Comparative study of mandibular linear measurements obtained by cone beam computed tomography and digital calipers

Pablo Tarazona-Álvarez [1], Javier Romero-Millán [1], David Peñarrocha-Oltra [1], María-Ángeles Fuster-Torres [2], Beatriz Tarazona [3], Miguel Peñarrocha-Diago [4]

[1] Master in Oral Surgery and Implantology. Valencia University Medical and Dental School. Valencia, Spain

[2] Master in Oral Surgery and Implantology. Professor of the Master in Oral Surgery and Implantology. Valencia University Medical and Dental School. Valencia, Spain

[3] Associate Professor of Orthodontics. Valencia University Medical and Dental School. Valencia, Spain

[4] Chairman of Oral Surgery. Director of the Master in Oral Surgery and Implantology. Valencia University Medical and Dental School. Valencia, Spain

Correspondence:
Clínicas odontológicas
Gascó Oliag 1
46021, Valencia, Spain
miguel.penarrocha@uv.es

Abstract

Objectives: Cone beam computed tomography (CBCT) is an innovative dental of imaging system characterized by rapid volumetric imaging with patient exposure to a single dose of radiation. The present study was carried out to compare the linear measurements obtained with CBCT and digital caliper in 20 mandibles from human cadavers.
Study design: A total of 4800 linear measurements were measured between different mandibular anatomical points with CBCT and digital caliper. The real measurements were defined as those obtained with the digital caliper. Posteriorly, the mandibles were scanned to obtain the CBCT images, with software-based measurements of the distances.
Results: The measurements obtained with the digital caliper were greater. The CBCT technique underestimated distances greater than 100 mm.
Conclusions: CBCT allows to obtain linear mandibular anatomical measurements equivalent to those obtained with digital caliper. The differences existing between both methods were clinically acceptable.

Key words: Computed tomography, cone beam CT, accuracy, reliability, digital caliper.

Introduction

Cone beam computed tomography [CBCT] is an image scanning and volumetric reconstruction technique that allows us to obtain linear measurements in three dimensions using computer software (1). CBCT can be used in different fields in dentistry, such as implantology and orthodontics (2). However, in order to optimize application of the technique, it is necessary to analyze the accuracy of the data obtained on performing linear measurements (3). The literature contains several studies comparing the linear distances recorded on the surface of models with those obtained by CBCT. They found statistically significant but clinically irrelevant differences (4), with errors ranging from 0.01-0.85 mm (5,6). However, few

studies have compared the measurements obtained by CBCT imaging versus the real or actual measurements recorded from mandibles in cadavers (5,7).

The present study compares the linear measurements obtained by CBCT and digital caliper in 20 mandibles from human cadavers.

Material and Methods

20 mandibles from human cadavers supplied by the Department of Anatomy [Valencia University Medical and Dental School, Valencia, Spain] were used to obtain 20 linear measurements from different anatomical points described in table 1. Figure 1 shows the different anatomical landmarks in the sagittal and coronal views.

Table 1. Anatomical points used as references for the measurements.

▪ Go: Midpoint along the curvature of the mandibular angle between the lower body margin and the posterior margin of the mandibular ramus seen from sagittal.
▪ Mco: Most medial point of the condyle seen from coronal.
▪ Psco: Point along the posterosuperior surface of the mandibular condyle.
▪ Ment: Mental foramen.
▪ Co: Condylion.
▪ Lco: Most lateral point of the condyle seen from coronal.
▪ Pog: Most anteroinferior midpoint of the chin convexity seen from sagittal.
▪ InfSig: Lowermost point of the sigmoid concavity from sagittal.
▪ Cp: Coronoid process.

Fig. 1. Anatomical points used as references for the measurements. Sagittal and coronal views.

The measurements on the CBCT images were the same as those carried out on the mandibles with the digital caliper. A high precision digital caliper with a standard error of 0.02 mm [Halfords Advanced Professional Vernier®, United Kingdom] was used to obtain the real measurements from the human mandibles. Each mandible was scanned with the Picasso Dental Master 3D® system [Ewoo technology, Republic of Korea, 2005].

Imaging was performed with a voxel resolution of 0.1 mm and a field of view [FOV] of 20 x 19 cm, with 80 kVp and 5 mA irradiation, and an exposure time of 12-24 seconds. The images obtained were 1 mm axial or sagittal acquisitions and coronal reconstructions. The software was Ezimplant® [Vatech, Yongin-Si, Republic of Korea] (Fig. 2).
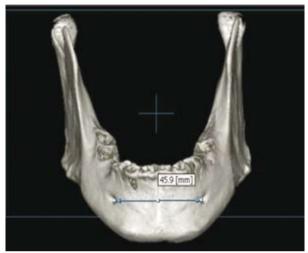

Fig. 2. Linear distance between the mental foramina (Ment-Ment) with CBCT.

All mandibles were examined independently by two observers. Each observer measured the distances in triplicate using both Ezimplant® software [Vatech, Yongin-Si, Republic of Korea] and digital caliper, with calculation of the averages of the distances obtained by the two observers with both methods.

- Statistical analysis

The intraclass correlation coefficient was used to determine interobserver error. The t-test with Bonferroni correction was performed for analysis and comparison of the 20 measurements made on the 20 mandibles by the two observers. The level of significance was $p \leq 0.0025$. All calculations were performed using the Statistical Package for Social Sciences [SPSS version 15, Chicago, IL, USA].

Results

The linear measurements obtained in the mandibles with both the digital caliper and CBCT are described in table 2. The intraclass correlation coefficient ranged from 0.941-0.998 mm in the measures analyzed using CBCT and from 0.974-0.999 mm in the measures obtained with the digital caliper, reflecting high reliability between the two observers.

Comparison of the linear measurements made with digital caliper and CBCT showed no significant differences for 95% of the distances analyzed [$p>0.0025$], though differences were recorded for the remaining 5% [$p<0.0025$]. The average discrepancy between the li-

Table 2. Description of the measures used between different anatomical points.

Lco-Lco	Most lateral point of right condyle to most lateral point of the left condyle.
Mco-Mco	Most medial point of the right condyle to left condyle.
Mco-Lco R	Width of the right condyle.
Mco-Lco L	Width of the left condyle.
PscoPog R	Point along the posterosuperior surface of the right mandibular condyle to most anteroinferior midpoint of the chin convexity seen from sagittal.
PscoPog L	Point along the posterosuperior surface of the left mandibular condyle to most anteroinferior midpoint of the chin convexity seen from sagittal.
InfSigGo R	Lowermost point of the sigmoid concavity to midpoint along the curvature of the mandibular angle between the lower body margin and the posterior margin of the right mandibular ramus.
InfSigGo L	Lowermost point of the sigmoid concavity to midpoint along the curvature of the mandibular angle between the lower body margin and the posterior margin of the left mandibular ramus.
AltAgMen R	Height of the alveolar crest at right mental foramen.
AltAgMen L	Height of the alveolar crest at left mental foramen.
CoGo R	Condylion to midpoint along the curvature of the mandibular angle between the lower body margin and the posterior margin of the right mandibular ramus.
CoGo L	Condylion to midpoint along the curvature of the mandibular angle between the lower body margin and the posterior margin of the left mandibular ramus.
CpGo R	Coronoid process to midpoint along the curvature of the mandibular angle between the lower body margin and the posterior margin of the right mandibular ramus.
CpGo L	Coronoid process to midpoint along the curvature of the mandibular angle between the lower body margin and the posterior margin of the left mandibular ramus.
CpCo R	Coronoid process to right condylion.
CpCo L	Coronoid process to left condylion.
AltCrest Pog	Height of the alveolar crest at the most anteroinferior midpoint of the chin convexity.
Ment-Ment	Distance between mental foramens.
Ment-Pog R	Right mental foramen to most anteroinferior midpoint of the chin convexity.
Ment-Pog L	Left mental foramen to most anteroinferior midpoint of the chin convexity.

near distances obtained with both methods ranged from 0.001-0.82 mm. Observer 1 did not report statistically significant differences for any of the 20 distances analyzed. However, CBCT underestimated the actual measurements obtained with the digital caliper in 17 of the 20 distances analyzed (Table 3). Observer 2 in turn reported a statistically significant discrepancy for one of the 20 linear distances [PscoPogL, p=0.000] (Table 3), and in the same way as the Observer 1, CBCT underestimated the actual measurements obtained with the digital caliper in 16 of the 20 distances analyzed (Table 3). Only one distance [PscoPogL] had a statistically significant discrepancy between the two methods (Table 3).

Discussion

Mandibular linear measurements has been analyzed previously with CBCT and compared with two-dimensional techniques (5). However few studies have analyzed the accuracy of CBCT in human skulls. In the present study the two observers made 4800 linear measurements, and only 240 [5%] showed significant differences between analysis performed with the digital caliper and the measurements obtained by CBCT. The remaining 4560 measurements [95%] showed no statistically significant differences between the two techniques, the observed minimum discrepancy [5%] being considered clinically acceptable (8). Hilgers *et al*. (9) reported good accuracy

and reliability of CBCT in a study of 11 measurements in 25 mandibles of cadavers, though there were significant discrepancies in some of their measurements. In the same line, Moreira *et al*. (7) found no statistically significant differences between CBCT and digital caliper in their measurements of 15 human skulls, in coincidence with the findings published by Kamburoglu *et al*. (10).

In our study CBCT was seen to underestimate the true measurements, though the difference was only statistically significant for distances greater than 100 mm and in low density zones such as the condyle. Distances with important but nonsignificant differences may be due to several causes, e.g., areas of low density secondary to dehydration that are not exactly reproducible by CBCT and therefore cannot be accurately analyzed by the Ezimplant® software (11), or measurements in excess of 100 mm (12).

In 60% of the measurements made with two types of CBCT, Damstra *et al*. (4) observed a tendency to underestimate with dry mandibles respect to the reference measurements. In the same line, two studies (13,14) with human adult skulls or synthetic mandibles also recorded a underestimation with CBCT images. Other authors (3,15,16), in obtaining measurements of structures inside the skull, also reported underestimation with the use of CBCT. However Baumgaertel *et al*. (17) reported systematic overestimation when analysis was performed

Table 3. Linear measurements obtained in the mandibles with digital caliper and CBCT (X^A: CBCT underestimated measurements by Observer 1; X^B: CBCT underestimated measurements by Observer 2).

Global Measurements	Methods	Measurements	Differences	P-Value
Lco-Lco	Caliper	106.1673	- 0.82053 ^{A}	0.014
	CBCT	107.8475		
Mco-Mco	Calipers	76.5523	-0.61775	0.029
	CBCT	77.1700		
Mco-Lco R	Caliper	16.8640	+0.36150 ^{AB}	0.022
	CBCT	16.5025		
Mco-Lco L	Caliper	17.1023	+0.32975 ^{AB}	0.022
	CBCT	16.7725		
PscoPog R	Caliper	117.9825	+0.76750 ^{A}	0.068
	CBCT	117.2150		
PscoPog L	Caliper	118.1795	+2.1295 ^{AB}	0.001
	CBCT	116.0500		
InSigGo R	Caliper	46.5168	+0.28675 ^{AB}	0.008
	CBCT	46.2300		
InSigGo L	Caliper	46.3245	+0.19200 ^{AB}	0.047
	CBCT	46.1325		
AltAgMen R	Caliper	22.7610	+0.12350 ^{AB}	0.005
	CBCT	22.6375		
AltAgMen L	Caliper	22.8053	+0.05525 ^{AB}	0.326
	CBCT	22.7500		
CoGo R	Caliper	62.0400	+0.12375 ^{AB}	0.239
	CBCT	61.9163		
CoGo L	Caliper	63.0555	+0.26800 ^{AB}	0.017
	CBCT	62.7875		
Cp Go R	Caliper	57.1575	+0.15750 ^{AB}	0.018
	CBCT	57.0000		
Cp Go L	Caliper	58.9425	+0.17750 ^{AB}	0.150
	CBCT	58.7650		
Cp Co R	Caliper	30.6975	-0.05000 ^{AB}	0.455
	CBCT	30.7475		
Cp Co L	Caliper	31.2885	-0.05400 ^{A}	0.622
	CBCT	31.3425		
Altcrest Pog	Caliper	23.7175	+0.10500 ^{AB}	0.052
	CBCT	23.6125		
Ment-Ment	Caliper	41.0393	+0.00100 ^{B}	0.937
	CBCT	41.0240		
Ment Pog R	Caliper	27.8085	+0.02100 ^{AB}	0.290
	CBCT	27.7875		
Ment Pog L	Caliper	27.5825	+0.08000 ^{AB}	0.311
	CBCT	27.5025		

on a segmented basis. A possible explanation for this may be the software used [Ezimplant®, Vatech, Yongin-Si, Republic of Korea]. Glover *et al.* (11) offered another possible explanation, the so-called partial volume effect, which occurs when a voxel is occupied by two structures with two different densities, and CBCT records an average of both for that voxel. Thus, when a voxel exhibits two different densities, the resulting end density is the average of both structures, with interpretation of part of one structure or the other.

Conclusions

CBCT is a reliable and accurate method for analyzing linear measurements made on mandibles of human cadavers. It must be taken into account that there were statistically nonsignificant discrepancies in the linear measurements analysis. However, further studies are needed to determine the cause of the results founded in this study.

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