Original Article

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Evaluation of linear tomography and cone beam computed tomography accuracy in measuring ridge bone width for planning implant placement

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Abstract

The development of oral implantology has led to the establishment of various image-acquisition methods as important surgical diagnosis tools, such as linear (LT) and cone beam computed tomography (CBCT), indicated for planning implant placement surgeries. However, there still is little information in the literature regarding details on the difference between the accuracy of these methods. **Aim:** The aim of the present study was to assess the difference between the accuracy of LT and CBCT in measuring ridge bone width. **Methods:** A sample of ten human skulls was used, totaling 40 edentulous sites, marked with 2-mm gutta-percha balls in the buccal and lingual plates. Buccal-lingual measurements of ridge width were performed on the images of both tomography types. Direct caliper measurements were used as control values, to which all LT and CBCT measurements were compared. **Results:** CBCT images showed significantly more accurate results in comparison with the direct caliper measurements ($p<0.05$). **Conclusions:** CBCT proved more reliable than LT regarding ridge bone measurements for dental implant planning.

Keywords: linear tomography, cone beam computed tomography, dental Implant, surgical planning.

Introduction

With the development of implant-related treatments, presurgical assessment has became critical to evaluating the dimensions of the available alveolar bone, and to locating important anatomical structures, such as the mandibular canal, especially in cases with atrophic alveolar ridges and great bone loss[1]. Standard panoramic and periapical radiographs do not provide cross-sectional information, and are therefore insufficient for implant site evaluation[2-3]. Tomographic images are useful for assessing information on ridge measurements three-dimensionally, considered essential for the surgical planning of implant placement[4-5].

Linear tomography (LT) is an accessible radiographic technique used for the cross-sectional imaging of edentulous jaws and is relatively inexpensive compared

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with computed tomography (CT). It has the advantage of exposing the patient to less radiation than CT when used for a single site[6].

In the last decade, the development of volumetric tomography devices – considered important techniques for using a three-dimensional image navigation system – allowed the professional to perform image-guided surgical planning and to fabricate a stereolithographic surgical guide[7-8]. Cone beam computed tomography (CBCT) units have been widely used in maxillofacial studies. Compared with other CT methods, CBCT offers advantages such as reduced effective radiation doses, shorter acquisition scan times, easier imaging, and lower costs[9-10].

The buccal-lingual ridge width has been described as an important measurement for implant treatment planning, since it can be used as a parameter to evaluate and compare the accuracy of different image-acquisition methods[11-12]. Furthermore, although radiographic methods have been compared and evaluated for the surgical planning of implant placement cases[13-14], there still is little information in the literature regarding details on the difference between the accuracy of commonly used tomographic methods, LT and CBCT, in measuring ridge width. Thus, the objective of the present study was to compare the accuracy of LT and CBCT in measuring the ridge bone width of edentulous sites in human skulls.

Material and methods

Ten human dry skulls were used as a sample, in which two edentulous sites in the maxilla and two in the mandible were selected, totaling 40 sites. Measurements were conducted according to a previously described methodology[15]. The skulls were marked with 2-mm gutta-percha balls, one in the buccal plate and other in the lingual plate. The balls were placed at two points located 3 to 8 mm perpendicularly away from the crest of the ridge. The buccal-lingual ridge width was calculated by measuring the distance between the two gutta-percha balls, performed for each of the edentulous sites evaluated. The skulls were supported on the LT and CBCT devices by a chin holder and a head strap. The orientation of the skull for scan was with the Frankfort horizontal parallel to the floor and the midsagittal plane perpendicular to the floor. Direct caliper measurements were performed and considered the control values of this study, to which all LT and CBCT measurements were compared.

LT images were obtained with a panoramic machine that has a linear tomographic function (Vera View Scope X-600, Morita, Tokyo, Japan), with exposure conditions of 60 kV and 4 mA and with a 0.5-mm copper filter. The tomographic projection angle was set at 60º with nominally 1.0-mm thick slices at 1.0-mm intervals. The cross-sectional images obtained were processed and used to perform buccal-lingual measurements (Figure 1), which were traced on acetate paper using a clear plastic ruler and a mechanical #2 lead pencil. The measurements obtained were adjusted for magnification error.

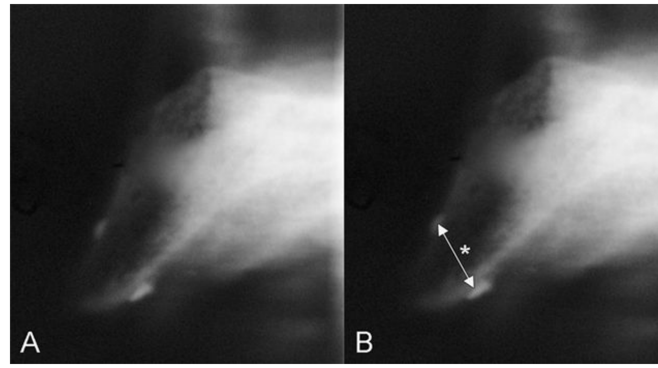

Fig.1. A. LT cross-sectional image of a marked maxillary edentulous site used to perform measurements. **B.** Indication of measurement (asterisk) position between the buccal and lingual markers in the same image.

A CBCT unit (Classic i-CAT, Image Sciences International, Hatfield, PA, USA) was used and configured with a diagnostic protocol used for dental implants (0.25-mm voxel, 120kVp, 3 to 8mA), in order to obtain digital cross-sectional images (Figure 2), in which buccal-lingual measurements were performed by using CT imaging software (ImplantViewer 2.709, Anne Solutions, São Paulo, SP, Brazil) on a personal computer (Figure 3).

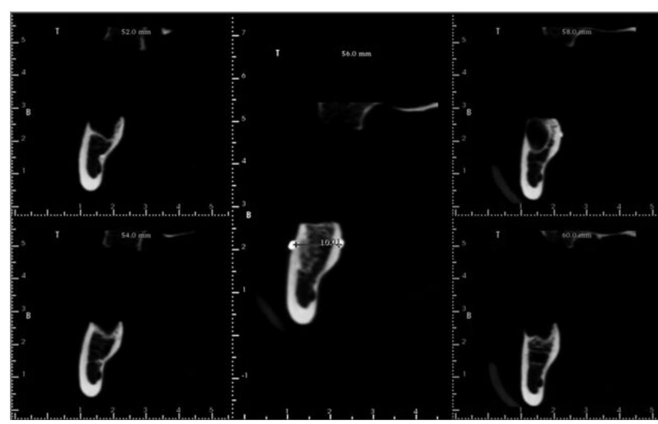

Fig. 2. CBCT cross-sectional image of a marked mandibular edentulous site, which was digitally measured by using the imaging software.

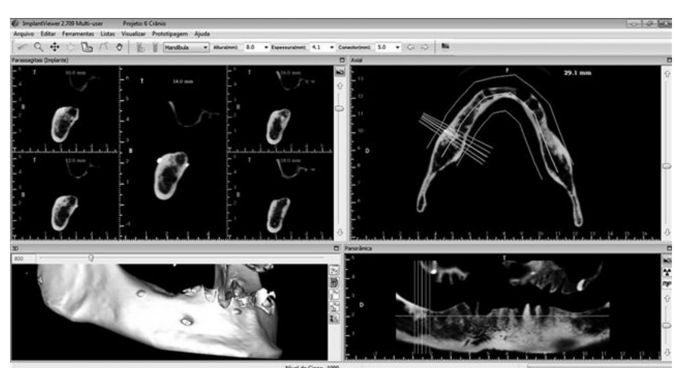

Fig. 3. Screen view of the CT imaging software used to perform CBCT measurements.

All caliper, LT and CBCT measurements (in millimeters) were recorded separately in a random order by two trained independent observers. Measurement reproducibility was

Table 1- Comparison between data for image-acquisition methods and direct caliper control measurements.

Image-acquisition methods	Number of sites showing deviation degrees in comparison with direct caliper measurements				P*
	Up to 0.5 mm	From 0.51 to 1mm	From 1.01 to 2 mm	Over 2 mm	
LT	21 (52.5%)	15 (37.5%)	3 (7.5%)	1 (2.5%)	P=0.004
CBCT	36 (90%)	4 (10%)	-	-	P=0.244

LT = linear tomography; CBCT= cone beam computed tomography. *significant level according to the Wilcoxon *T* test.

assessed by having each observer repeat both caliper and CBCT measurements separately after a 2-week interval to eliminate memory bias. Measurement reliability assessment of replicate measurements was made using the concordance correlation coefficient (CCC). One observer served as the main observer and intra-observer reliability was estimated between measurements performed 2 weeks apart.

For the purpose of data analysis, deviations in LT and CBCT measurements compared to direct caliper measurements were recorded and grouped into four different deviation degrees: up to 0.5 mm, from 0.51 to 1 mm, from 1.01 to 2 mm, and over 2 mm.

The statistical analysis was performed using the Wilcoxon *T* test, a hypothesis test indicated to detect possible significant differences between two related samples or repeated measurements on a single sample, and commonly mentioned in articles on accuracy comparisons between different image-acquisition methods[13,16]. A p value under 0.05 was considered a statistically significant difference.

Results

Comparison between data for image-acquisition methods and direct caliper control measurements are shown in Table 1. Intra-observer reproducibility was confirmed, insofar as the CCC ranged between 0.83 and 0.91 for the measurements.

In assessing the buccal-lingual measurements, CBCT presented more accurate results than LT, in comparison with the control measurements. This fact was confirmed by statistical analysis, insofar as a p value under 0.05 was found for the comparison between LT and direct caliper measurements. Additionally, most edentulous sites analyzed (62.5%) showed differences from 0 to 0.2 mm between CBCT and direct caliper measurements.

Positive deviations (larger values for tomographic images than for direct caliper measurements) were more frequent than negative deviations in both image-acquisition methods (67% of the analyzed cases). However, negative deviations were observed more often in CBCT images than in LT images.

Discussion

The lower consistency of LT measurements in comparison with CBCT measurements, observed in the present study, was in agreement with the findings of a previous investigation, which compared measurement results among tomographic techniques for dental implant planning, not including CBCT, as the analysis showed that LT results were less accurate in comparison with all CT methods analyzed[13].

The importance of evaluating ridge bone dimensions in cases of dental implant surgeries has been described in the literature[7-9]. As observed in the present study, CBCT has been regarded as a high-quality reliable image-acquisition method for the dentomaxillofacial area, in comparison with other tomographic methods[16-17]. However, a study comparing different CT methods found that a protocol of multidetector CT yielded more accurate linear measurements in comparison with those performed by CBCT images[18].

For the purpose of evaluating preoperative assessment accuracy with tomographic images, LT and CBCT buccal-lingual measurements have also been compared with ridge-mapping preoperative buccal-lingual measurements, performed after penetration of patients' soft tissues with calipers[11-12]. A study on LT found no significant differences between LT and ridge-mapping measurements, although both methods underestimated ridge dimensions[11]. On the other hand, a similar study on CBCT found that ridge-mapping preoperative measurements were more consistent than CBCT measurements[12]. The findings of the above-mentioned studies, taken together, contrast with those of the present study, insofar as CBCT images provided reliable and more accurate measurements in comparison with LT, supporting the fact that there is still controversy in the literature on image-acquisition methods for measuring ridge width.

The findings of the present study are in agreement with those of a recent similar study on CBCT measurements in human dry skulls, which indicated the effectiveness of both 2-D and 3-D CBCT reconstructions in measuring specific distances[19]. The authors also stated that skull orientation during CBCT scanning has not been found to affect accuracy or reliability of measurements, as also observed in the present study.

In conclusion, CBCT was presented as a more accurate image-acquisition method in comparison with LT in providing information on ridge width measurements, which important to perform a precise surgical planning for implant placement.

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