EUROMEDITERRANEAN BIOMEDICAL JOURNAL
2020,15 (18) 77–81
(FORMERLY: CAPSULA EBURNEA)

Original article

VALIDITY AND RELIABILITY OF MEASUREMENTS OF THE PARAMETERS OF SMILE AESTHETICS: A COMPARISON BETWEEN DIGITAL AND PLASTER MODELS

Giuseppa Bilello [1], Angela Puma [1], Antonino Puma [2], Giuseppe Currò [1], Giuseppe Pizzo [1]

1. Department of Surgical, Oncological and Oral Sciences, University of Palermo, Italy
2. Private Practice, Ravanusa, Italy

ARTICLE INFO

Article history:
Received 03 May 2020
Revised 19 May 2020
Accepted 23 May 2020

Keywords:
Digital model, Intraoral scanner, Plaster cast, Aesthetics, Dental measurements, Connecting space.

ABSTRACT

This study aims to evaluate the validity and reliability of the TRIOS3 Color intraoral scanner (3Shape A/S, Copenhagen, Denmark) and its associated Ortho Analyzer™ software in measuring parameters of smile aesthetics compared with measurements on plaster casts. The study sample comprised plaster casts and digital models obtained from 30 subjects. Height (H), mesiodistal diameter (MDD) and connecting space (CS) of the anterior teeth were measured with a digital calliper on the plaster models and with the orthodontic software on the digital models. Validity was assessed using a 2-tailed paired *t*-test; the reliability of measurements for intra-examiner was evaluated with the Intra-class Correlation Coefficient (ICC). There were no statistically significant differences between the measurements made with the two methods. The ICC is 99% for height and MDD measurements, slightly lower in the evaluation of the CS. Linear measurements made on digital model have clinically acceptable accuracy and reliability. The TRIOS3 Color intraoral scanner represents a valuable tool for dental practice, particularly in evaluating parameters of smile aesthetics.

1. Introduction

Successful dental treatment requires comprehensive diagnosis and treatment planning. The study of periapical and/or panoramic X-rays, evaluation of photographic records and analysis of study models is fundamental. Plaster study models have always represented the gold standard in the reproduction of dental arches. Around 1980, scanning systems were developed and introduced into the dental practice systems for digitizing plaster impressions as well as systems for digital acquisition of dental arches with intraoral scanners (1). Plaster study models are acceptably reliable for a complete evaluation of the patient's occlusion, symmetry of the dental arches and palate, position of teeth and their dimension, study of Spee and Wilson curves, overbite, overjet and Bolton analysis (2,3). The disadvantages of using plaster casts include physical storage, the risk of damage, fractures, or inaccuracies such as air bubbles, high weight, difficult communication with patients and colleagues, difficulty accessing to the model from many locations. Intraoral 3D scans are easy to store and transfer, have no risk of physical damage, and are immediately available to discuss treatment with the patient during the record taking visit (4–7).

Moreover, in the traditional impression tray, inaccurate impression dimensions, too much or too little impression material, inappropriate adhesion of the impression to the impression tray, and the impression disinfection procedure can be responsible for errors and inaccuracies in the plaster model (8). On the other hand, the digital models of the jaws do not require disposal, nor do they require the packaging and transportation that the impression materials and plaster models do; for these reasons, it is both a more economical and more ecological technique.

Various scanning intraoral systems have been introduced in clinical dental practice as a replacement for the dental impression-taking procedure. An intraoral scanner is easy to use and generates stereolithography (STL) files that can be used to make digital models. Today new intraoral scanners are small in size, produce fast image creation and no pre-scan dust is required on dental elements. These features lead to greater patient acceptance and reduce the clinician's work time.

In orthodontics, the treatment plan aims to restore the occlusion, the correct ratio between upper and lower jaw for chewing function and, in particular, the aesthetics of teeth and soft tissue. The main objective of any aesthetic dental treatment is to obtain a beautiful smile, which is an integral part of the individual's appearance.

* *Corresponding author*: Giuseppe Pizzo, *giuseppe.pizzo@unipa.it*
DOI: 10.3269/1970-5492.2020.15.18

Today's society develops around the digital world and our images are conveyed daily through selfies, photos or videos. Therefore, both the clinician and the layperson are aware of the role of smile and aesthetics. This requires us to carefully evaluate the dental and gingival parameters to enhance the aesthetics of the smile. To establish a treatment plan, it is not enough just to recognize what interferes with the smile, but a diagnosis must be made using parameters to establish what is not normal and must be corrected.

The Facial Aesthetic Reference Diagram (DFAR) is an auxiliary diagnostic tool that helps the dentist in the correct objective evaluation of the smile by facilitating diagnosis and treatment planning. Its function is to provide a model of the correct position and relationship between teeth, as well as their relationship with gums and lips in frontal view, suggesting what needs to be created in aiming for the best possible dental aesthetics (9). One element described by DFAR is the connecting space. Unlike the point of contact, the connecting space is larger, broader, and can be defined as zones in which two adjacent teeth appear to touch. This space is defined by reference points that are the point of contact and the gingival papilla. Morley and Eubank defined that the best ratio between the front teeth follows the 50-40-30 rule for connecting space (9–11).

The band called “connector band” is formed through the union of the contact point line and the gingival papilla with a hang-glider shape; modifications in this band, for dental treatments or dental remodeling, will be responsible for aesthetic modifications. The height/width ratio of the maxillary incisors should also be evaluated with the aim of achieving proportions in the smile that harmonize with the face (11).

The present study aims to evaluate the validity and reliability of the TRIOS3 Color intraoral scanner and its associated Ortho Analyzer™ software (3 Shape A/S, Copenhagen, Denmark) in measuring parameters of smile aesthetics compared with measurements on plaster casts. Measurements of height (H), mesiodistal diameter (MDD) and connecting space (CS) of the anterior teeth were made on the digital and the plaster models

2. Methods

Study sample

This study protocol conformed to the ethical guidelines of the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards and was approved by the Institutional Review Board of the University of Palermo General Hospital (A.O.U. Policlinico "Paolo Giaccone"; approval number 11/2019). The study was registered at the German Registry of Clinical Trials (DRKS-ID: DRKS00020590).

The study sample comprised plaster casts and digital models obtained from 30 subjects randomly selected among those who underwent dental visit at a dental practice located in Sicily (Italy) during February 2020. All the subjects volunteered to participate and provided informed consent. Thirty sets of plaster casts and thirty sets of digital models were available for the study; each enrolled set of the model included a plaster cast and a digital model derived from the same subject. The sample size seemed to be adequate because previous studies with digital and plaster models used a similar sample size (5, 12–15).

The traditional impression was made with an irreversible hydrocolloid (xantALGIN® select; Heraeus Kulzer, Hanau, Germany) using commercial impression trays.

All impressions were cast in conventional material (gypsum Ortotypo 4; LASCOD, Sesto Fiorentino, Italy) within an hour of the impression and conventionally trimmed. The bite was recorded by hand with a wax wafer. The intraoral 3D scan was performed using TRIOS3 Color intraoral scanner (3Shape A/S) in the following sequence: lower jaw, upper jaw and bite registration, according to the manufacturer's recommendation. The Ortho Analyzer ™ software (3Shape A/S) was used to obtain all measurements.

Both the traditional impression and the intraoral 3D scan were performed by the same operator during a single session. The inclusion criteria of the participating subjects included both male and female; age between 18 and 40 years; permanent dentition from first molar to first molar; all teeth without carious lesions, or crown defects that would affect the mesiodistal morphology of the crown. The exclusion criteria included Angle’s Class II and Class III malocclusion, severe crowding, anterior cross-bite, gingival recession, presence of fixed restorations, and heavily restored teeth. The dental casts enrolled did not present positive or negative bubbles, missing tooth material or breakage. The digital models do not present image distortions or imperfections.

Data collection

The following measurements were made: mesiodistal diameter (MDD) of crown of the upper central and lateral incisors, taken at the maximum convexity of the mesial and distal surfaces; height (H) of the upper central and lateral incisors, measured from the incisal edge to the gingival zenith; connecting space (CS) between upper central incisors, upper right/left central and lateral incisor, upper right/left lateral incisor and canine. The space between gingival papillary tip (the orange point in Figure 1) and contact point (the red point in Fig. 1) is called connecting space. So, connecting space is delimited by the contact points and gingival papilla (9). All plaster measurements were made with an electronic digital calliper to the nearest 0.01mm, from the frontal view to provide better visibility. To evaluate the contact point, if necessary, the model is rotated to the occlusal view.

The intraoral 3D scan visible on the PC is transferred in STL format to Orthon Analyzer ™ software to make measurements digitally on the digital model. As in the plaster model, measurements are made in frontal view as shown in Figure 2.The manipulation of the digital model is allowed though image handler methods. The program’s zoom, rotation and panning features were fully exploited. The measurements of H and CS were made parallel to the buccal surfaces; the MDD measurements were made parallel to the occlusal surfaces. All recordings were made to the nearest 0.01 mm.

Validity was considered as the extent to which the new diagnostic test (digital model) measured against the gold standard (dental cast) (15). Reliability was considered to be the extent to which the measurements were repeatable under identical conditions. It refers to the ability of a device to produce consistent results and was gauged by the concordance between replications (12, 16).

Data Analysis

All measurements were recorded in an Excel 2017 spreadsheet (Microsoft, Redmond, WA) and analysed using the multi-paradigm numerical computing software MATLAB 2019b developed by The Math Works, Inc. (Natick, MA) through the built-in Statistics and Machine Learning Toolbox.

An alpha value of 0.05 was considered significant. Individual variables were evaluated by the Shapiro-Wilk test to assess the normality of the distributions. Validity was assessed using a 2-tailed paired *t*-test between recordings from the digital and conventional method of impression. The *t*-test was used to validate the hypothesis that there would be no difference between the paired sets of measurements. The reliability of measurements for intra-examiner was evaluated with the Intra-class Correlation Coefficient (ICC) by repeating all measurements at a two-week interval. The individual operator took the measurements on the digital model and the plaster model under a standardized workflow.

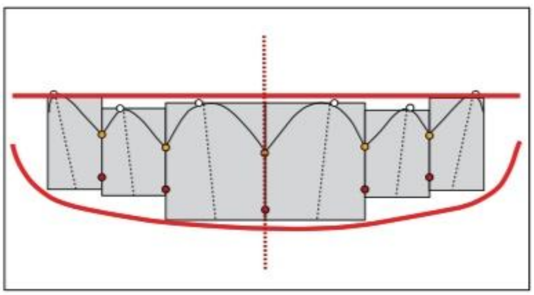

Figure 1. The Facial Aesthetic Reference Diagram (DFAR), with new reference points: contact points and gingival papillary tips. Redrawn from Câmara (9)

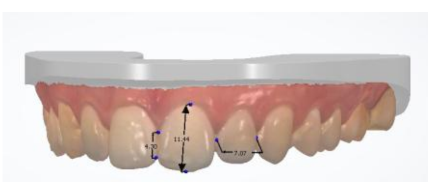

Figure 2. Measurement with Ortho Analyzer™ software.

3. Results

Normality tests showed a normal distribution of data according to the Gauss curve. Mean biases, standard deviation, mean differences between measurements (on digital and on plaster models) and *P* values for the paired *t*-test are given in Table 1.

According to the 2-tailed paired *t*-test, there were no statistically significant differences between measurements made on dental casts, obtained from conventional impressions, and digital model made with TRIOS3. Statistically significant differences ($P < 0.05$) were found for three out of a total of fourteen measurements (Table 1). The results show that the dental heights on the plaster model are higher than those on the digital model with an average difference ranging from 0.011 to 0.029 mm (Table 1). The widths of the central incisors are larger in the conventional model, unlike the MDD of the lateral incisors which are larger in the digital model with an average difference of 0.011 mm. The mean differences in the CS are between -0.031 mm and 0.043 mm.

As shown in Table 2, the ICC test demonstrates a high reliability value for intra-examiner measurements taken directly on digital and plaster models.

The values in the parameter height and MDD were 99%, in both the digital model and the dental cast. For the CS values, the average value of ICC in the plaster cast is 93%, while in the digital model it is 95%.

	Digital Calliper (mm)		Ortho Analyzer™ (mm)		Dental cast vs Digital model	
Measurement	Mean	SD	Mean	SD	Mean difference (mm)	p-value
H 11	9.482	0.755	9.469	0.753	0.013	0.420
H 21	9.569	0.898	9.557	0.923	0.011	0.432
H 12	8.037	1.018	8.008	1.041	0.029	0.012
H 22	7.946	1.028	7.921	1.031	0.025	0.064
MDD 11	8.839	0.463	8.803	0.444	0.036	0.015
MDD 21	8.785	0.411	8.778	0.429	0.007	0.497
MDD 12	6.79	0.443	6.801	0.444	-0.011	0.463
MDD 22	6.772	0.407	6.783	0.402	-0.011	0.376
CS 1121	4.181	0.866	4.192	0.826	-0.011	0.008
CS 1112	3.39	0.796	3.34	0.766	0.043	0.697
CS 2122	3.077	0.722	3.073	0.711	0.004	0.841
CS 1213	2.224	0.476	2.214	0.492	0.008	0.546
CS 2223	1.975	0.457	2.01	0.454	-0.031	0.118

Table 1. Comparison between digital calliper and Ortho Analyzer ™ measurements.

	Digital Calliper	Ortho Analyzer™
Measurement	ICC	ICC
H	0.990	0.993
MDD	0.993	0.992
CS	0.934	0.948
CS 1112	0.965	0.970
CS 1121	0.949	0.979
CS 1213	0.913	0.931
CS 2122	0.943	0.955
CS 2223	0.908	0.913

Table 2. Intra-class Correlation Coefficient (ICC) for evaluating the reliability of plaster cast and digital model.

4. Discussion

A number of studies have evaluated the accuracy of the linear and dental arch measurements comparing the plaster model with a digital model obtained by scanning the physical plaster model. Sousa et al. (13) and Quimby et al. (17) found no statistically significant differences between manual and digital measurements.

Santoro et al. (4) found statistically significant differences in tooth size and overbite, although it is considered clinically insignificant.

Muller et al. (14) evaluated the Bolton radio and arch length and found that the digital model needs less time and it is quite reliable.

Unlike previous studies, the present study compares conventional plaster models with digital models obtained by scanning the arches with an intraoral scanner. Specifically, the study evaluated the validity and reliability of the TRIOS 3 Color intraoral scanner and its associated Ortho Analyzer™ software in measuring parameters of smile aesthetics compared with measurements on plaster casts.

For most of the linear measurements made on the digital models, no statistically significant differences were found when compared to measurements made manually with a digital calliper on a plaster model of dental arches. According to the paired t-test, there were statistically significant differences in only three linear measurements. These results are consistent with those from previous studies (8, 12, 18). Naidu et al. (12) used impressions from 30 subjects, obtained with the intraoral scanner, concluding that the measurements of the dental diameters and the calculation of the Bolton index have a clinically acceptable accuracy, excellent reliability and reproducibility. Glisic et al. (18) compared the accuracy of the digital model using the measurements of the distance between the upper canines and upper first molars, and no significant difference between the procedures was shown. However, in contrast to the results of Camardella et al. (8), in the present study most of the distances measured on digital models were slightly smaller compared to the measurements on plaster models. Only values of MDD of the upper lateral incisors and two CS were higher in the intraoral scanner model. These differences may be due to a number of reasons: (1) there are no physical barriers in the positioning of the points in the digital model; (2) the digital model is not affected or damaged by the positioning of tip of the calliper; (3) smaller measurements in the plaster model may be due to shrinkage or possible dimensional changes of the alginate impressions; (4) with the digital software it is possible to evaluate the contact points on an enlarged image.

When measuring the CS, particularly for aesthetic evaluation, the digital model has advantages and greater reliability. The identification of the contact point, the apex of the gingival papilla and consequently the measurement of the CS is easier and more reliable in the digital model. The latest generation of intraoral scanners, including the one used in this study, performs colour dental scans and faithfully reproduces the colour and pigmentations of the tooth element and soft tissue.

In addition to colour vision provided by the intraoral scanner used in this study, the associated Ortho Analyzer™ software allows the dentist to view and analyse digital images by applying various functions, such as zoom, rotation around the 3 axes, and image section. So, dentist has better views and more accurate measurements because anatomic details can be more accurately viewed (19, 20). Moreover, it is possible to delete the established point and reposition it as often as deemed necessary without the risk of altering or compromising the affected area, unlike the plaster model where it is possible to determine iatrogenic imperfections.

The orthodontic software also allows to obtain a report, with printing possibilities, where all the measurements we have calculated are noted and named. Conversely, in the plaster model the colour information is lost, and when estimating the contact point, the operator will tend to underestimate the measurement due to difficulty in positioning the tip of the calliper, particularly in cases with rotated or crowded teeth. Additionally, it can happen that the contact point can turn into an area and the papilla ends up blurring with the surface of the element or being compromised by a bubble. In such cases, the dentist will need to take the alginate impression again.

Among the advantages provided by the intraoral scanner, it must be noted that the impression taking procedure is facilitated: on the computer screen there is the visualization of the processed image and the dentist is able to scan the same area several times, delete the incorrect parts of the image and resume the scan from a generic point, or even re-scan the entire arch in an easy and fast way. The result will be a precise scan without image splitting or artefacts. Digital models of the jaws can also be combined with conical beam computed tomographic scans to provide a real view of the anatomy and position of teeth which is useful both in orthodontics (to assess root position) and in oral surgery (to plan surgery and make surgical templates) (21, 22). Moreover, the orthodontic software offers the possibility to observe, prior to orthodontic treatment, how the position correction of the dental elements influences the CS, the gingival contour and the surrounding tissues. This feature is very useful to evaluate the aesthetic result at the dental and soft tissue level.

Finally, a number of studies assessed patient satisfaction with a questionnaire to determine patient experience of impression taking: most patients reported that the intraoral scanning procedure is more comfortable than conventional impression taking, as it leads to less breathing difficulty, feeling of vomiting, temporo-mandibular joint pain and discomfort when opening the mouth(23–26).

In conclusion, the present study showed that measurements on digital models have good accuracy and high reliability. These findings suggest that the TRIOS3 Color intraoral scanner and its associated Ortho Analyzer™ software can be an excellent substitute for the dental cast and digital calliper in measuring the parameters of smile aesthetics.

References

1. González Guzmán JF, Teramoto Ohara A. Evaluation of three-dimensional printed virtual setups. Am J Orthod Dentofac Orthop. 2019;155:288–95.
2. Weber F. Interceptive-preventive orthodontics. Salzman JA Orthod Dly Pract Philadelphia JB Lippincott Co. 1974;211–45.
3. Hou H, Wong R, Hagg E. The uses of orthodontic study models in diagnosis and treatment planning. Hong Kong Dent J. 2006;3(852):107–15.
4. Santoro M, Galkin S, Teredesai M, Nicolay OF, Cangialosi TJ. Comparison of measurements made on digital and plaster models. Am J Orthod Dentofac Orthop. 2003;124:101–5.
5. Liang YM, Rutchakitprakarn L, Kuang SH, Wu TY. Comparing the reliability and accuracy of clinical measurements using plaster model and the digital model system based on crowding severity. J Chinese Med Assoc. 2018;81:842–7.
6. Kasparova M, Grafova L, Dvorak P, Dostalova T, Prochazka A, Eliasova H, et al. Possibility of reconstruction of dental plaster cast from 3D digital study models. Biomed Eng Online. 2013;12:49.
7. McGuinness NJ, Stephens CD. Storage of orthodontic study models in hospital units in the U.K. Br J Orthod. 1992;19:227–32.

8. Camardella LT, Breuning H, de Vasconcellos Vilella O. Accuracy and reproducibility of measurements on plaster models and digital models created using an intraoral scanner. J Orofac Orthop. 2017;3:211–20.
9. Câmara CA. Aesthetics in Orthodontics: Six horizontal smile lines. Dental Press J Orthod. 2010;15(1):118–31.
10. Morley J, Eubank J. Macroesthetic elements of smile design. J Am Dent Assoc. 2001;132:39–45.
11. Sarver DM. Principles of cosmetic dentistry in orthodontics: Part 1. Shape and proportionality of anterior teeth. Am J Orthod Dentofac Orthop. 2004;126:749–53.
12. Naidu D, Freer TJ. Validity, reliability, and reproducibility of the iOC intraoral scanner: A comparison of tooth widths and Bolton ratios. Am J Orthod Dentofac Orthop. 2013;144:304–10.
13. Sousa MVS, Vasconcelos EC, Janson G, Garib D, Pinzan A. Accuracy and reproducibility of 3-dimensional digital model measurements. Am J Orthod Dentofac Orthop. 2012;142:269–73.
14. Mullen SR, Martin CA, Ngan P, Gladwin M. Accuracy of space analysis with emodels and plaster models. Am J Orthod Dentofac Orthop. 2007;132:346–52.
15. Stevens DR, Flores-Mir C, Nebbe B, Raboud DW, Heo G, Major PW. Validity, reliability, and reproducibility of plaster vs digital study models: Comparison of peer assessment rating and Bolton analysis and their constituent measurements. Am J Orthod Dentofac Orthop. 2006;129:794–803.
16. Roberts CT, Richmond S. The design and analysis of reliability studies for the use of epidemiological and audit indices in orthodontics. Br J Orthod. 1997;24:139–47.
17. Quimby ML, Vig KWL, Rashid RG, Firestone AR. The accuracy and reliability of measurements made on computer-based digital models. Angle Orthod. 2004;74:298–303.
18. Glisic O, Hoejbjerre L, Sonnesen L. A comparison of patient experience, chair-side time, accuracy of dental arch measurements and costs of acquisition of dental models. Angle Orthod. 2019;89:868–75.
19. Koretsi V, Tingelhoff L, Proff P, Kirschneck C. Intra-observer reliability and agreement of manual and digital orthodontic model analysis. Eur J Orthod. 2018;40:52–7.
20. Kiviahde H, Bukovac L, Jussila P, Pesonen P, Sipilä K, Raustia A, et al. Inter-arch digital model vs. manual cast measurements: Accuracy and reliability. Cranio - J Craniomandib Pract. 2018;36:222–7.
21. Lee RJ, Pham J, Choy M, Weissheimer A, Dougherty HL, Sameshima GT, et al. Monitoring of typodont root movement via crown superimposition of single cone-beam computed tomography and consecutive intraoral scans. Am J Orthod Dentofac Orthop. 2014;145:399–409.
22. Lee RJ, Weissheimer A, Pham J, Go L, De Menezes LM, Redmond WR, et al. Three-dimensional monitoring of root movement during orthodontic treatment. Am J Orthod Dentofac Orthop. 2015;147:132–42.
23. Burhardt L, Livas C, Kerdijk W, van der Meer WJ, Ren Y. Treatment comfort, time perception, and preference for conventional and digital impression techniques: A comparative study in young patients. Am J Orthod Dentofac Orthop. 2016;150:261–7.
24. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: A review of the current literature. BMC Oral Health. 2017;17:149.
25. Yuzbasioglu E, Kurt H, Turunc R, Bilir H. Comparison of digital and conventional impression techniques: Evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. BMC Oral Health. 2014;14:10.
26. Joda T, Brägger U. Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial. Clin Oral Implants Res. 2016;27:e185–9.

.