

Research Article

# A Comparative Study of Two Digital Model Analysis Based on Bolton Ratio

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## Abstract

**Objective:** The goal is to assess the intra - and inter - examiner reliability of Bolton analysis using two commonly used software packages, OrthoCad and NemoCast, based on digital model measurements.

**Method:** Fifty patients' pretreatment models of different malocclusions were selected and 3 - dimensional virtual orthodontic models created using iTero element 2 scanners. Three examiners measured tooth widths at their greatest mesio - distal dimension, determining anterior and total Bolton discrepancies utilizing the respective software. Statistical analyses were performed using SPSS IBM24.0, Intraclass Correlation Coefficient (ICC) and Concordance Correlation Coefficient (CCC) package programs to investigate accuracy, repeatability and reliability of OrthoCAD software compared to Nemocast software for conducting Bolton analysis.

**Results:** For both software the Inter - examiner and intra - examiner total as well as anterior Bolton ratios' correlation coefficient values were high and reproducible and no statistically significant differences were detected, which meant that the reproducibility/reliability was almost perfect. However, Nemocast and OrthoCad created total and/or anterior ratios were found to be statistically different.

**Conclusion:** Orthocad and Nemocast are well established software and both can generate reproducible results which can be used easily by trained clinicians. Further upgrading of these computerized software is needed to overcome problems encountered in identifying landmarks. Further improvement of these and other similar software is likely to make them more user friendly.

**Keywords:** OrthoCad; Nemocast; Reliability; Reproducibility; Bolton Analysis

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## Introduction

Since early days of orthodontic treatment, plaster models have been deemed indispensable for evaluating tooth dimensions, arch shapes and inter - arch relationships [1]. Naidu and Freer tested reliability of IOC scanner and its dedicated software OrthoCAD became one of the pioneers in offering virtual digital dental casts to orthodontic professionals, enabling them to view the image and manage it in a virtual 3D environment [2,3]. Thus, the digital era in orthodontics behooved teaching institutions and private practices alike to utilize screen images of dental arches. Costalos, et al., tested the OrthoCAD - supported ABO grading system for orthodontic models [4]. They concluded that, plaster and digital models exhibited similar scores, calibration of examiners is essential for unerring results and inter - examiner reliability was better with digital models. Furthermore, the progress of clear aligner software also contributed to the popularity of high - quality virtual models [5]. Hence the gold standard at this time is three - dimensional images or 'virtual orthodontic models' and over the years as 3D modelling technologies improved, model analysis became ever more revolutionary [6]. The superiority of images was outlined by Harrell, et al., as immediate availability of models, reducing costs as well as storage space requirements, efficiency in measuring dental variables, producing diagnostic

setups, transfer of records between colleagues and assessing malocclusions or grading models by various indices [7]. It would be not too unreasonable to add to this list the possibility of superimposing models utilizing 3D reverse engineering software.

There are numerous comparative tooth size measurement studies conducted on digital and plaster models [2,8 - 12]. They concluded that the accuracy is clinically acceptable and reproducible and there was no significant difference between the measurements made on digital models with those from plaster dental casts. Same conclusion was reached by Bootvong, et al., who reviewed a group of papers that studied the assessment of tooth dimensions obtained from plaster models and their corresponding virtual models [13]. Dalstra, et al., White, et al., Flügge, et al., recommended utilization of digital models [14 - 16].

Different groups of authors tested the accuracy of measuring anatomic dental points on plaster versus computer - based models and concluded that both methods were clinically acceptable [17 - 19]. Santoro, et al., reported clinically insignificant yet statistically significant tooth size and overbite measurements while comparing OrthoCAD models with plaster models. These authors tested the accuracy of determining tooth size, overbite and overjet pitting the conventional approach to digital.

Mullen, et al., compared the accuracy and time to perform the Bolton analysis with emodels and plaster models [9]. They stated that the difference between the Bolton ratio calculations as well as the arch length calculations were statistically insignificant. However, the average calculation time was significantly shorter in favor of emodels.

Bolton tooth - size analysis is a standard diagnostic tool in clinical orthodontics which has achieved universal acclaim [20 - 22]. The use of Intraoral and tabletop dental scanners in clinical practice is useful and has significant promise. The accessibility of digital scanners, printers and software technologies nowadays allows these systems to be more affordable as these devices became faster and more reliable. Tunca, et al., stated that traditional versus OrthoCad methods are interchangeable [23]. Researchers in this field showed that intraoral scanning was easily accepted by the patients and much more preferred than manual impression [24].

The objective of this study was to employ two frequently used software in evaluating the Bolton analysis intra - and inter - examiner reliability during the process of digital model measurements. Since a review of the literature did not identify any similar research work contrasting OrthoCAD and Nemocast software in this context, the authors felt it would be worthwhile to investigate this point.

## Materials and Methods

Pretreatment models of Angle's class I, II and III patients attending the Department of Orthodontics of Istanbul Medipol University were randomly selected. The age range of the selected sample was 14 - 24 years. The study was approved by the Istanbul Medipol University Ethics Committee (E - 10840098 - 772.02 - 6092, 27 September 2023). The inclusion criteria were 1 - Permanent dentition in both arches; 2 - No edentulous spaces; 3 - No dental abnormalities (i.e. peg - shaped lateral incisors etc); 4 - No heavy restorations that could affect the mesiodistal width of the tooth; 5 - No missing teeth; 6 - High - quality dental casts in order to have impeccable 3D virtual models; 7 - No previous or existing orthodontic treatment. The initial sample was 70 patients but after applying the above inclusion criteria, the sample size was reduced to 50 patients.

The plaster models were scanned using iTero element 2 (Align Technology, San Jose, CA, USA) in order to obtain 3 - D virtual orthodontic models, which were visually controlled for their precision and in case of inadequacies, scanning was repeated until high - quality virtual models were acquired. Then the 3 - D models were exported from OrthoCad (Cadent, Carlstadt, NJ, USA) to NemoCast software (Nemotec, Madrid, Spain). Three examiners working independently recorded the teeth width (Fig. 1,2). Mesiodistal widths were measured from the greatest mesiodistal diameter from the anatomic mesial contact point to the anatomic distal contact point of each tooth parallel to the occlusal plane [25].

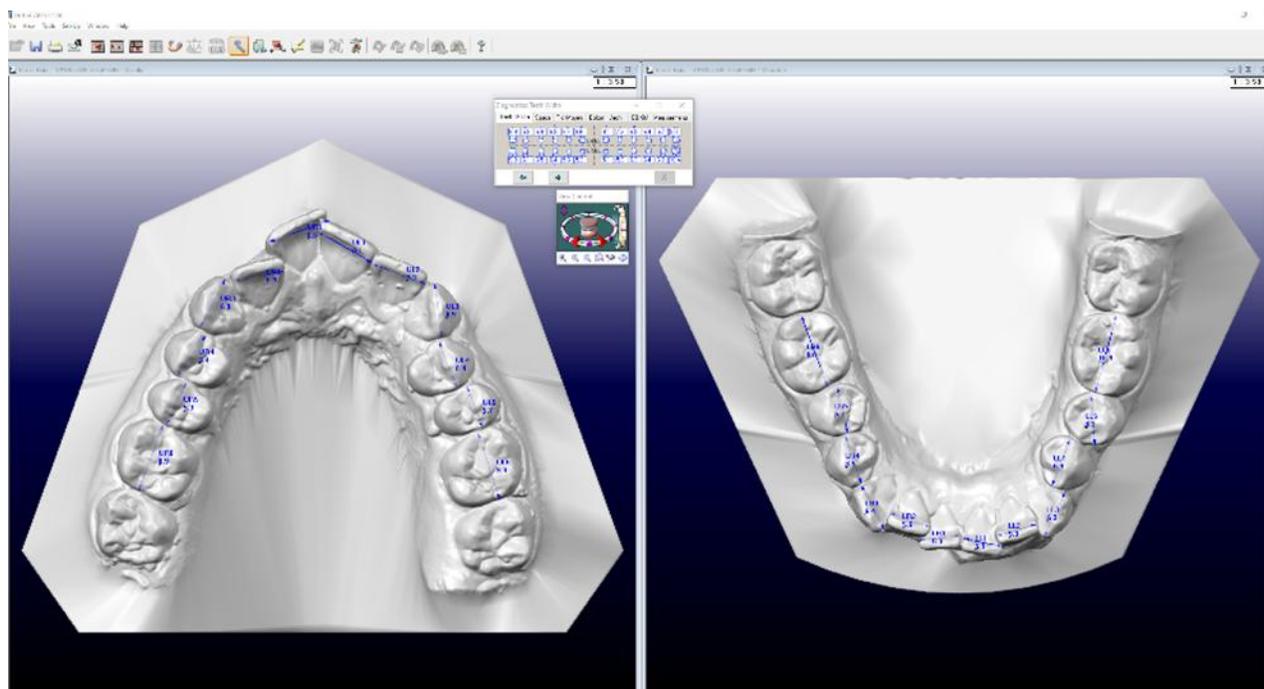
Each examiner started measuring the maximum mesiodistal width of each tooth using the diagnostic tool of OrthoCad (version 2.7.9.601) and calculated the Bolton analysis. Then Nemocast (2020 fall edition) was used to do the measurements and calculate the Bolton analysis. As mentioned above, the measurements were made from the occlusal view in both software to provide better visibility (Fig. 1,2). The diagnostic tool of OrthoCad software (version 2.7.9.601) and the manual calculation mode of Nemocast (2020 fall edition) were used. During this joint effort, Bolton analysis was performed both by measuring the discrepancy between

the anterior 6 maxillary and mandibular teeth and the discrepancy for the 12 teeth from first molar to first molar in both arches complying with the standard practice.

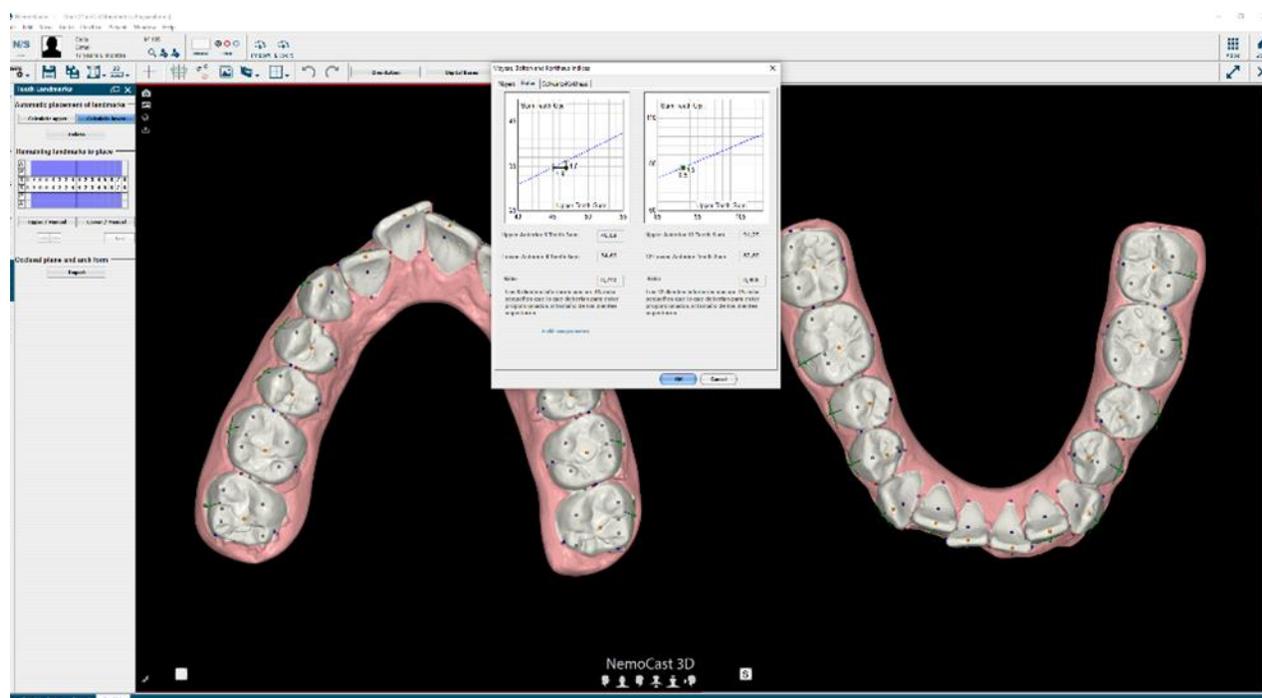
The three examiners recorded the measurements utilizing both software within 3 months. After a month interval, the three examiners reassessed the measurements for the whole sample (50 models) using both software to monitor the inter - and intra - examiner reliability. The examiners were not blinded to the patient's personal data such as name and age but were blinded to the patient's initial diagnosis and treatment plan.

#### *Statistical Analysis*

Statistical analyses of the data were performed using MedCalc and SPSS IBM24.0 package program, to investigate the accuracy and repeatability of the methods. Descriptive statistics such as Median, means and standard deviations of the total and anterior Bolton for OrthoCad and Nemocast software were calculated for each examiner separately and were used to test for any significant variations between the two software. An Intraclass Correlation Coefficient (ICC) and Concordance Correlation Coefficient (CCC) was calculated for each examiner to assess the reliability of OrthoCAD software compared with Nemocast software. Interexaminer error was evaluated and the mean values of the measurements by each examiner were compared. Normality test of continuous measurements were performed using Kolmogorov Smirnov and skewness and kurtosis.



**Figure 1:** An example of using the diagnostic tool in OrthoCad to measure the width of teeth.



**Figure 2:** An example of using the manual calculation in NemoCast to measure the Bolton ratio.

## Results

The chosen population exhibited normal distribution. The descriptive statistics of this study showed that median and mean values were very near, hence the randomly collected data was deemed to be normal (Table 1). Table 2 shows the Inter - examiner (reproducibility/reliability) which is almost perfect in total Bolton and anterior Bolton for both software. The OrthoCad and NemoCast generated intra - examiner total, as well as anterior ratios' correlation coefficient values, were high and reproducible and no statistically significant differences were detected (Table 3).

When OrthoCad and Nemoceph were compared, clinically significant differences were detected between total and anterior ratios calculated with these respective software. In other words, NemoCast and OrthoCad created total and/or anterior ratios were found to be statistically different (Table 4,5).

		Min - Max	Median	Mean
<b>Examiner 1</b>	OrthoCad - T - 1	0,877 - 0,972	0.915	0,917 ± 0,021
	OrthoCad - T - 2	0,876 - 0,972	0.915	0,917 ± 0,021
	NemoCast - T - 1	0,869 - 0,973	0.919	0,923 ± 0,026
	NemoCast - T - 2	0,8030,982	0.921	0,921 ± 0,031
	OrthoCad - A - 1	0,733 - 0,826	0.775	0,777 ± 0,024
	OrthoCad - A - 2	0,733 - 0,831	0.776	0,777 ± 0,025
	NemoCast - A - 1	0,73 - 0,958	0.782	0,789 ± 0,039
	NemoCast - A - 2	0,732 - 0,968	0.783	0,79 ± 0,04
<b>Examiner 2</b>	OrthoCad - T - 1	0,876 - 0,971	0.914	0,917 ± 0,21
	OrthoCad - T - 2	0,874 - 0,971	0.914	0,917 ± 0,021
	NemoCast - T - 1	0,869 - 0,936	0.92	1,092 ± 1,193
	NemoCast - T - 2	0,866 - 0,972	0.919	0,923 ± 0,026
	OrthoCad - A - 1	0,733 - 0,83	0.775	0,778 ± 0,025
	OrthoCad - A - 2	0,734 - 0,835	0.775	0,777 ± 0,025
	NemoCast - A - 1	0,73 - 0,949	0.783	0,791 ± 0,038
	NemoCast - A - 2	0,732 - 0,961	0.783	0,791 ± 0,04

<b>Examiner 3</b>	OrthoCad - T - 1	0,878 - 0,971	0.915	0,917 ± 0,021
	OrthoCad - T - 2	0,874 - 0,972	0.914	0,917 ± 0,022
	Nemocast - T - 1	0,867 - 0,973	0.919	0,923 ± 0,025
	Nemocast - T - 2	0,868 - 0,978	0.92	0,924 ± 0,025
	OrthoCad - A - 1	0,737 - 0,85	0.776	0,777 ± 0,026
	OrthoCad - A - 2	0,734 - 0,828	0.776	0,777 ± 0,024
	Nemocast - A - 1	0,733 - 0,956	0.786	0,792 ± 0,04
	Nemocast - A - 2	0,735 - 0,963	0.788	0,794 ± 0,041

**Table 1:** This table represents the descriptive statistics. Mean values of Bolton ratios and anterior ratios obtained by digital model analyses. T (total Bolton ratio), A (anterior Bolton ratio), 1 and 2 denote first and second round of measurements.

	<b>Examiner 1 - Examiner 2 - Examiner 3</b>		<b>Interpretation</b>
	<b>ICC</b>	<b>95% Confidence Interval</b>	
OrthoCad A - 1	0.9931	0,9890 to 0,9959	Almost Perfect
OrthoCad A - 2	0.997	0,9953 to 0,9982	Almost Perfect
Nemocast A - 1	0.9713	0,9541 to 0,9827	Almost Perfect
Nemocast A - 2	0.9726	0,9562 to 0,9836	Almost Perfect
OrthoCad T - 1	0.9956	0,9929 to 0,9973	Almost Perfect
OrthoCad T - 2	0.9959	0,9934 to 0,9975	Almost Perfect
Nemocast T - 1	0.9969	0,9937 to 0,9976	Almost Perfect
Nemocast T - 2	0,9698	0,9517 to 0,9819	Almost Perfect

**Table 2:** Represents the intra - class correlation coefficient, which gives the inter - examiners reproducibility/reliability. T (total Bolton ratio), A (anterior Bolton ratio), 1 and 2 denote first and second round of measurements. ICC (intra - class correlation coefficient).

n:50		<b>Examiner 1</b>	
		<b>ICC</b>	<b>95% Confidence Interval</b>
<b>OrthoCad</b>	A (1. - 2.)	0,9937	0,9890 to 0,9964
	T (1. - 2.)	0.9948	0,9908 to 0,9970
<b>NEMOCAST</b>	A (1. - 2.)	0.9963	0,9935 to 0,9979
	T (1. - 2.)	0.9768	0,9595 to 0,9868
n:50		<b>Examiner 2</b>	
		<b>ICC</b>	<b>95% Confidence Interval</b>
<b>OrthoCad</b>	A (1. - 2.)	0,991	0,9842 to 0,9949
	T (1. - 2.)	0.9917	0,9854 to 0,9953
<b>NEMOCAST</b>	A (1. - 2.)	0.9966	0,9940 to 0,9981
	T (1. - 2.)	0.9851	0,979 to 0,9915
n:50		<b>Examiner 3</b>	
		<b>ICC</b>	<b>95% Confidence Interval</b>
<b>OrthoCad</b>	A (1. - 2.)	0,9768	0,9595 to 0,9868
	T (1. - 2.)	0.9924	0,9867 to 0,9957
<b>NEMOCAST</b>	A (1. - 2.)	0.9986	0,9976 to 0,9992
	T (1. - 2.)	0.9961	0,9931 to 0,9978

**Table 3:** Represents the intra - examiners reproducibility/reliability. T (total Bolton ratio), A (anterior Bolton ratio), 1 and 2 denote first and second round of measurements. ICC (intra - class correlation coefficient). N (sample number).

N:50	Examiner 1			Examiner 2		Examiner 3	
		CCC	95% Confidence Interval	CCC	95% Confidence Interval	CCC	95% Confidence Interval
	<b>A1</b>	0.9937	0,9890 to 0,9964	0.613	0,4526 to 0,7350	0.5045	0,3178 to 0,6536
	<b>A2</b>	0.5967	0,4361 to 0,7205	0.5859	0,4229 to 0,7121	0.4525	0,2664 to 0,6060
<b>OrthoCad -</b>	<b>T1</b>	0.6938	0,5313 to 0,8071	0.6914	0,5260 to 0,8064	0.7061	0,5474 to 0,8158
<b>Nemocast</b>	<b>T2</b>	0.6744	0,5180 to 0,7871	0.6957	0,5338 to 0,8084	0.7035	0,5443 to 0,8138

**Table 4:** Concordance correlation coefficient between OrthoCad - NEMOCAST for total and anterior Bolton ratio. T (total Bolton ratio), A (anterior Bolton ratio), 1 and 2 denote first and second round of measurements. ICC (intra - class correlation coefficient). N (sample number). CCC (Concordance Correlation Coefficient).

n:50	Examiner 1			Examiner 2			Examiner 3			p
	Min - Max	Median	Mean $\pm$ SD	Min - Max	Median	Mean $\pm$ SD	Min - Max	Median	Mean $\pm$ SD	
<b>OrhoCad - T</b>	- 0,00041 - 0,00044	- 0.0002	- 0,0003 $\pm$ 0,002	- 0,0062 - 0,004	- 0.0003	- 0,0002 $\pm$ 0,0027	- 0,006 - 0,0048	- 0.0004	- 0,0003 $\pm$ 0,0026	0.95
<b>OrhoCad - A</b>	- 0,01 - 0,004	- 0.0006	- 0,0003 $\pm$ 0,003	- 0,0057 - 0,0113	- 0.0006	0,0001 $\pm$ 0,0033	- 0,0237 - 0,23	- 0.0005	0,0002 $\pm$ 0,0054	0.87
<b>Nemocast - T</b>	- 0,01 - 0,09	- 0.001	0,0014 $\pm$ 0,013	- 0,016 - 8,432	0.001	0,1687 $\pm$ 1,193	- 0,005 - 0,005	- 0.002	- 0,0016 $\pm$ 0,0022	0.001
<b>Nemocast - A</b>	- 0,01 - 0,01	- 0.001	- 0,0007 $\pm$ 0,0034	- 0,012 - 0,006	- 0.001	- 0,0006 $\pm$ 0,0032	- 0,007 - 0,004	- 0.002	- 0,0019 $\pm$ 0,0021	0.002
<b>T (I - N)</b>	- 0,09 - 0,01	0	- 0,0016 $\pm$ 0,013	- 8,4288 0,0019	- 0.0012	- 0,1689 $\pm$ 1,192	- 0,006 - 0,009	0.0014	0,0013 $\pm$ 0,0032	0.013
<b>A (I - N)</b>	- 0,01 - 0,01	0.0007	0,0004 $\pm$ 0,0044	- 0,0046 - 0,0018	0.0003	0,0007 $\pm$ 0,0043	- 0,0247 - 0,0299	0.0017	0,0021 $\pm$ 0,0062	0.029

**Table 5:** Comparison for the 3 examiners for Total and Anterior Bolton between Nemocast and OrhoCad, difference I - N in T and A, have statistically significant difference. ( $p < 0,05$ ). SD (Standard deviation), T (total Bolton ratio), A (anterior Bolton ratio).

## Discussion

A tooth-size study typically requires a Boley gauge, Vernier caliper or a needle - point divider. Indeed many clinicians still use these traditional devices to measure variations in tooth size. However, they are not in the majority as was shown by Shreidan who said only 47% of orthodontists he surveyed regularly use Bolton analysis [14]. The surge of computerized orthodontic diagnosis is likely to render this customary approach obsolete and already digital methods are in vogue. Hence the goal of our study was to compare the measurement accuracy of the Bolton tooth - size difference between the OrthoCad and Nemocast software. Digital Bolton analysis has been available in orthodontics for many years. OrthoCAD accuracy for Bolton analysis was shown by Naidu and Freer over a decade ago. Nemocast (Nemostudios, Madrid, Spain) has a good reputation and underwent an improvement process over the years [2]. Hence the effectiveness of both software is well established. Our literature review did not reveal previous research comparing the two software utilized in this study. Apart from contrasting the two methods, intra - and inter - examiner reliability within each was evaluated during the process of digital model measurements.

The use of digital models in clinical practice has significant promise if the models are dependable and simple to operate [24]. Like many other researchers who naturally share this opinion, we chose to work on accurately prepared virtual models. Besides fracture, loss and difficulties in storage disadvantages linked to plaster models, their three - dimensional operation in the semi - adjustable articulators is practically defunct due to virtual digital articulators and three - dimensional orthognathic surgery planning software. Dalstra, et al., White, et al., and Flügge, et al., are among the workers who favored virtual digital models [14-  
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<https://athenaumpub.com/journal-of-dental-health-and-oral-research/>

16]. At this time, digital orthodontic model technologies are almost perfected and problems of laboratory time, archiving and cost inherent in stone models are eliminated. Furthermore, the transferability of digital models to any location is unrivaled. It is well known that if pouring of stone is delayed with alginate impressions, plaster models may lack accuracy. Hence there might be marginal dimensional errors in measuring. This is another shortcoming no matter how remote.

These computer programs give numerous different analyses in addition to the Bolton analysis. OrthoCad and Nemocast have too many diagnostic tools to list individually. In this article, only Bolton analysis was investigated.

Selecting exactly the same mesial or distal points of tooth crowns on plaster model images generated by the Nemocast versus Orthocad software is practically impossible, which may explain the variations in total and anterior Bolton ratios between the two software. This issue may have been considerably influenced by the inability to enlarge digital models. According to Houston, the difficulty in identifying landmarks is one of the greatest sources of random error [26]. This is of particular importance for digital models, because a 3-dimensional structure appears as a 2-dimensional image, making it more difficult to detect landmarks [17,19]. Furthermore, it may be difficult for examiners to locate the exact mesial and distal locations on tooth crowns, making it difficult to quantify consistently and accurately. Using the OrthoCad software for the Bolton tooth-size study, Tomasetti, et al., reached the same finding [20,21].

In our study, when OrthoCad and Nemoceph were compared, clinically significant differences were detected between total and anterior ratios calculated with these respective software [22-30]. In other words, Nemocast and OrthoCad created total and/or anterior ratios were found to be statistically different. These deviations could be attributable to a number of factors: 1 - OrthoCad and Nemocast may have different fabrication process distortions; operators were less familiar with the Nemocast software than they were with OrthoCad. 2-In comparison to OrthoCad, the Nemocast software is more complex and requires an excessive number of steps and additional time to calculate the Bolton analysis. 3-Potential operator differences, it was difficult to pinpoint the exact mesial and distal points to be used for the width measurement when clicking the mouse on tooth locations for width. OrthoCad utilizes a "click and drag" method to mark the mesial and distal points, making it difficult to measure tooth widths consistently and precisely. 4 - differences in model details between OrthoCad and Nemocast software around tooth borders or contact points to determine an accurate point of measurement.

The intra - examiner and inter - examiner coherence of total and anterior Bolton ratios were almost perfect for both software which means that both software are beneficial. These offer time - efficient and reproducible methods of teeth measurements. Clinicians can orientate themselves rapidly to these software. Thus these are invaluable tools in a teaching clinic. These can substitute for the original ways of tooth size measurement, but further upgrades in the computerized methods are advised to overcome the drawbacks discussed above. Finally, it is the decision of the clinician to decide if these software alternative methods are acceptable and cost - effective.

### **Conclusion**

Orthocad and Nemocast are new and promising software that will be enormously popular in the near future, both of them can generate reproducible results and can be used easily by trained clinicians. Some of the drawbacks especially those related to the difficulty in identifying landmarks need to be solved and these computerized software should be upgraded to make them more precise and user friendly. Further research using layer samples could be helpful in order to evaluate various software in calculating the Bolton ratios which are indispensable for detailing and finishing stage of fixed appliance treatment.

### **Conflict of Interest**

There are no conflicts of interest that may have influenced the research, authorship or publication of the article.

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### **Ethical Statement**

This project was exempt from IRB review as it did not qualify as human subject research under federal regulations.

## Author Contributions

Jumana Al - Abbadi, Başak Baş, Rojda Akçar, contributed to the conception, design, data acquisition, analysis and interpretation, drafted and critically revised the manuscript and gave the final approval; Anwar Rahamneh, M.Alp Tavas, contributed to the conception, design and data interpretation, critically revised the manuscript and gave the final approval. All authors gave final approval and agreed to be accountable for all aspects of the work.

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