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Precision of Tooth Size Measurement in Digital Models Acquired by Intraoral Scanning and by Scanning of Plaster Models Versus Conventionally Cast Models †

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Abstract: This study compared the precision of extracting mesio-distal tooth size of each participant, from plaster models, digital models, and by scanning plaster models using the iTero Element 5D Plus scanner. Ten participants were included in the study. Descriptive analysis was carried out and the reproducibility of measurements for the three methods was assessed with the intraclass correlation coefficient (ICC). The overall reproducibility of mesio-distal tooth size measurements on digital models was comparable to direct measurements on plaster models and the digital replicate of the study models. A trend towards lower reproducibility was found for measurements of posterior maxillary teeth in digital models.

Keywords: intraoral scanners; digital models; model scanning; 3D models; model analysis; orthodontics; precision; accuracy

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1. Introduction

Traditionally, diagnostic measurements were obtained from plaster models with a digital calliper. The literature recognizes manual measurements using callipers as accurate and reliable [1–3]. In recent years, conventional plaster models have been replaced by digital models that are becoming more common due to the benefits related with storage, retrieval, reproduction, and communication. On that account, the clinician can have easy access to diagnostic and routine measurements and perform various analyses [4].

Different methods can obtain digital models. Several studies have evaluated the reliability of 3D digital models, obtained with extra-oral scanners on plaster models such as 3Shape D250 3-dimensional (3D) scanner (3Shape, Copenhagen, Denmark) [3,5], Ortho Insight 3D laser scanner (Motion View LLC, Chatanooga, TN, USA) [6], and R500 3Shape scanner (3Shape, Copenhagen, Denmark) [7]. Scans with the 3Shape D250 showed high precision values with mean deviations of 10 µm and, root mean square errors of 20 µm [5].

Three dimensional (3D) digital models can also be acquired with intraoral scanners. Pelliteri et al. [7] studied the accuracy and efficiency of 3D digital models using three different intraoral scanners, Carestream CS3600 (Onex Corporation, Rochester, NY, USA), CEREC Omnicam(Dentsply Sirona, Charlotte, NC, USA) and Trios 3Shape (3Shape, Copenhagen, Denmark). Variations between the three intraoral scanners and the polyvinyl siloxane (PVS) impression scan ranged from 100 to 200 µm.

Intraoral scanners, such as iTero, can also be used to scan plaster models. Reported values of mean deviations of 25 µm and root mean square errors of 51 µm [5] confirm that the iTero intraoral scan can generate 3D digital models of plaster models with precision.

The availability of several software applications enables clinicians to import digital models and move their generated images around three axes of rotation as well as measuring tooth size and arch width and length [4] and calculate Bolton ratios [6], such as OrthoCAD (Cadent, Carlstadt, NJ, USA), E-models (GeoDigm Corporation, Falcon Heights, MN, USA), Ortho AnalyzerTM (3Shape, Copenhagen, Denmark), SureSmile (OraMetrix, Richardson, TX, USA), Maestro3D (AGE Solutions, Pisa, Italy), NemoCast (Nemotec, Madrid, Spain), and DigiModel (OrthoProof, Nieuwegein, Netherlands) [4,6,8,9].

Most studies found that even though the reproducibility of digital models is acceptable for clinical diagnosis and investigation measurement, precision varies across studies according to the clinician's experience and ability and the visualization tools offered by different software. Therefore, the precision and accuracy of different measurements and techniques should be evaluated in the practice of evidence-based clinical orthodontics [2].

The aim of this study was to determine and compare the precision of mesio-distal tooth size measurements in plaster models using a digital calliper with measurements obtained with NemoCast software in digital models acquired through intraoral scanning and by scanning plaster models using the iTero Element 5D Plus scanner.

2. Materials and Methods

The present pilot study was undertaken at the Egas Moniz School of Health and Science. Ethical approval was secured from the Ethics Committee, and consent forms were obtained from the participants. The study sample consisted of 10 patients with full permanent dentition randomly selected from the clinical archives of the postgraduate orthodontics program. Each case had available dental study models and intraoral digital scans. Digital models were acquired both through intraoral scanning and by scanning the plaster models using the iTero Element 5D Plus scanner (Align Technology, San Jose, CA, USA) (Figure 1).

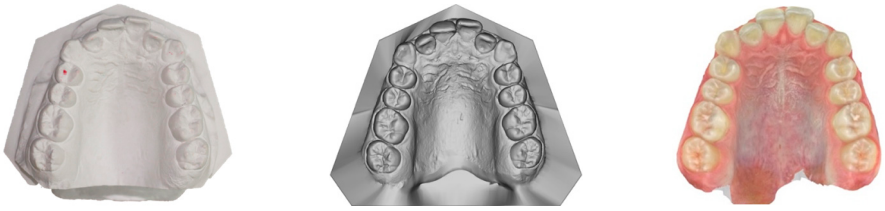

Figure 1. Dental models used in the study. Left to right: Conventional plaster study model, 3D scanning of plaster model, 3D intraoral scan.

The iTero Element 5D Plus acquisition method is based on parallel confocal microscopic features colour scanning and does not require opacification. The scanning procedure started from the occlusal surface, progressing to the buccal and lingual surfaces. A sample size calculation determined that a 10 to 13 dental study models are required to obtain a statistical power of 95% [4].

One examiner (M.J.) was trained in using the three different methods, measuring with a digital calliper, scanning the plaster models and measuring of the 3D virtual images with NemoCast software v2021. The measurements from conventional dental casts were obtained with a 145 mm digital calliper (Hammacher, Solingen, Germany) with 0.01 mm accuracy. Digital model images were analyzed by using Nemocast software (Figure 2). Measurements were recorded in a Microsoft Excel spreadsheet (Microsoft, Redmond, DC, USA) and analyzed with SPSS Statistics version 28.0 (SPSS, Chicago, IL, USA). Descriptive analysis of the mean error of mesio-distal tooth size duplicate measurements was carried out and the reproducibility of measurements assessed with the intraclass correlation coefficient (ICC).

Figure 2. Mesiodistal tooth measurements from the Nemocast software. Mesial point landmarks are marked as a red circle and distal point landmarks as a blue circle.

3. Results

The intra-examiner mean random errors of mesio-distal tooth size ranged from 0.07 to 0.20 mm for measurements obtained with a digital calliper on plaster models, from 0.07 to 0.29 mm for measurements obtained with Nemocast in digital models acquired through iTero intraoral scanning, and from 0.07 to 0.28 mm for measurements obtained with Nemocast in digital models acquired using iTero scanning of plaster models.

Intraclass correlation coefficients (ICC) for mesio-distal tooth size measurements (Table 1) ranged from 0.630 to 0.990 for the digital calliper (mean ICC = 0.921), from 0.524 to 0.965 for Nemocast/iTero intraoral scanning (mean ICC = 0.885), and from 0.281 to 0.971 for Nemocast/iTero plaster scanning (mean ICC = 0.855).

Table 1. Reproducibility of tooth size measurements evaluated by intraclass correlation coefficient.

	Digital Calliper/Plaster Model	Nemocast/Intraoral Scan	Nemocast/Plaster Scan	Mean
Upper Arch				
16	0.908	0.693	0.685	0.762
15	0.972	0.935	0.909	0.939
14	0.951	0.915	0.804	0.890
13	0.630	0.943	0.840	0.804
12	0.931	0.930	0.962	0.941
11	0.990	0.944	0.935	0.956
21	0.969	0.965	0.971	0.968
22	0.974	0.864	0.957	0.932
23	0.927	0.900	0.490	0.772
24	0.961	0.941	0.942	0.948
25	0.933	0.853	0.648	0.811
26	0.847	0.665	0.281	0.598
Lower Arch				
36	0.989	0.947	0.914	0.950
35	0.979	0.912	0.835	0.909
34	0.890	0.915	0.961	0.922
33	0.904	0.867	0.902	0.891
32	0.895	0.965	0.961	0.940
31	0.905	0.524	0.861	0.763
41	0.919	0.937	0.968	0.941
42	0.878	0.932	0.965	0.925
43	0.915	0.952	0.900	0.922
44	0.932	0.921	0.915	0.923
45	0.967	0.927	0.955	0.950
46	0.931	0.888	0.949	0.923

4. Discussion

The reproducibility of mesiodistal tooth measurements can be affected by numerous variables, including inclination, rotation, interproximal contacts, and anatomical differences. In this study, repeated measurements had acceptable correlations and mean errors were determined to be within clinically acceptable limits for all methods.

Even though the iTero intraoral scan is not optimized for plaster model scanning, results were comparable to iTero intraoral scan in vivo. Difficulty in capturing the morphology of a study model seem to be related to the presence of undercut areas. This problem can be solved by positioning the cast model from several different angles, rather than relocating the scanner while capturing scanned images of the occlusal, buccal, and lingual surface, allowing the production of a 360° model with greater accuracy [10].

In this study, the largest errors tended to be found in maxillary arch scans. This finding is in agreement with a previous study in which full arch scans showed a greater mean error in maxillary scans compared to mandibular scans [11]. The lower reproducibility that was observed in this study in the measurement of some posterior teeth has been previously attributed to errors in scanning [11]. Images acquired by several scanners showed distortion patterns, which can compromise the accuracy of linear measurements, with a tendency for greater deviation in the molar area [7]. The 3D and 2D error analyses also displayed a trend of greater distortion of digital scans compared to conventional measurements in the molar region [7].

5. Conclusions

(1) The overall reproducibility of mesiodistal tooth size measurements on digital models was comparable to direct measurements with a calliper on plaster models. (2) Similar reproducibility was found for measurements performed on digital models acquired by scanning plaster models and by intraoral scanning. (3) A trend towards lower reproducibility was found for measurements of posterior maxillary teeth in digital models.

Author Contributions: M.J. is the principal investigator, collecting study data, taking direct measurements, using the software, validating the measurements, collecting references, and writing the proceeding draft. P.M.P.: conceptualization, supervision, co-editing and co-writing up, and revising the final draft of the Proceeding. L.P.: undertaking the statistical analysis. I.B.: second supervisor, co-editing and co-writing up the proceeding. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are available upon request.

Conflicts of Interest: The authors declare no conflict of interest.

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