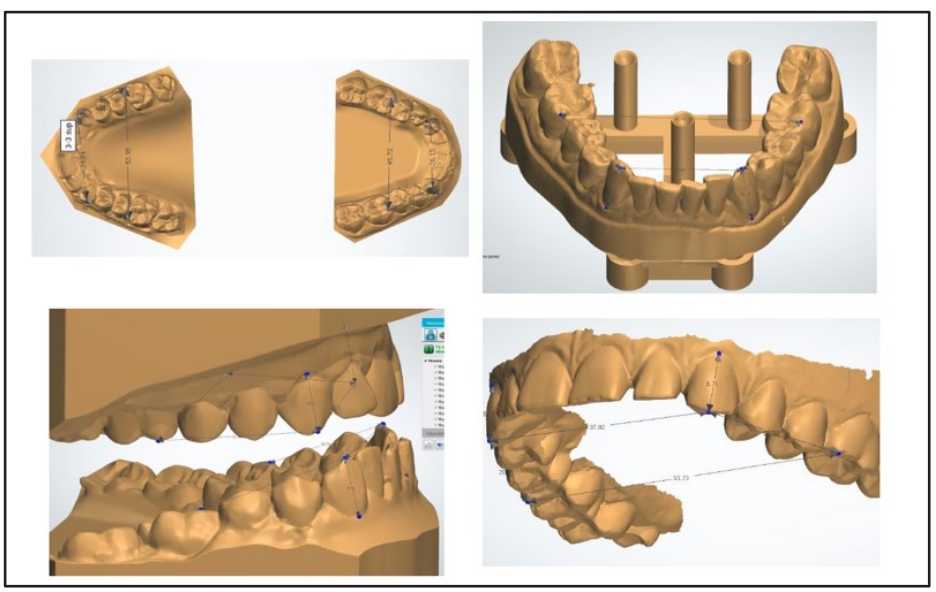

Fig. 1. *Measurements detected in every model*

Shapiro-Wilk test was performed to examine the normal distribution of the values. The other tests performed were Student's t-test, Repeated Measures Anova, Wilcoxon test and Friedman test. A significance level of 5% was chosen, which means that statistical significance is gained with $p<0.05$.

The answers from the questionnaires and the calculation of the time required for each scan were compared to calculate which scanner is more appreciated by both the patients and the operators and which works faster.

RESULTS

Intra-operator reliability

The 3Shape Trios scanner has good reliability, showing no significant differences between the first and the second measurements for none of the parameters ($p>0.05$). The measurement errors are within 0.03 mm, and the correlation coefficients range from 0.998 to 1. Similar results have been detected for the Carestream CS3500 scanner, which has very low average errors (with a maximum of 0.2 mm) and correlation coefficients between 0.999 and 1. Two of the measurements obtained with the 3M True Definition scanner were significant, but their correlation coefficients were 1 and 0.999: which means that the differences were due to a calibration error. These differences were equal to 0.05 and 0.04 mm. The other variables did not show statistically significant differences, with a high correlation coefficient (0.944 – 1); this means that intra-operator reliability with this scanner is good but not as good as the previous ones.

Accuracy analysis in .stl models

3-3 upper: the measurements are similar between the four scanners, and the values have a normal distribution ($p>0.05$ in the SW test). The means are between 34.22 and 34.30 mm, with no significant differences ($p>0.05$). Even when comparing pairs of measurements, there are no statistically significant differences.

6-6 upper: the variables are normally distributed, and the measurements are similar, varying between 50.06 and 50.14 mm, without any statistical difference.

3-6 right upper: there is a slight lack of normality due to a negative curve asymmetry, but the alternative statistical tests are similar, so this variation does not have consequences on the analysis, and the reliability is good. The means are in the range of 20.21-20.25 mm. Therefore, it is possible to conclude that this variable is measured similarly by the four scanners.

3-6 left upper: the values are normally distributed, and the means are similar, staying within a range from 19.24 to 19.29 mm, without statistically significant differences.

3 right upper: there is an adaptation of the measures to the normality model; furthermore, the values are homogeneous and vary from 9.44 to 9.49 mm. There are no statistically significant differences.

3 left upper: the measures do not differ from the normal curve model, and the averages are within the range of 9.47-9.53 mm, without any statistically significant difference.

3-3 lower: the values are normally distributed, and the means are very similar, between 24.02 and 24.20 mm, and the differences are not statistically significant.

6-6 lower: the values have a normal distribution, and any deviation from the standard curve is not statistically significant. Therefore, the means are similar, and range between 42.86 and 42.93 mm, and their differences have no statistical significance.

3-6 right-lower: the values are not normally distributed ($p<0.01$), and there is a negative asymmetry. This lack of normality does not seem to cause alterations in the comparison tests. The average value obtained with the ZFX Evolution is 20.61 mm and is lower than the other means, ranging from 2.70 to 2.78 mm. The differences are significant, with $p<0.01$ in the Friedman test but $p<0.1$ in the Anova test. Student's t-test and Wilcoxon test show that the difference between the mean obtained with the ZFX Evolution and the means obtained with the 3Shape scanner (20.78 mm) and the 3M scanner (20.78 mm) has statistical significance, with $p<0.05$ (Table I); this means that the ZFX Evolution scanner measures this variable in a different way than the other scanners.

3-6 left lower: the measurements do not differ from the standard curve model, and the means vary from 20.73 to 20.77 mm; the differences have no statistical significance.

3 right lower: No significant deviations from the standard curve, and the means are homogeneous.

3 left lower: the four values are generally distributed without statistically significant differences from the standard model. The means range from 9.88 to 9.94 mm, and the difference is not statistically significant.

When it is said that a parameter has similar means without statistically significant differences, it means that both a multivariate analysis of variance and a pairwise comparison was performed, and the differences were not statistically significant, with a p-value> 0.05; this means that these parameters were measured similarly by all scanners.

Time required for the scans

The time required for each scan was evaluated by analysing the upper arch, the lower arch, the occlusion scan and the total scan time, shown in the graph below (Fig. 2). The Trios scanner has a reduced scan time, followed by the True Definition scanner.

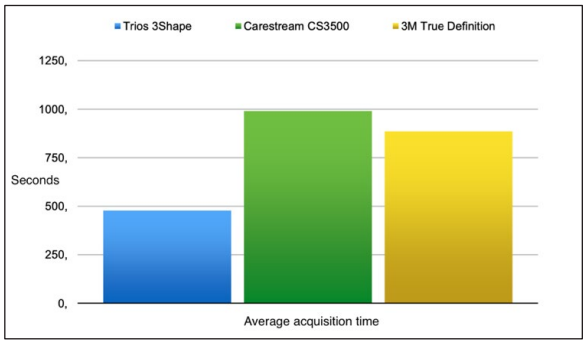

Fig. 2. *Total acquisition time.*

Opinions expressed by patients and operators

The analysis of the answers given by the patients showed that they preferred the 3Shape Trios in terms of ergonomics, versatility and ease of use. On the other hand, the answers given by the operators showed that they preferred the 3M True Definition, thanks to its lightness, speed and versatility in obtaining the .stl file.

DISCUSSION

Digital technologies are becoming part of daily clinical practice in dentistry, as they are a very useful tool for diagnosis and treatment plans. Unlike plaster models, digital models are easy to archive (5-7). This study has compared four different scanners in terms of precision, the time required and the preferences of both patients and operators. Statistically significant differences between the measurements have not been detected, except for one parameter, which was the distance between the lower canine and the lower first molar on the right side; this parameter represented a statistical weakness and, in general, it was possible to say that the four scanners analysed were very accurate.

Table I. *Differences between the values detected with the scanners: 3-6 right lower.*

Scanner	Mean	D.E.	Anova MR F	Anova MR P	Test Friedman Chi²	Test Friedman P	pairs	Student MR /t/	Student MR P	Test Wilcoxon /Z/	Test Wilcoxon P
(1) 3Shape	20.78	2.32					(1) - (2)	0.08	.939 NS	0.56	.575 NS
(2) 3M	20.78	2.41					(1) - (3)	1.33	.224 NS	1.36	.173 NS
(3) Carestream	20.70	2.31	2.73	.070 NS	11.84	.008**	(1) - (4)	2.41	.047 *	2.37	.018 *
(4) ZFX Evolution	20.61	2.31					(2) - (3)	1.30	.234 NS	1.26	.208 NS
							(2) - (4)	2.41	.047 *	2.37	.018 *
							(3) - (4)	1.22	.261 NS	1.36	.173 NS

NS = p>0.05 *= p<0.05 ** = p<0.01

The Trios scanner was the most appreciated by the patients because it is comfortable, fast and has pleasing aesthetics. The questionnaires showed that the other scanners were also appreciated, but patients argued that the Carestream CS3500 does not have pleasing aesthetics. Moreover, it should be noted that the 3M True Definition scanner requires powder in the mouth.

The operators liked the True Definition scanner more than the others. The 3Shape also received very good reviews regarding aesthetics and ease of learning how to use the software. However, the Carestream software seems less accurate in the model's optimisation because it does not cancel the errors automatically, as the other scanners do; in particular, when there is a missing tooth, errors are generated, and the total scan time is elongated. The questionnaires also showed that the patients prefer digital acquisition of dental impressions to the traditional system with alginate or PVS.

The literature has compared models obtained from digital scans with plaster models obtained from traditional dental impressions, and it appears that the two techniques can be compared in terms of accuracy (19-21). However, technology has improved over the years, and it is possible to find many studies on scanners that are no longer used today in literature.

This article provides an evaluation of current digital systems; in particular, previous scanners have shown significant differences between an intraoral acquisition and an extraoral acquisition and this study aimed to evaluate if this difference is still present.

CONCLUSIONS

Digital methods are becoming part of daily clinical practice in dentistry; digital models are a useful tool and can be obtained from a direct scan of the arches or a plaster model from a traditional dental cast.

The analysis conducted in this study shows that the digital models obtained with the three intraoral scanners tested (Trios 3Shape, Carestream CS3500 and 3M True Definition) are all good and accurate, but there are some differences in terms of comfort and scanning time. The ZFX Evolution scanner is also accurate, even though a discrepancy was found regarding the symmetry of a variable analysed. The study sample selected is small, but each model has analysed many measurements, ensuring a good reliability level. Digital systems are undergoing a rapid evolution; in the future, digital models will probably replace traditional models, guaranteeing precision, comfort and reduced time required.

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