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Comparison of Bolton analysis and tooth size measurements obtained using conventional and three-dimensional orthodontic models

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ABSTRACT

Objectives: The aim of this study was to compare the accuracy, reproducibility, efficacy and effectiveness of measurements obtained using digital models with those obtained using plaster models. **Materials and Methods:** A total of 20 digital models were produced by the Ortho Three-dimensional Models (O3DM) Laboratory and their software (O3DM version 2) was used to obtain measurements. Identical plaster models were used to obtain measurements of teeth with a vernier caliper. The maximum mesiodistal width of each study model, from first molar to first molar, was measured. All measurements were repeated at least 1 month later by the same operator for both digital and manual methods. The data were analyzed using Cronbach α, Wilcoxon signed rank test and the McNemar test. **Results:** Cronbach α value of the data at T1 and T2 for 6 anterior and 12 overall teeth measured using the two methods was very close to the ideal value of 1, indicating high intra-observer reliability. The Wilcoxon signed rank test showed statistically significant differences between the two methods ($P = 0.000$, $P < 0.001$). The measurements obtained using the digital models were lower than those obtained using the plaster models. No statistically significant differences were found between the two methods for anterior Bolton discrepancies ($P = 0.375$) or overall Bolton discrepancies ($P = 0.00$). Paired comparisons of repeated measurements for Bolton ratios showed no statistically significant differences for anterior or overall Bolton discrepancies ($P = 0.688$ and $P = 0.375$, respectively). **Conclusions:** Use of O3DM software is an acceptable alternative to the traditional vernier caliper method in orthodontic practice.

Key words: Bolton ratio, digital model, tooth size, vernier caliper

INTRODUCTION

The relationship of the total mesiodistal width of the maxillary teeth to that of the mandibular teeth was calculated by Bolton in 1958.[1] This relationship is crucial in the creation of an occlusion without diastemas, rotations or crowding; with proper overjet and overbite; and a class one molar relationship in the finishing stage of orthodontic treatment. Therefore, it is crucial to accurately measure the mesiodistal width of the teeth to have an ideal occlusion at the end of treatment.

A Boley gauge (vernier caliper) or needlepoint dividers are often used to measure mesiodistal width to calculate the Bolton ratio on plaster models. In 1995, Shellhart *et al*. found the vernier caliper to be slightly more reliable than needlepoint dividers for Bolton analysis.[2] Many alternate methods for obtaining measurements using plaster models have been investigated over the years.[3-9] Champagne, in 1992, photocopied plaster models and used these images to measure mesiodistal width.[4] Champagne reported that this method does not produce accurate and reliable measurements compared with manual

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measurements performed using plaster models.[4] "Travelling microscope,"[5] holographic system[6] and stereophotogrammetry[10,11] are other methods that failed to replace the conventional plaster models.

In contemporary orthodontics, digital three-dimensional (3D) orthodontic models are becoming a vital alternative to traditional models for some diagnostic measurements, such as Bolton ratio, tooth size, arch width, overjet, overbite and arch length.[12-15] According to Profit, computer analysis requires less time.[16] Additional benefits are easier storage and retrieval, accurate basic diagnostic setups for extraction cases and E-mail consultation with the help of digital 3D study models. Today, many companies offer computer-based 3D models for basic orthodontic model analysis, including OrthoCad (Carlstadt, NJ, USA), OrthoProof (Albuquerque, New Mexico, USA), Ortho 3D Models (O3DM, ORTHOLAB, Sp. Zo.o., Poland) and Orthomodel (Orthomodel Inc., Gayrettepe, Istanbul, Turkiye). It is important that orthodontists be able to rely on a system before using it in clinical practice. Advantages of the company O3DM are replacement plaster models, preservation of existing clinic operating procedures, computer storage of all patient information, easy data searching and processing, a wide range of built-in diagnostic tools and data loss protection. However, to date, no study has compared the accuracy, reliability, efficacy and effectiveness of manual and computerized Bolton analysis with the aid of O3DM software.

The purpose of the present study was to compare the O3DM system, which uses digital models, with the manual method of measurement with vernier caliper and plaster models with regard to accuracy, reproducibility, efficacy and effectiveness of measurements.

MATERIALS AND METHODS

A total of 20 pretreatment models were selected from the archive of the Orthodontics Department of Cumhuriyet University's Faculty of Dentistry. All models had permanent dentition erupted from first molar to first molar. Teeth having normal crown morphology due to restoration, caries, attrition or fracture were not included. The plaster study models had no voids or blebs and no fractures on the teeth.

Alginate impressions of both arches of each patient were taken and plaster models were fabricated before being sent to the O3DM laboratory in Poland. Digital models were produced by the O3DM laboratory and their software (O3DM version 2) was used to take measurements on the digital models. The same plaster models that were used for hand measurements with vernier caliper were also used for Bolton analysis.

The maximum mesiodistal width of each tooth on each study model, from first molar to first molar, was measured by one operator holding caliper parallel to the occlusal plane of the tooth. A digital caliper with a vernier scale accurate to 0.01 mm was used. On the computerized models, tooth size was measured using O3DM measurement tools (version 2), accurate to 0.1 mm, by the same operator. The occlusal view of the posterior teeth and the facial view of the anterior teeth were used to record the maximum mesiodistal width of each tooth.

All digital and manual measurements were repeated at least 1 month to test the reliability of the operator's measurement. In this study, digital and plaster models were used to calculate Bolton discrepancies and the sum of the mesiodistal width of 6 and 12 teeth and these measurements were compared with each other.

Statistical analyses

Statistical analyses were performed with SPSS version 14.0 for Windows (SPSS Inc., Chicago, IL, USA). The accuracy and repeatability (intra-observer reliability) of measurements obtained using the digital and study models were evaluated with Cronbach α. Measurements obtained using plaster and digital models were compared by the Wilcoxon signed rank test. The accuracy and repeatability of Bolton ratios were evaluated with the McNamar test.

RESULTS

T1 and T2 (for intra-observer reliability) measurements of 6 anterior teeth (sum of mesiodistal measurements) obtained using plaster models and digital models were compared by Cronbach α. Table 1 summarizes the measurements at T1 and T2 for 6 anterior teeth with these two methods. For all measurements, Cronbach α was very close to the ideal value of one. T1 and T2 measurements of 12 teeth (sum of mesiodistal measurements) obtained using plaster and digital models were also compared by Cronbach α. The data at T1 and T2 for 12 teeth for both methods indicate high intra-observer reliability (close to the ideal value of one) [Table 1].

Measurements obtained using plaster and digital models were compared by the Wilcoxon signed rank test, which showed statistically significant differences between the two methods (P = 0.000, P < 0.001) [Table 2]. The measurements obtained using the digital models were lower than those obtained using plaster models [Table 3].

The differences between measurements obtained using plaster and digital models for anterior Bolton discrepancies and overall Bolton discrepancies were calculated. No statistically significant differences were found between the two methods for anterior Bolton discrepancies (P = 0.375) or overall Bolton discrepancies (P = 0.00).

Paired comparisons of repeated measurements to test intra-observer reliability for Bolton ratios obtained using plaster and digital models showed no statistically significant differences between the two methods for anterior Bolton discrepancies (P = 0.688) or overall Bolton discrepancies (P = 0.375), indicating high intra-observer reliability.

DISCUSSION

Technological developments have allowed clinicians to display plaster study models as 3D images. Today, many clinicians routinely use 3D models for diagnosis and treatment plans and for measurements such as Bolton ratio, tooth size, overjet, overbite, peer assessment rating index, etc., In our clinic, we use O3DM software for these diagnostic purposes and this software is becoming more important in obtaining accurate measurements for ensuring excellent treatment plans.

The results of this study support the validity and reliability of Bolton ratios calculated using digital models. There were no statistically significant differences in Bolton ratios calculated using digital and plaster models of the same patient. Similar to our findings, Stevens *et al*. found no significant difference when comparing the reliability of tooth size measurements obtained using plaster and digital models.[17] Although one-third of the differences in tooth size measurements were statistically significant, differences were 0.01-0.16 mm, which was within the clinically insignificant range. They also reported that no clinically significant differences were found for mean anterior or overall Bolton ratios. Mullen *et al*.[18] compared the Quick Ceph computer system with digital calipers for calculating Bolton ratios and found no significant difference between the two methods; the mean difference was 0.05 ± 1.87. In addition, after using 50 digital models to evaluate the accuracy, reproducibility, efficacy and effectiveness of measurements, Quimby *et al*.[13] reported that this technique produces accurate and reproducible results for the routine measurements obtained in most orthodontic practices.

In the present study, Cronbach α indicated high intra-observer reliability for the measurements obtained at T1 and T2, both on digital and plaster models. This indicates excellent reproducibility of measurements obtained using both digital and plaster models. Mullen *et al*. found a slightly greater difference in repeated measurements obtained using digital models compared with repeated measurements obtained using plaster models.[18] They presumed that this difference was due to use of a different version of software for the second measurements. Furthermore, they found a statistically significant difference between the measurements obtained using

Table 1: Intra-examiner reliability for the sum of 6 anterior teeth and 12 teeth derived from plaster and digital models. Values close to 1 indicate high intra-observer reliability

Groups	Cronbach's α	Lower bound	Upper bound
Plaster mand 6	979	943	992
Plaster mand 12	984	956	994
Plaster max 6	990	972	996
Plaster max 12	988	968	995
Digital mand 6	946	856	980
Digital mand 12	965	907	987
Digital max 6	949	864	981
Digital max 12	970	930	990

Mand: Mandiblar, Max: Maxillary

Table 2: Statistical analysis of mesiodistal tooth width measurements. Wilcoxon signed ranks test was used for the comparison of the two methods

Values	Digital mand 6*f*, plaster mand 6*f*	Digital mand 12*f*, plaster mand 12*f*	Digital max 6*f*, plaster max 6*f*	Digital max 12*f*, plaster max 12*f*
Z	−3.553	−3.724	−3.638	−3.726
P	0*	0*	0*	0*

*Significant at P < 0.001, *f*: Sum of mesiodistal width

Table 3: Mean, SD, minimum and maximum values derived from digital and plaster models

Groups	Mean[a]	Standard deviation[a]	Minimum[a]	Maximum[a]
Plaster mand 6*f*	36.4556	205.461	33.70	39.80
Digital mand 6*f*	348.444	218.369	30.60	37.40
Plaster mand 12*f*	868.833	362.593	80.20	91.30
Digital mand 12*f*	823.611	368.353	75.60	87.10
Plaster max 6*f*	468.389	248.363	43.40	50.90
Digital max 6*f*	450.111	276.913	40.60	49.40
Plaster max 12*f*	946.000	462.843	86.50	101.70
Digital max 12*f*	903.056	439.685	83.80	98.70

[A]Units are represented in millimeters. *f*: Sum of mesiodistal width; Mand: Mandiblar, Max: Maxillary, SD: Standard deviation

a mandibular plaster cast at T1 and T2 ($P < 0.05$); however, there were no significant differences in measurements of maxillary plaster casts. Similar to our results, Quimby *et al*.[13] reported a high degree of reproducibility for repeated measurements obtained using both plaster and digital models.

In the present study, there were statistically significant differences between measurements obtained using plaster and digital models for 6 anterior teeth and 12 overall teeth ($P = 0.000$, $P < 0.001$), but these differences were within a clinically acceptable small range for each tooth (~0.27-0.30 mm). The measurements obtained using digital models were lower than those obtained using plaster models. By using the same plaster models for measurements obtained manually and digitally, we avoided distortion and variation among alginate impressions. Therefore, differences between alginate impressions are not responsible for this finding. Most previous studies have reported that measurements obtained using digital models were lesser than those obtained using plaster models.[14,18] Although Quimby *et al*.[13] found that measurements obtained using digital models were greater than those obtained using plaster models, the differences were less than 1 mm. Santoro *et al*. found statistically significant differences between measurements obtained using digital and plaster models.[14]

The results of the present study represent statistically significant differences between measurements obtained for 6 anterior teeth and 12 overall teeth using plaster and digital models; however, these differences did not affect the Bolton ratios. There were no statistically significant differences between the two methods for anterior Bolton discrepancies or overall Bolton discrepancies. As long as the differences in measured tooth size are generalized and uniform, they do not cause any variation in proportional measurements.

CONCLUSION

The results of the present study indicate that Bolton analysis can be performed reliably using digital models for clinical use, without any restrictions.

Statistically significant differences were found between measurements obtained for width of 6 anterior teeth and 12 overall teeth using plaster and digital models; however, these differences were not within the clinically significant range (~0.27-0.30 mm) and had no negative effects on Bolton ratios.

The accuracy, reproducibility and effectiveness of O3DM are clinically acceptable, making it an alternative to the traditional vernier caliper in orthodontic practice.

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