Research Article

Is Cone-Beam Computed Tomography (CBCT) Effective in Arch Discrepancy Measurement? A Comparative Study Using a Digital Program

Beatriz Tarazona*[1], Pablo Tarazona-Álvarez[2], Rosa Cibrián[3], José Luis Gandía[4], Vanessa Paredes[5]

[1] Doctor of Dental Surgery. Master of Orthodontics. University of Valencia, Spain

[2] DDS. Master in Oral Surgery and Implantology. University of Valencia, Spain

[3] Full Professor of Physiology. Faculty of Medicine and Dentistry. University of Valencia

[4] Full Professor of Orthodontics. Director of Master in Orthodontics. Faculty of Medicine and Dentistry. University of Valencia

[5] Doctor of Dental Surgery. Master in Orthodontics. Associate Professor of Medicine and Dentisty. University of Valencia

*Corresponding author: Dr. Beatriz Tarazona Álvarez, Clínica Odontológica, Departamento de Estomatología. Unidad Docente de Ortodoncia., Gasco Oliag nº1 ,46010 Valencia, Spain, E-mail: beatriz.tarazona@hotmail.com

Abstract

Aims: To evaluate the reliability and reproducibility and calculating arch discrepancy measurement using cone-beam computed tomography (CBCT) and comparing it to measurements obtained using the 2D Digital Method.

Material and Methods: Traditional dental plaster casts were obtained from 50 patients and then digitalized, so as to be able to measure them using the Digital Method. Likewise, CBCTs were undertaken on those same patients using the Dental Picasso Master 3D® and the images obtained analysed using the InVivoDental program.

Results: Determining the regression lines from both measuring methods, as well as the difference in values between them, shows how the two methods are comparable, despite the fact that the measurements analysed presented statistically significant differences.

Conclusions: The three-dimensional models obtained from the CBCT are as accurate and reproducible as the digital models obtained from plaster casts for calculating arch discrepancy measurement. The differences existing between both methods were clinically acceptable.

Keywords: Tooth Sizes; Digital Models; Arch Discrepancy Measurement; CBCT

Introduction

Arch discrepancy measurement is one of the most important calculations when it comes to devising a correct diagnosis and treatment plan. Any small millimetric difference can be crucial in deciding on one treatment or another, with or without extractions.

Arch discrepancy measurement is the difference between the space available for the positioning teeth (arch length) and the space we need for doing so (total sum of the mesiodistal diameter of the teeth). This calculation is made by orthodontists during orthodontic diagnosis. However, calculating it is slow and laborious, leading to a great loss of time for the professional and often causing it not to be undertaken, as the results of surveys carried out among North American orthodontists show [1].

With the advent of Digital programs, calculating arch discrepancy became quicker, simpler and more effective than the Traditional Method using plaster casts. Digital programs have been tested previously in multiple

studies, reliability is identical to Traditional methods and can therefore be used for measuring tooth sizes, and therefore for the calculation of arch discrepancy [2,3].

With the introduction of cone-beam computed tomography (CBCT) into orthodontic diagnosis, we can obtain three-dimensional, high-quality study models on which we are able to undertake measurements of tooth sizes, and, therefore, calculate arch discrepancy measurement.

Several published studies have analysed tooth sizes using CBCT compared to Digital Methods, in patients [4,5] or on skulls [6], but none has analysed osteo-dental discrepancy. Obviously, we cannot undertake a CBCT on all our patients just to measure tooth sizes. However, in those cases where a CBCT is required as part of the orthodontic diagnosis, we can undertake the necessary dental measurement -tooth sizes or arch discrepancy measurement - on the three-dimensional models.

With digital models we obtain two-dimensional (2D) images. However, with CBCT we obtain 3D models and images are dynamics. They can move, rotate, zoom, flip, crop and measure without loss of information, which is not true images of 2D method that it is a still a single image.

Furthermore, with many of digital models, it is necessary to send impressions or study models of the patient, so it is necessary to have plaster models also. The three-dimensional models have multiple advantages over physical plaster models, such as sharing them with other professionals from anywhere in the world for diagnostic opinions. Also, we do not have the problem of physical storage, avoiding having large spaces for storage them for years. Moreover, there is no risk that they may lose or break.

Obviously, 3D models have also disadvantages such as radiation or the high price of segmentation, but if we need to do a CBCT it can be useful to have 3D models instead of traditional models.

The aim of our study is, therefore, to analyse the reliability and reproducibility of calculating arch discrepancy measurement using CBCT. We compare those measurements with those obtained from Digital Models which consider as the reference standard.

Materials and Methods

50 patients were selected: 27 women and 23 men from the Orthodontics Department of the Faculty of Medicine and Dentistry at the University of Valencia, Spain. The mean age of the patients was 30.22 years. CBCTs were undertaken on all patients due to the fact that they were to undergo orthognathic surgery. In addition, plaster cast study models were made for all of them.

Inclusion criteria were as follows:

1. Permanent dentition from the first molar to the first contralateral molar.
2. Absence of anomalies in number, shape and size.
3. Good quality study models.
4. Absence of large-scale occlusal restorations or prostheses.

The Digital Model employed was developed by a work group of the University of Valencia. Its reliability and reproducibility had previously been tested. In this method, the plaster cast models were scanned using a conventional scanner. Once the images were obtained, they were then stored in the computer and analysed using a computer program, as can be observed on the left-hand side of Figure1.

The CBCT scanner employed was the Dental Picasso Master 3D® (EWOO technology, Republic of Korea. 2005), belonging to the Faculty of Medicine and Dentistry at the University of Valencia. All patients were scanned in maximum intercuspation, without inserting a wax bite, so avoiding appliances during the subsequent fragmentation. The dimensions for the full head scan were 200x150 mm (12bits) over 15 seconds. Slice thickness was 0.1mm and scanning covered 360º. The field of view (FOV) used generated 496 images, with a voxel size of 0.4mm. In addition, a 50 kV tube voltage range and a 6 mA intensity range were used. The main radiation dose was 150 mSv.

The InVivoDental (Anatomage, San Jose, California) program was used for analysing the images from the CBCT. Once obtained from the CBCT, they were securely sent in DICOM format through the web page of the InVivoDental company, where they were segmented manually by a member of that company's staff, so as to obtain images of the three-dimensional models as can be observed on the right-hand side of Figure1.
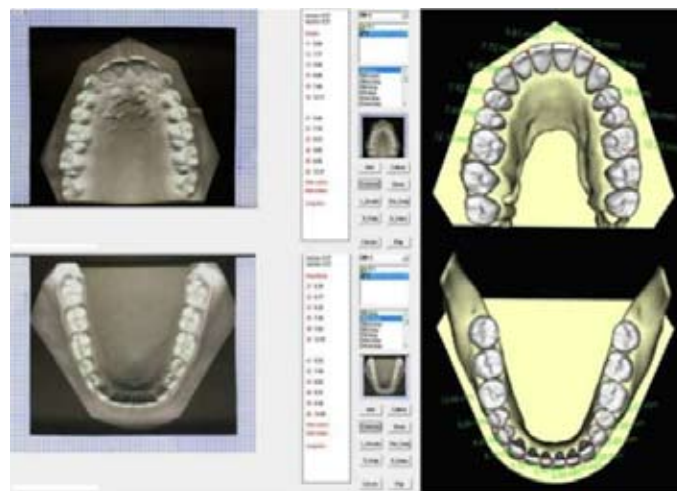
Figure 1. Mesiodistal tooth sizes using the Digital Method and CBCT.

Once the sample was obtained, a single previously-trained operator proceeded to undertake dental measurements on each of the models described: Digital and Three-Dimensional. Having obtained these, arch discrepancy measurement was then calculated.

In order to obtain arch discrepancy we measured tooth size in each arch between first molars. Then, we measured arch length. And finally, we subtracted the sum of tooth size with the arch length. In both models, the software and the computed calculate arch discrepancy automatically, once we measured tooth sizes and arch discrepancy.

Results

All the measurements obtained were introduced into a spreadsheet and analysed using the SPSS v. 15.0 statistics program for Windows.

Statistical analysis

The intraobserver and interobserver error were calculated for tooth sizes, as they are the basis for calculating arch discrepancy measurement. In order to calculate the intraobserver error, 15 of the 50 patients were randomly selected and a single observer measured the tooth sizes three times at intervals of at least one week. Reproducibility of Three-Dimensional Models was 1.08% for tooth sizes and 1.1% for Digital Models. The two methods were, therefore, perfectly comparable.

The interobserver error was also calculated. To do so, a second well-trained observer undertook the measurements on three occasions at intervals of at least one week. Reproducibility for tooth sizes of the Three Dimensional Models was 1.2% and 1.4 for Digital Models.

The correlation between the variables of both methods was determined by means of Pearson's correlation coefficient, the slope and ordinate at origin and their respective confidence intervals of 95%. Table 1 shows the data for upper and lower arch discrepancy measurement, and both jointly. Pearson's correlation coefficients were very high for all of them (0.924, 0.974 and 0.972 for upper and lower arch discrepancy measurement, and jointly). Figure 2 shows the line of fit for all these values.

Arch discrepancy measurement	ORDINATE AT ORIGIN	CONFIDENCE INTERVAL 95%	SLOPE	CONFIDENCE INTERVAL 95%	r-Pearson
SUPERIOR	0.316	-0.287/0.920	0.924	0.831/1.057	0.924
LOWER	0.110	-0.198/0.417	1,027	0.957/1.097	0.974
OVERALL	**0.153**	**-0.159/0.465**	**0.986**	**0.922/1.050**	**0.972**

Table 1. Ordinate at origin and slope with their respective confidence levels (95%) and r-Pearson correlation coefficients for the superior, lower and joint arch discrepancy measurement.
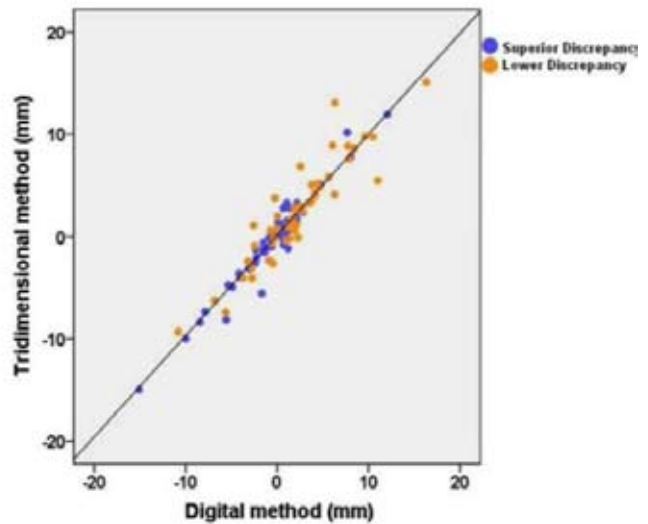

Figure 2. Dispersion diagram (%): of the Digital Method (ordinate axis) and of the Three-Dimensional Method or CBCT (abscissa axis), of upper osteo-dental discrepancy (in orange), and lower (in blue).

The difference between both Methods was calculated as the differences between the mean values calculated using each Method (Three-Dimensional -Digital). The mean differences of the upper and lower arch discrepancy measurement with their standard deviations and their respective confidence intervals at 95% are shown in Table 2 and a graphic representation of these differences in Figure 3.

Arch discrepancy measurement	MEAN	CONFIDENCE INTERVAL 95%	DS	SIG
CBCT-DIGITAL	0.140	-0.165/0.446	1.541	0.364

Table 2: Mean differences (CBCT-Digital Method) with their standard deviations and error and their respective confidence levels (95%) for the joint arch discrepancy measurement.
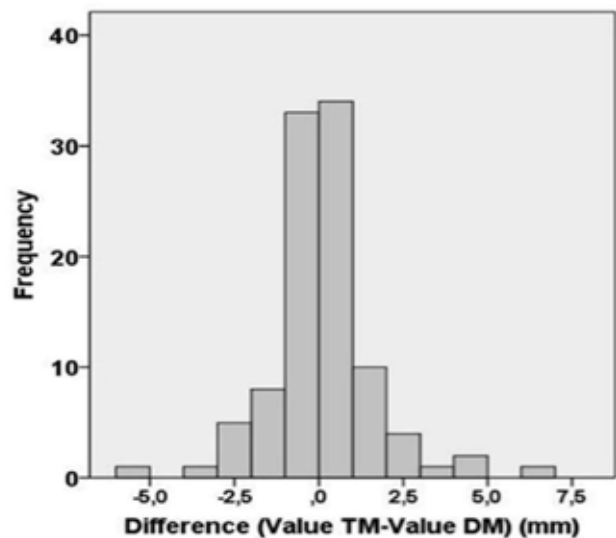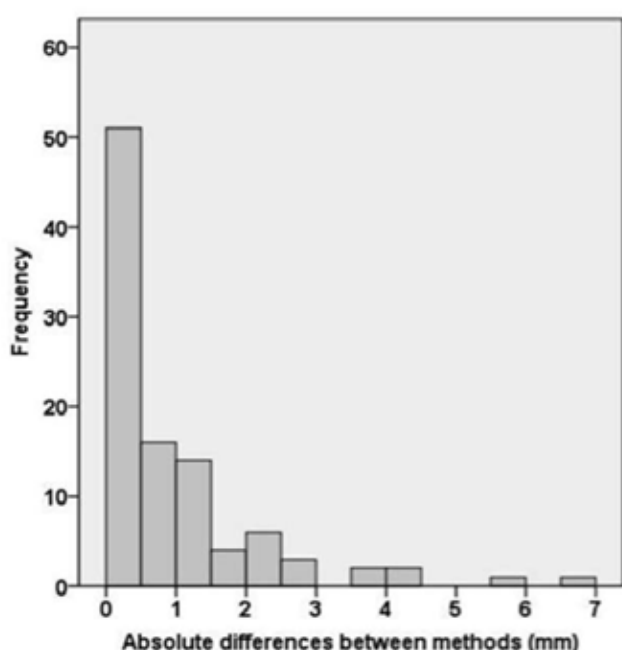

Figure 3. Bar chart of different means (mm) of osteo-dental dis-

crepancy between both Methods.

The arch discrepancy measurements being positive and negative, we decided to calculate the mean of the absolute differences, in order to avoid error compensation. The mean absolute differences of upper and lower arch discrepancy measurement with their standard deviations and respective maximum and minimum intervals are shown in Table 3 and a graphic representation of these differences in Figure 4.

Arch discrepancy measurement	MEAN	DS	MAXIMUM DIFFERENCES
CBCT-DIGITAL	0.959	1.210	6.75/0.02

Table 3. Mean absolute differences (CBCT-Digital Method) with their standard deviations and error and their maximum differences for the joint arch discrepancy measurement.

Figure 4. Bar chart of mean absolute differences (mm) of osteo-dental discrepancy between both Methods.

Discussion

The measuring of the tooth sizes and the later calculation of arch discrepancy measurement that we have usually carried out using 2D digital study models can now be undertaken accurately on Three-Dimensional study models obtained from a CBCT.

Tooth sizes measurements analysed by means of CBCT have already been documented in previous studies (6). The aim of our study, however, was to see whether calculating arch discrepancy measurement based on these measurements is equally accurate.

Firstly, Pearson's correlation coefficients are very high for upper, lower and joint arch discrepancy measurement,

r = 0.924, r = 0.974 and r = 0.972 respectively, which shows that both measurement methods are comparable. The lowest Pearson's correlation coefficient was for upper arch discrepancy measurement and the highest for lower arch discrepancy measurement.

Secondly, the slope and ordinate at origin contain 1 and 0 in their respective confidence intervals for both discrepancies and for both jointly. This indicated that both methods are identical and perfectly comparable.

We also found several differences between the CBCT and Digital Method in calculating thee mean arch discrepancy measurement. These differences were very small, 0.14. These small differences are shown in the bar chart of Figure 3, with values very close to 0, which also indicates that both Methods are not identical, but present very small differences. If we observe the absolute differences between both Methods, we see that they are a little bigger, 0.959. These differences can also be observed in Figure 4, as they show values close to 0.

We can, therefore, say that the small differences between both methods show that both are comparable, as they are not clinically significant.

We have tried to find out whether arch discrepancy measurement can be calculated by a CBCT, as we did not find any study that relates CBCT to arch discrepancy measurement. The only similar study is that of Kau (4) who analysed the Little Index using both models and concluded that both methods were equally accurate. Arch discrepancy is the most discrepancy index used, more than Little Index. That´s we calculated discrepancy index instead of Little Index. Also, digital models are different from our study. Having undertaken our study, we can say that both methods are very similar; and, therefore, we can use the CBCT for calculating arch discrepancy measurement.

However, the advantages of CBCT should be assessed in terms of additional cost compared to the conventional radiograph. Segmentation of the models further increases the cost (the expenses of InVivo segmentation are around 70 dollars per patient). It would be better if we could measure directly form the CBCT avoiding segmentation, but nowadays this is not possible. We can not obtain good images for measuring tooth sizes.

Moreover, the use of CBCT exploration exposes the patient to ionizing radiation. In those patients with implants, prostheses, amalgams… image quality is not as accurate.

Lastly, CBCTs are not justified for all orthodontic patients. So we could conclude that arch discrepancy could be calculated in 3D models in those patients who had a CBCT because is necessary for his diagnosis and

treatment plan. In the remaining patients, we can continue using other type of study models.

Conclusion

The conclusions of the study are as follows:

CBCT allows us to determine upper and lower arch discrepancy measurement accurately and reproducibly in comparison to measurements obtained from Digital Models, which, in turn, are obtained from the digitalization of traditional plaster cast models. The differences existing between both Methods are clinically acceptable.

References

1. Bolton WA. The clinical application of a tooth-size analysis. Am J Orthod. 1962, 48(7): 504-529.

2. Tomassetti JJ, Taloumis LJ, Denny JM, Fischer JR. A comparison of 3 computerized Bolton tooth-size analyses with a commonly used method. Angle Orthod. 2001, 71(5): 351-357.

3. Paredes V, Gandia JL, Cibrian R. Determination of Bolton tooth-size ratios by digitization, and comparison with the traditional method. Eur J Orthod. 2006, 28(2): 120-125.

4. Kau CH, Littlefield J, Rayny N, Nguyen JT, Creed B. Evaluation of CBCT Digital models and traditional models using the Little's Index. Angle Orthod. 2010, 80(3): 435-439.

5. Tarazona B, Llamas JM, Cibrian R, Gandia JL, Paredes V. A comparison between dental measurements taken from CBCT models and those taken from a Digital Method. Eur J Orthod. 2013, 35 (1): 1-6.

6. Baumgaertel S, Palomo JM, Palomo L, Hans MG. Reliability and accuracy of cone-beam computed tomography dental measurements. Am J Orthod Dentofacial Orthop. 2009, 136(1): 19-25.