Diagnostic Value of Manual and Computerized Methods of Dental Casts Analysis

A. Tehranchi [1, 2]✉, M. Nouri [2], R. Massudi [3], M. Katchooi [4], H. Rahimi [5]

[1] Associate Professor, Department of Orthodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[2] Associate Professor, Iran Center of Dental Research,
[3] Assistant Professor, Department of Orthodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[4] Assistant Professor, Laser Research Institute, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[5] Dentist, Private Practice
[6] Post Graduate Student, Department of Orthodontics, School of Dentistry, Islamic Azad University, Tehran, Iran

Abstract:

Objective: The aim of this study was to evaluate the validity of computerized and manual methods of dental cast analysis.

Materials and Methods: Twenty set-ups of upper and lower casts using artificial teeth corresponding to various malocclusions were created for a diagnostic in vitro study. Values of tooth size were calculated from the isolated artificial teeth out of the set-ups, results were considered as a gold standard for the tooth size. Arch width was calculated from the existing set-ups on the dentins.

Impressions were taken of the casts with alginate and duplicated with dental stone. Models were measured with digital caliper manually. Then images were taken from the occlusal views of the casts by a digital camera. Measurements were done on digital images with the AutoCAD software.

The results of the computerized and manual methods were compared with the gold standard. Intra class correlation coefficient of reliability was used to measure the accuracy of the methods and the Friedman technique used to evaluate the significance of differences.

Results: Results indicated that all measurements were highly correlated, e.g. gold standard and manual (0.9613-0.9991), gold standard and computerized (0.7118-0.9883), manual and computerized (0.6734-0.9914). Statistically significant differences were present between these methods (P<0.05), but they proved not to be clinically significant.

Conclusion: Manual measurement is still the most accurate method when compared to the computerized measurements and the results of measurement by computer should be interpreted with caution.

Key Words: Dental Models; analysis; Dentition

✉ Corresponding author:
A. Tehranchi, Department of Orthodontics, Dental School, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
azitatehranchi@yahoo.com

INTRODUCTION

Successful orthodontic treatment is based on comprehensive diagnosis and treatment planning [1]. Establishing a diagnosis for an orthodontic patient requires the synthesis of a variety of information from clinical exam, radio-graphs, and study cast analysis [2]. Dental casts can be assessed in two or three dimensions using direct or indirect techniques. Indirect techniques involve the conversion of the study cast to be measured into an intermediate form [3]. Research about study cast production

and storage forms a considerable part of both historic and contemporary clinical orthodontics [3]. It is considered that in alternative methods of cast analysis, a series of measurements and valuable data for different population groups could be provided and compared with each other [4,5]. Nowadays, many orthodontists tend to digitize orthodontic records and use the computer to assist diagnosis and treatment planning. Proffit [6] stated that one advantage of digitizing tooth dimensions for space analysis is that the computer can quickly provide a tooth size analysis.

Computer technology is expanding to include more areas in various scientific fields as well as orthodontics [7].

Advances in computer vision have started to infiltrate the specialty of orthodontics. During the past few years, a number of new products have appeared to be capable of extracting the structure of an object by digital imaging [8].

As Mullen et al [9] suggest, when performing a Bolton analysis the e-model can be as precise as traditional method of plaster models and digital calipers and is significantly faster. A clinician who has switched to using e-model software can be confident in his\her. Using traditional orthodontic imaging techniques may leave some areas of anatomy poorly visualized. Valuable information about various areas of the dentition may be obtained via CT scans and 3-dimentional (3D) set-ups [10].

Tomassetti et al [6] have compared three computerized Bolton tooth size analysis with manual Vernier caliper. The overall mean changes of three computerized methods compared to Vernier caliper of the same measurement, were: Quickceph (1.07 mm) Orthocad (1.02 mm), Hats (0.55 mm) [6] larger. Lowey [3] found this difference to be 1.0 mm larger. Zilberman et al [11] has evaluated these differences for each tooth and found Orthocad to

Table 1. Statistical Analysis of all measurements (tooth size, distance and sum) in the three methods (mm).

Groups	Method	Mean (mm)	Median (mm)	25th percentile	75th percentile	P value[*]
Incisors	Method A	6.06	5.39	5.06	7.35	
	Method B	6.05	5.78	5.03	7.32	0.015
	Method C	6.01	5.80	4.93	7.19	
Canines	Method A	6.90	6.80	6.36	7.40	
	Method B	6.80	6.70	6.35	7.30	0.002
	Method C	6.80	6.80	6.29	7.20	
Premolars	Method A	6.47	6.36	6.16	6.85	
	Method B	6.43	3.38	6.17	6.76	0.001
	Method C	6.14	6.03	5.92	6.5	
Molars	Method A	9.61	9.52	8.91	10.26	
	Method B	9.55	9.48	9.98	10.11	0.001
	Method C	9.15	9.05	8.61	9.75	
Intercanine	Method A	28.42	25.98	24.19	33.57	
	Method B	28.23	25.71	24.25	33.21	0.583
	Method C	28.48	26.28	24.52	34.09	
Intermolar	Method A	37.40	36.82	35.67	40.52	
	Method B	38.03	36.74	35.84	40.85	0.001
	Method C	38.62	37.13	36.2	41.47	
Total 1	Method A	84.02	83.96	80.74	87.68	
	Method B	83.96	84.04	80.39	87.36	0.001
	Method C	81.69	81.89	77.34	85.78	
Total 2	Method A	64.05	64.07	59.30	68.86	
	Method B	63.71	63.62	59.00	68.15	0.001
	Method C	62.25	62.64	56.98	67.29	

Total 1=first molar to first molar, Total 2=second molar to second molar, [*]=using Friedman test

be related to gold standard by a range of 0.784 to 0.976. This demonstrates that more research should be done in this field in order to have more accurate results, also some equipments are too complex to be available in orthodontists' offices, and it might be better to use less sophisticated but more available ways of imaging.

Therefore, the aim of the present study was to evaluate the accuracy of the manual measuring method using calipers as well as the computerized method using AutoCAD software on digital images and to compare these two methods.

MATERIALS AND METHODS

A diagnostic in vitro study was designed to evaluate the validity of the conventional and computerized imaging methods using the gold standard. Ten pairs of artificial teeth set-ups, which simulated various types of malocclusions, were developed, including: rotations, abnormal inclinations, spacing, and different depths of curve of Spee, overjet and overbite [9].

Before creating the set-ups, the mesiodistal size of each artificial tooth was measured by a digital caliper (Mitutoyo CD-15, Tokyo, Japan) as the gold standard of tooth size. Intercanine and intermolar distances were measured directly on set-ups (Method A).

All set-ups were duplicated using Alginate (Orthoprint, Zhermach, Italy, Iso 1563, ADA) resulting in dental stone models (Rapidure, Dentaurum, Germany). Models were trimmed as an orthodontic standard model.

Mesiodistal dimensions, intercanine and intermolar distances were measured on the stone models using the same digital caliper manually

(Method B) [12-14].

In computerized digital imaging method, digital images from occlusal surfaces of each mandibular and maxillary cast were taken by a digital camera (Sony Cybershot DSGF717 5MP, Japan), which was adjusted to the level of 20 cm from the base. In order to assess the magnification of the system, a calibrated scale was placed at the level of the occlusal surfaces of the casts. Computerized measurements including mesiodistal size of each tooth, intercanine and intermolar distances were calculated on the digital images by AutoCad software (Ver. 2004) (Method C).

The database was divided into eight groups and investigated:

1-centrals, 2-canines, 3-premolars, 4-molars, 5-total 1 (sum of tooth size from second premolar to second premolar) 6-total 2 (sum of tooth size from 1st molar to 1st molar) 7-intercanine distance, 8-intermolar distance.

The random and systematic errors between manual and computerized methods were calculated by using the formula described by Dahlberg [15] $(S = \sqrt{(\sum d^2)/2n})$ which were from 0.33 to 0.014 mm. Descriptive statistical elements such as mean, average, standard deviation, and correlation coefficient were assessed for each of the eight groups using the three methods.

Accuracy of these methods was evaluated by means of intraclass correlation coefficient of reliability and significances of differences were analyzed using the Friedman technique.

The Dahlberg formula was used to calculate the differences between the manual and computerized methods as well as the reliability of each method.

Table 2. Correlation coefficient of relation of three methods in different groups of study.

Methods	Incisors	Canines	Premolars	Molars	Intercanine distance	Intermolar distance	Total 1	Total 2
Method A to Method B	0.9935	0.9752	0.9613	0.9878	0.9991	0.9921	0.9841	0.9972
Method A to Method C	0.9871	0.9204	0.7118	0.9157	0.9581	0.9883	0.9705	0.9884
Method B to Method C	0.9914	0.9378	0.6734	0.9103	0.9588	0.9911	0.9706	0.9881

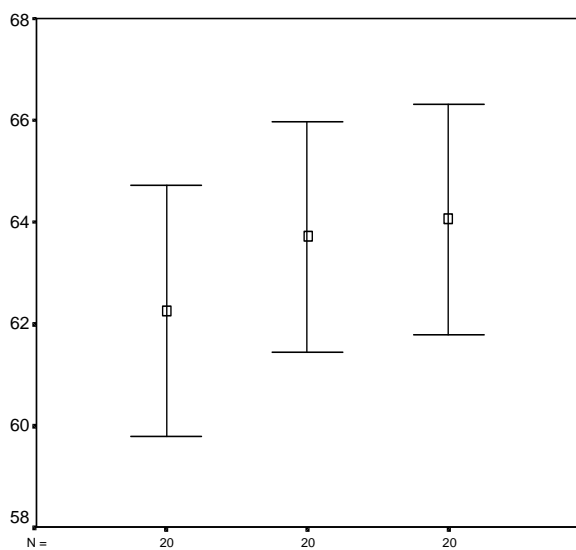Total 1=first molar to first molar, Total 2=second molar to second molar

Fig 1. Coefficient of reliability of the eight groups using the paired methods.

Fig 2. Confidence intervals of: manual (M), gold standard (G), and computerized (C) methods.

RESULTS

There was statistically significant difference (P<0.05) between most of the measurements made by these three methods, but comparing the differences derived from the Dahlberg formula and mean differences it seems that they would not be statistically significant through Dahlberg formula. Systematic error values between computerized and manual method in incisors, canines, premolars, molars, intercanine and intermolar distances were 0.1147, 0.1377, 0.2965, 0.3544, 0.9766, and 0.5126, respectively (Table 1).

In addition, most of the measurements made by the three methods were highly correlated: manual method to gold standard (0.9613-0.9991), computerized method to gold standard (0.7118-0.9883), manual method to computerized method (0.6734-0.9914) (Table 2).

The highest differences among three methods were in the premolar region, which is demonstrated in Fig 1. Mean difference of second premolar to second premolar overall estimation was approximately 2.0 mm between gold standard and computerized method (Fig 2).
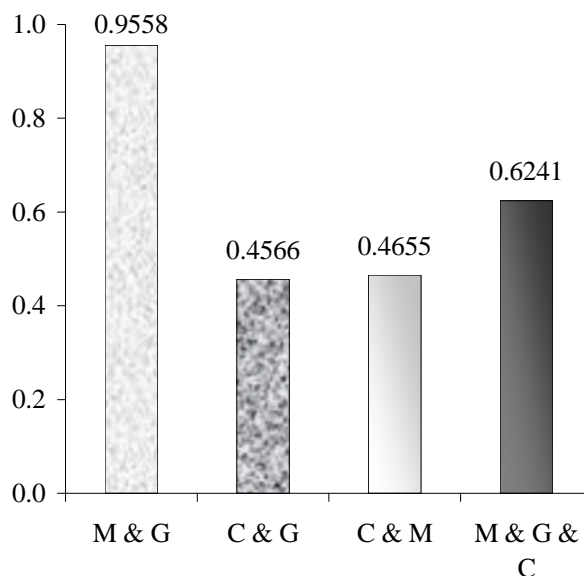
DISCUSSION

In the present study, the actual size of the measurements of artificial teeth was used as the gold standard, similar to Zilberman et al [11] in evaluating the validity of OrthoCad system. Some details that were considered in the present study to increase the validity were:

1. All the impressions and stone models were prepared in standard and similar conditions.
2. The accuracy of each method was evaluated in nearest to 0.01 mm.
3. All digital images were taken in standard daylight to have similar shadows and lights in all images.
4. Variation in space discrepancies, inclination, rotation and anatomical variation of the teeth in the set-ups.

Direct measurements made of casts with digital caliper were found to be the most accurate and reproducible, however, the computerized method is easy to handle and a range of valuable data could be restored if needed.

The major factors causing differences are:
1. Assessment of Contact Points: Assessment of the actual proximal contact point varies

from time to time, this even exists in 3D cast analysis systems such as OrthoCad [6,7,9,16].

2. Conversion of a 3D Object to a 2D Image: When a 3D dental cast is converted to a 2D digital image, convex structures of teeth, curve of spee, inclination, and rotation may influence measurements.

The highest difference was found in the premolar- followed by the molar-group. This was similar to the results obtained by Zilberman et al [11], who stated that it could be contributed to crowding, usually pronounced in the posterior regions of the set-ups. However, in this study it could be related to identification of the actual height of contours in the premolar and molar groups due to the morphology of the posterior teeth.

Another method that was proposed over the years, was photocopies from occlusal surfaces of the dental casts, a two dimensional indirect method which was compared with manual method by Schirmer and Wiltshire [13]. The mean arch length measurements differed by 4.7 mm in the maxilla and by 3.1 mm in the mandible [17], which in our technique was approximately 2.0 mm.

In the Champagne study [18], the total arch length differences were between 0.2 mm and 6.9 mm. Although these methods are easily handled, are not as accurate as manual methods. Some other methods like Hologram and reflex microscope that might be more accurate might not be as practical and easy to handle [3,6]. Stevens et al [19] concluded preliminary results did not indicate that digital models would cause an orthodontist to make a different diagnosis of malocclusion compared with plaster models; digital models are not a compromised choice for treatment planning or diagnosis.

As in Goonewardene et al [12] acknowledged digital copies of study models may avoid the storage and retrieval issues of plaster study models, but measurements made on digital models may not be as accurate as measurements made on traditional study models. Moreover, reliable measurements of the irregularity index and the tooth size-arch length (TALD, four- and six-segments) can be made on digital models. Computer measurements of TALDs on digital models were more consistent than manual measurements of TALD on plaster models [12].

However as more suppliers of these services are emerging, an ongoing development is expected which could finally result in new applications, such as dental set-ups, automatic recognition of points and calculation of measurements, treatment and surgical planning, evaluation of treatment results, forensic use, digital bracket positioning, and direct intraoral scanning [20].

CONCLUSION

In comparison with the gold standard, the manual method is the most accurate and reproducible method. Mesiodistal tooth size assessment in computerized method is smaller than manual method. This difference (2.0 mm) may not be clinically significant.

In measurements of arch width, the two methods were more similar which means the computerized method could be reliable in evaluating arch width and form, but in cast space analysis, it was not as accurate and reliable as manual measurements.

ACKNOWLEDGMENTS

REFERENCES
1- Proffit WR, Field HW. Contemporary Orthodontics. 3rd ed. St Louis: The CV Mosby Co; 2000. pp. 145-7, 165-70.

2- Pair JW, Luke L, White S, Atchinson K, Englehart R, Brennan R. Variability of study cast assessment among orthodontists. Am J Orthod Dentofacial Orthop 2001 Dec;120(6):629-38.

3- Lowey MN. The development of a new method of cephalometric and study cast mensuration with a computer controlled, video image capture system. Part II: Study cast mensuration. Br J Orthod 1993 Nov;20(4):315-31.

4- Brook AH, Pitts NB, Renson CE. Determination of tooth dimensions from study casts using an image analysis system. J Int Assoc Dent Child 1983 Dec;14(2):55-60.

5- Brook AH, Pitts NB, Yau F, Sandar PK. An image analysis system for the determination of tooth dimensions from study casts: comparison with manual measurements of mesio-distal diameter. J Dent Res 1986 Mar;65(3):428-31.

6- Tomassetti JJ, Taloumis LJ, Denny JM, Fischer JR Jr. A comparison of 3 computerized Bolton tooth-size analyses with a commonly used method. Angle Orthod 2001 Oct;71(5):351-7.

7- Santoro M, Galkin S, Teredesai M, Nicolay OF, Cangialosi TJ. Comparison of measurements made on digital and plaster models. Am J Orthod Dentofacial Orthop 2003 Jul;124(1):101-5.

8- Halazonetis DJ. Acquisition of 3-dimensional shapes from images. Am J Orthod Dentofacial Orthop 2001 May;119(5):556-60.

9- Mullen SR, Martin CA, Ngan P, Gladwin M. Accuracy of space analysis with emodels and plaster models. Am J Orthod Dentofacial Orthop 2007 Sep;132(3):346-52.

10- Macchi A, Carrafiello G, Cacciafesta V, Norcini A. Three-dimensional digital modeling and setup. Am J Orthod Dentofacial Orthop 2006 May; 129(5):605-10.

11- Zilberman O, Huggare JA, Parikakis KA. Evaluation of the validity of tooth size and arch width measurements using conventional and three-dimensional virtual orthodontic models. Angle Orthod 2003 Jun;73(3):301-6.

12- Goonewardene RW, Goonewardene MS, Razza JM, Murray K. Accuracy and validity of space analysis and irregularity index measurements using digital models. Aust Orthod J 2008 Nov;24(2):83-90.

13- Prabhakaran S, Sriram CH, Muthu MS, Chandrasekhar RR, Sivakumar N. Dental arch dimensions in primary dentition of children aged three to five years in Chennai and Hyderabad. Indian J Dent Res 2006 Oct-Dec;17(4):185-9.

14- Hashim HA, Al-Ghamdi S. Tooth width and arch dimensions in normal and malocclusion samples: an odontometric study. J Contemp Dent Pract 2005 May 15;6(2):36-51.

15- Dalhberg G. Statistical methods for medical and biological students. London: George Allen & Unwin Ltd; 1940. pp. 122-32.

16- Marcel TJ. Three-dimensional on-screen virtual models. Am J Orthod Dentofacial Orthop 2001 Jun;119(6):666-8.

17- Schirmer UR, Wiltshire WA. Manual and computer-aided space analysis: a comparative study. Am J Orthod Dentofacial Orthop 1997 Dec;112(6): 676-80.

18- Champagne M. Reliability of measurements from photocopies of study models. J Clin Orthod 1992 Oct;26(10):648-50.

19- 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 Dentofacial Orthop 2006 Jun;129(6):794-803.

20- Mårtensson B, Rydén H. The holodent system, a new technique for measurement and storage of dental casts. Am J Orthod Dentofacial Orthop 1992 Aug;102(2):113-9.