The Comparison of Diagnostic Measurements Using Two Different Three-Dimensional Digital Orthodontic Model Software Systems

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Abstract: *Objective:* The purpose of this study was to evaluate and compare the reliability and accuracy of diagnostic measurements performed using two different three-dimensional (3D) digital orthodontic model software systems.

Materials and Methods: The dental casts of 20 patients with permanent dentition were selected and scanned with an orthodontic 3D scanner (3Shape R700, Copenhagen, Denmark). Two different digital model software programs, Orthomodel (v.1.01, Orthomodel Inc., Istanbul, Turkey) and O3DM (v.2.0, O3DM Thunoegade, Aarhus C, Denmark) were used for diagnostic measurements including tooth width, Bolton discrepancies, intermolar and intercanine distances. A total of 34 measurements were calculated on each digital model. All measurements were repeated by the same observer over 10 randomly selected dental casts at least two weeks later for intraobserver reliability. Results were analyzed statistically. The paired samples t-test was used to compare the differences between the measurements obtained with both softwares. The intraobserver reliability was determined using Cronbach's alpha test.

Results: Cronbach's alpha value indicated a very high level of reliability for all measurements. Orthomodel and O3DM software programs showed significant differences in the mesiodistal widths of some teeth and the sum of maxillary 6 teeth widths ($p<0.05$), but not in the Bolton ratios and transverse arch width measurements.

Conclusions: Both digital model softwares demonstrated clinically acceptable measurements despite of the differences in some measurements essential for diagnosis and treatment planning.

Keywords: Diagnostic analysis, digital orthodontic models, 3D digital model softwares.

1. INTRODUCTION

The golden key of successful orthodontic treatment planning is precise diagnostic information. The application of computer science to orthodontics has directed clinicians to create databases for patients using digital technology instead of the classic diagnostic methods including photographs, radiographs, or plaster models [1]. Diagnostic information has been transformed from a traditional two-dimensional approach to an advanced three-dimensional (3D) technique. In parallel with increasing tendency of paperless orthodontic office, the use of 3D cephalometric and digital photography, and especially digital study models gained popularity in clinical practice [2].

Traditional plaster study models have been regarded as indispensable to obtain dental measurements for years [2, 3]; however, these models require three stages (impression taking, plaster model pouring and trimming) for production. It is a lot of work for dental staff and clinicians with the requirement of additional storage areas, risks of fragility, degradation and loss. Virtual 3D models can easily store, share information for consultation, provide efficient retrieval and decreased measurement times for diagnosis [4, 5]. Commercially available digital study models can be produced in one of two ways: directly, with intraoral scanners or indirectly, with laser triangulation or computed tomography scanning of plaster models or impressions [6].

Different 3D digital software programs such as OrthoCad (Carlstadt, NJ, USA), OrthoProof (Albuquerque, NM, USA), Orthoanalyzer (3Shape, Copenhagen, Denmark), O3DM (O3DM, Aarhus, Denmark) [7], and Orthomodel (Orthomodel Inc., Istanbul, Turkey) have been developed for the archiving, communication, and analyzing of 3D digital models. In the literature, numerous researchers investigated the accuracy and reproducibility of orthodontic diagnostic measurements performed by different 3D digital model softwares and found clinically acceptable and reproducible results when compared with traditional model analysis [2, 3, 5, 8-17]. Although

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Table 1: Statistical Analysis of Maxillary Tooth Width Measurements Obtained with Different Digital Model Softwares

Measurements	Ortomodel	O3DM			95% CI	
	Mean ± SD	Mean ± SD	Mean diff	SD	Lower/Upper	P value
Max R central incisor	7.37 ± 0.16	7.89 ± 0.12	-0.52	0.12	-0.77/-0.27	0.00*
Max R lateral incisor	5.60 ± 0.18	5.86 ± 0.18	-0.26	0.11	-0.50/-0.03	0.03*
Max R canine	6.64 ± 0.12	6.93 ± 0.12	-0.29	0.12	-0.53/-0.04	0.02*
Max R first premolar	5.83 ± 0.13	5.93 ± 0.16	-0.10	0.16	-0.43/0.23	0.52
Max R second premolar	5.82 ± 0.12	6.12 ± 0.21	-0.30	0.23	-0.77/0.17	0.19
Max R first molar	9.31 ± 0.12	9.45 ± 0.18	-0.14	0.14	-0.44/0.15	0.32
Max L central incisor	7.47 ± 0.12	7.81 ± 0.13	-0.34	0.08	-0.51/-0.16	0.00*
Max L lateral incisor	5.54 ± 0.11	5.92 ± 0.13	-0.38	0.11	-0.61/-0.15	0.00*
Max L canine	6.65 ± 0.19	6.90 ± 0.09	-0.26	0.18	-0.64/0.13	0.18
Max L first premolar	6.04 ± 0.12	5.88 ± 0.15	0.16	0.17	-0.19/0.51	0.35
Max L second premolar	5.72 ± 0.09	6.11 ± 0.19	-0.39	0.22	-0.85/0.06	0.09
Max L first molar	9.31 ± 0.24	9.43 ± 0.13	-0.12	0.18	-0.50/0.25	0.50

SD: Standard deviation; diff: differences; CI: Confidental interval, Max: Maxillary.

* Indicates significance at p<0.05.

plaster study model has been used as gold standard in previous studies that compared the efficacy of different 3D digital dental model softwares, it is emphasized that minor differences and random errors will always be inevitable due to small variations in the positioning of a caliper during the traditional model analysis made on plaster study models [2]. Moreover, taking into the consideration the fact that the ever-increasingly importance of diagnostic information obtained with digital study models at the stage of determining a treatment planning or consulting with colleagues, we aimed to evaluate and compare the reliability of orthodontic diagnostic measurements performed on different 3D digital model softwares according to each other regardless of plaster study models.

For this purpose, the null hypothesis of this study is that there are no differences between the reliability and accuracy of the diagnostic measurements obtained with the different digital model software programs tested in this study.

2. MATERIALS AND METHODS

The plaster dental casts of 20 patients with permanent dentition were selected from the Department of Orthodontics at the Cumhuriyet University. The casts with tooth cracks or abrasions, restorations affecting the mesiodistal or buccolingual diameter of the crown, and congenital tooth agenesis were not included in this study. The selected casts were sent to O3DM laboratory (Ortolab Sp., Czestochowa, Poland) in which 3D digital models were created with a 3D laser scanner (3Shape R700, Copenhagen, Denmark). This scanner performed the operation by using a laser source, two cameras, and a table on which the model was affixed. The table translated, rotated, and tilted the model during the scanning. In the first step, the maxillary and mandibular models were scanned separately. After that, they were scanned together as they were in centric occlusion position (without wax bite). Firstly, O3DM software (v.2.0, O3DM Thunoegade, Aarhus C, Denmark) was used to perform diagnostic analysis. Secondly, each O3DM model was exported as a stereolithography (STL) file format and imported into Orthomodel software (v.1.01, Orthomodel Inc., Istanbul, Turkey) for diagnostic analysis. STL file format based on surface geometry of the 3D object and supported by 3D digital model software programs is widely used for rapid prototyping and computer-aided manufacturing [19]. A total of 34 measurements including tooth widths, Bolton analysis and transversal distances (intermolar and intercanine widths) were calculated for each digital model by one examiner (B.A) with two different softwares.

The rotating tool was used to find more adequate view for the location of corresponding landmarks on digital models. The tooth widths were measured by the help of the occlusal view for posterior teeth, and frontal view for anterior teeth with respect to the widest mesiodistal areas of each tooth. The transversal distances between the mesiopalatinal cusp tips of maxillary first molars and the central fossa of mandibular molars were measured to calculate the maxillary and mandibular intermolar widths, respectively. The intercanine widths were measured as the distances between the cusp tips of canines. Moreover, both softwares allowed the examiner to calculate Bolton analysis parameters including the sum of maxillary and mandibular anterior 6 teeth and 12 teeth from first molar to first molar, overall and anterior ratios automatically. All measurements were repeated by the same researcher over 10 randomly selected dental casts at least two weeks later for the assessment of the intraobserver reliability.

3. STATISTICAL ANALYSES

The results were statistically analyzed by SPSS (version 17.0, SPSS Inc, Chicago, IL, USA). The paired samples t-test was used to determine the differences. Cronbach's alpha test was applied for intraobserver reproducibility. The significance level was $p<0.05$.

4. RESULTS

For all measurements using the two digital model software programs, Cronbach's alpha value was very close to the ideal value of 1 indicated a high level of intraobserver reliability. According to our results, Orthomodel and O3DM showed significant differences in some measurements, especially in the maxillary and mandibular mesiodistal widths of some teeth as shown in Table **1** and **2**. Mesiodistal widths of maxillary right and left central incisors (-0.52 and -0.34), right and left lateral incisors (-0.26 and -0.38), right canine (-0.29) and mandibular right and left lateral incisors (-0.15 and -0.20), right central and canine (-0.20 and -0.44), and left first molar (-0.53) showed slight, but statistically significant differences ($p<0.05$). All of the widths of these teeth demonstrated lower values with Orthomodel digital model software program.

According to the results of Bolton analysis, no significant differences were found between the measurements of the sum of the overall 12 teeth

Table 2: Statistical Analysis of Mandibular Tooth Width Measurements Obtained with Different Digital Model Softwares

Measurements	Ortomodel	O3DM			95% CI	
	Mean ± SD	Mean ± SD	Mean diff	SD	Lower/Upper	P value
Mand L central incisor	4.64 ± 0.11	4.71 ± 0.08	-0.06	0.09	-0.25/0.12	0.48
Mand L lateral incisor	5.16 ± 0.09	5.36 ± 0.10	-0.20	0.09	-0.39/-0.02	0.03*
Mand L canine	5.75 ± 0.14	5.93 ± 0.13	-0.17	0.13	-0.45/0.11	0.22
Mand L first premolar	6.26 ± 0.10	6.23 ± 0.17	0.03	0.16	-0.31/0.36	0.88
Mand L second premolar	6.48 ± 0.16	6.45 ± 0.06	0.03	0.16	-0.29/0.36	0.83
Mand L first molar	9.32 ± 0.16	9.86 ± 0.12	-0.53	0.09	-0.71/-0.35	0.00*
Mand R central incisor	4.60 ± 0.08	4.80 ± 0.09	-0.20	0.03	-0.27/-0.12	0.00*
Mand R lateral incisor	5.36 ± 0.09	5.51 ± 0.10	-0.15	0.06	-0.28/-0.02	0.03*
Mand R canine	5.67 ± 0.12	6.11 ± 0.13	-0.44	0.11	-0.67/-0.21	0.00*
Mand R first premolar	6.49 ± 0.13	6.26 ± 0.15	0.23	0.16	-0.11/0.57	0.18
Mand R second premolar	6.39 ± 0.09	6.59 ± 0.19	-0.21	0.20	-0.62/0.21	0.31
Mand R first molar	9.70 ± 0.12	9.65 ± 0.12	0.05	0.12	0.12/-0.21	0.68

SD: Standard deviation; diff: differences; CI: Confidental interval, Mand: Mandibular.

* Indicates significance at $p<0.05$.

despite of the significant differences found in the mesiodistal widths of some teeth. However, there were statistically significant differences in the sum of the maxillary anterior 6 teeth (p=0.00, p<0.05). But this difference did not affect the results of Bolton ratios. The differences between both software systems for anterior and overall Bolton discrepancies were not statistically significant (Table **3**). Similarly, the measurements of the digital study models for intercanine and intermolar distances showed statistically no significant differences as shown in Table **4**.

5. DISCUSSION

With developments in computer technology, orthodontists are undergoing a gradual transition from using traditional to digital techniques in the fields of imaging, diagnosing, documenting, and communicating between clinicians and patients [1]. In recent years, 3D digital models obtained by scanning of plaster study models or intraoral scanning have become an alternative to conventional dental cast for diagnostic analysis and subsequent treatment planning. Nowadays, the accuracy of measurements with different 3D digital model softwares has gained an important role, since there is an advance toward digital study models in clinical practice. The study of Westerlund *et al*. [6] compared four digital software systems including OrthoCAD, Cadent, Carlstadt, NJ; O3DM, OrthoLab, Poznan, Poland; DigiModel, OrthoProof, Nieuwegein, Netherlands; OrthoAnalyzer, 3Shape, Copenhagen, Denmark regarding with their services, features, and usability. Although OrthoCAD and O3DM were considered to be easier for first-time users to learn, they reported that all systems were able to perform basic diagnostic measurements such as overbite, overjet, tooth size, arch length, space and Bolton analysis [6]. For this reason, O3DM and another software system Orthomodel that represented our geographic area were preferred between different commercially available software programs to perform digital model analysis in this study.

The reliability of diagnostic parameters measured by digital models in comparison with plaster models

Table 3: Statistical Analysis of Bolton Analysis Obtained with Different Digital Model Softwares

Measurements	Ortomodel	O3DM			95% CI	
	Mean ± SD	Mean ± SD	Mean diff	SD	Lower/Upper	P value
Max 12f	82.44 ± 1.28	83.45 ± 1.04	-1.00	1.09	-3.28/1.27	0.37
Max 6f	39.62 ± 0.56	41.32 ± 0.53	-1.69	0.34	-2.40/-0.98	0.00*
Mand 12f	76.50 ± 1.15	81.28 ± 4.10	-4.78	4.12	-3.41/3.85	0.26
Mand 6f	31.87 ± 0.88	32.42 ± 0.47	-0.55	0.68	-1.98/0.89	0.43
Bolton anterior ratio	80.53 ± 1.98	78.48 ± 0.73	2.05	1.84	-1.80/5.90	0.28
Bolton overall ratio	93.04 ± 1.46	92.00 ± 0.60	1.04	1.19	-1.46/3.53	0.40

SD: Standart deviation; diff: differences; CI: Confidental interval, Max: Maxillary, Mand: Mandibular; f: Sum of mesiodistal widths.
* Indicates significance at p<0.05.

Table 4: Statistical Analysis of Transversal Measurements Obtained with Different Digital Model Softwares

Measurements	Ortomodel	O3DM			95% CI	
	Mean ± SD	Mean ± SD	Mean diff	SD	Lower/Upper	P value
Max intercanine width	33.35 ± 0.95	34.92 ± 0.60	-1.57	0.75	-3.15/0.01	0.05
Max intermolar width	39.87 ± 0.82	39.75 ± 0.64	0.12	0.69	-1.32/1.56	0.86
Mand intercanine width	27.22 ± 0.41	27.05 ± 0.37	0.17	0.12	-0.09/0.42	0.18
Mand intermolar width	41.81 ± 0.59	41.48 ± 0.50	0.33	0.42	-0.55/1.21	0.44

SD: Standard deviation; diff: differences; CI: Confidental interval, Max: Maxillary, Mand: Mandibular.
* Indicates significance at p<0.05.

has been extensively discussed in previous studies. Many authors have found significant differences between the measurements of digital and conventional plaster models, but these differences were not considered clinically significant [9-12, 14-16]. On the other hand, little information is available about the comparability of diagnostic measurements obtained with different 3D digital orthodontic model analysis softwares on the same digital model [18].

According to our results, significant differences were found in some measurements, so the null hypothesis was partially rejected. Approximately half of the differences in tooth width measurements were statistically significant between both software systems, ranging from 0.03 mm to 0.53 mm. These differences could be explained with human errors during the identifying of landmarks. Generally the measurement accuracy up to 0.1 mm was accepted for clinical purposes [19]. Almost all of mean differences between both software programs were within the clinically acceptable range when the clinical threshold for a tooth-width discrepancy of 0.5 mm was applied [17]. For this reason, these differences could be neglected for clinical practice. On the other hand, the results of Bolton analysis showed insignificant differences despite of the small discrepancies in the tooth-width measurements. Both software systems showed similar anterior and overall Bolton ratios.

To our knowledge, the accuracy of diagnostic measurements on the same digital model using different digital model software systems have been compared for the first time in this study. For this reason, our findings could not be compared precisely with the results of any other studies that evaluated the accuracy of diagnostic measurements on digital models produced by direct or indirect approaches. Hayashi *et al*. [18] recently evaluated the reliability of the dental casts scanned with the same 3D scanner and analyzed transverse arch width measurements including the distances between canines, premolars, and molars by other software systems (SureSmile, Rapidform, and I-DEAS) on the same plaster model with and without standardization of target points. Contrary to our results, these investigators found significant differences between the arch width measurements obtained without standardization and reported that the mean values with standardization were significantly lower for all softwares. In this study, we evaluated and compared the measurements made on different software systems (O3DM and Orthomodel) without standardization. The transverse arch width results of our study demonstrated that both software programs could be used interchangeably during the assessment of arch dimensions. Today, numerous orthodontic scanners directly can export a file as STL format supporting the diagnostic analysis with different softwares. Although this output file allowed us to perform analysis on different software systems, high prices of digital model softwares limited the use of others for diagnostic analysis in this study. Moreover, the conversion of the output files with different extensions into STL file format would be time consuming, and that could be considered as a disadvantage. On the other hand, the comparability of digital diagnostic measurements should be precisely necessary for interdisciplinary information sharing and second opinions by the way of integration of output data with different softwares after the scanning process. Therefore, future studies will be required to evaluate the accuracy of diagnostic measurements for more precise results with more software programs supporting the same STL file format, and more dental models in each of these software programs must be evaluated.

CONCLUSIONS

Within the limitations of this study, the conclusions could be summarized as follows:

- No clinically significant differences were found between the mesiodistal widths of teeth measured by Orthomodel and O3DM digital model softwares.
- No significant differences were found in the anterior and overall Bolton ratios and transverse measurements calculated by both softwares.
- Both digital software systems provided adequate diagnostic information for clinical use.

DISCLOSURE STATEMENT

The authors report that they have no conflict of interest.

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