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Accuracy and reliability of linear measurements using tangential projection and cone beam computed tomography

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ABSTRACT

Background: Providing a cross-sectional image is essential for preimplant assessments. Computed tomography (CT) and cone beam CT (CBCT) images are very expensive and provide high radiation dose. Tangential projection is a very simple, available, and low-dose technique that can be used in the anterior portion of mandible. The purpose of this study was to evaluate the accuracy of tangential projection in preimplant measurements in comparison to CBCT.

Materials and Methods: Three dry edentulous human mandibles were examined in five points at intercanine region using tangential projection and CBCT. The height and width of the ridge were measured twice by two observers. The mandibles were then cut, and real measurements were obtained. The agreement between real measures and measurements obtained by either technique, and inter- and intra-observer reliability were tested.

Results: The measurement error was less than 0.12 for tangential technique and 0.06 for CBCT. The agreement between the real measures and measurements from radiographs were higher than 0.87. Tangential projection slightly overestimated the distances, while there was a slight underestimation in CBCT results.

Conclusion: Considering the low cost, low radiation dose, simplicity and availability, tangenital projection would be adequate for preimplant assessment in edentulous patients when limited numbers of implants are required in the anterior mandible.

Key Words: Cone beam computed tomography, dental implants, radiography

INTRODUCTION

During the last decade, there has been a growing trend to use three-dimensional imaging to improve dentomaxillofacial diagnosis.[1-3] The latest technology for this purpose is cone beam computed tomography (CBCT),[4-6] which provides high resolution, accurate, real size images without superimposition; however, it is expensive and not widely available. The most important disadvantage is higher exposure dose compared to conventional techniques.[4,7-13]

Lateral cephalometric projection has been used for imaging the mid-line region of the jaws prior to implant placement, especially in edentulous patients. This projection images the cross-sectional view of the midline, the inclination of the ridge and the relationship between the jaws. Furthermore, the magnification of the radiographs is known for each machine. However, the principle drawback for using this technique is the low resolution associated with all extraoral techniques, either film-screen based or digital.[4] It also exposes a large area of head and neck to radiation.[14]

Tangential projection is an old technique used for years to assess the mid-line of the jaws, and with some

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modifications for the intercanine regions.[15,16] It is also known as transymphyseal projection, and lateral view of anterior mandible and maxilla.[14,17] The technique has successfully been used to localize impacted teeth, lesions, and foreign bodies for years.[17] It also has been suggested for preimplant assessment.[14-17] The image of the ridges in this technique is just similar to lateral cephalometry, but it uses intraoral film with much superior resolution. It exposes a limited region of the jaws to X-ray; hence, does not expose unnecessary parts of head and neck.[14] In addition, the technique is very simple and widely available. It does not require special equipments, and can be easily performed in a dental office to facilitate and speed patient evaluation and treatment planning. It has considerably lower exposure in comparison to advanced techniques such as CT and CBCT.[14] There are few studies which have evaluated the use of this projection for this purpose; but they did not compare it to other techniques, especially recent ones such as CBCT.[14-17]

The purpose of this study was to evaluate the accuracy of tangential projection in preimplant measurements in the anterior portion of the mandible in comparison to CBCT.

MATERIALS AND METHODS

This experimental study was performed in the School of Dentistry, Isfahan University of Medical Science, Isfahan, Iran, in 2011.

Three dry edentulous human mandibles from donated skulls were provided by the Department of Anatomy, University of Medical Sciences, Isfahan, Iran. The mandibles showed no signs of previous trauma or deficiency.

Five regions were selected on each mandible; the mid-line, canine regions, and a point between these two on each side. Thus, a total of 15 sites were selected for evaluation. These regions were marked by drawing a line on the buccal surface from the alveolar crest perpendicularly to the inferior margin with a thin tip marker. Each line determined a "site of interest."

The specimens were placed in a plastic container with a 14 cm × 14 cm base, and immersed in water to simulate soft tissue for attenuating the X-ray. Each mandible was positioned so that the inferior border of mandible at the anterior region was parallel to the floor of the room.

Tangential radiography

To simulate the clinical situation, the distance between the end of position indicating device (PID), the film and the surface of mandible should be the same as in the patient with soft tissue. The distance between the film and the site of interest in the mandible was estimated to be about 4 cm according to clinical experiences, and 4 times distance (16 cm) was considered between the PID and film. Therefore the distance between the PID and the site of interest would be 12 cm.

A film holder was designed and prepared using two rigid plastic plates attached perpendicularly from one end [Figure 1]. One of the plates had a circular hole with 7 cm diameter for placing the end of PID and was placed vertically. The other plate was placed horizontally, with two slits on it. The first slit was 12 cm far from the vertical plate to indicate the proper place for the site of interest (subject slit) and the second one 16 cm away from perpendicular plate for placing the film (film slit). This film holder helped to make sure of proper positioning of the site of interest (described later). It also standardized the distances between the PID, film and site of interest, while simulating the clinical distances. Thus, the magnification factor in all tangential projections was the same. The container was placed on the film holder between the vertical plate and the film slit so that the site of interest was on the subject slit.

To provide the radiographs [Figure 2], a 4 mm piece of the end of a number 80 Gutta-percha was adapted and glued to the crest of the alveolar ridge, each time on one site of interest. The Gutta-percha was necessary for CBCT images to indicate the sites of interest, and was used here to provide the same situations in both techniques. The mandible

Figure 1: The fabricated film holder, the container, and a specimen positioned in it.

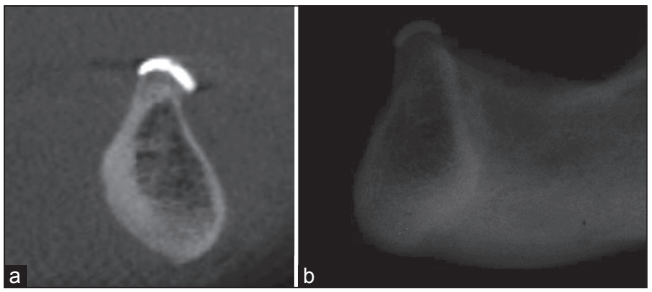

Figure 2: (a) cross sectional CBCT image, (b) tangential projection provide by the film holder.

was then placed in the container, so that the inferior border at the anterior region was parallel to the floor of the room. The site of interest was positioned on the subject slit with the slit exactly perpendicular to its buccal surface. The buccal plate of the mandible was parallel to the surface of the film and the end of PID, and the central ray passed tangential to it.

An occlusal film (Kodak-Ultraspeed, Cedex; France) was placed vertically in the film slit, and the site of interest was exposed with a long cone intraoral X-ray unit (Planmeca Intra, Helsinki, Finland). The exposure parameters (kilo voltage peak, milliamper and time) were optimized for each mandible with previous radiographs to obtain desirable density and contrast. After the exposure, the Gutta-percha was removed, and another site was prepared and exposed. The same protocol was repeated for all five sites in a mandible, and for all specimens. The radiographs were processed in an automatic film processor (Hope Dental Max, Hope X-ray Products, USA) and with Champion processing agent (Champion, Champion Co., England).

After preparing the tangential radiographs, a 5 mm lead ball attached to a plastic plate was placed on the subject slit and imaged to indicate the magnification factor of the technique. The measurements obtained from this technique were corrected by the calculated magnification factor.

Cone beam computed tomography

Five pieces of Gutta-percha were glued to all sites of interest on each mandible in the same manner as for the tangential technique to indicate the sites of interest in the images. Each mandible was positioned in the container and placed in the CBCT unit (Gallileos-Compact, Galaxis version 1.7.3545.16433, ID2 Sirona; Germany) so that the inferior border of the anterior portion of mandible was parallel to the floor and the indicating light was at the midline. The Galileos consists of an X-ray generator and an image intensifier as detector aligned and mounted facing each other on a U arm. The radiation source/detector unit completes a 200° rotation around the patient's head, acquiring projected images 1° apart. The scan time is 14 s. The X-ray detector component consists of a 23 cm image intensifier and a charge-couple device camera. Each of the captured projections is represented by a 1024 × 1024 pixel matrix, with a 12-bit grayscale.

The specimens were imaged by the high resolution image protocol. Panoramic and cross-sectional reconstructions were created and used for measurements.

Slicing the mandibles, measuring, and statistical methods

The mandibles were sliced at the lines that indicated the sites of interest, perpendicularly to the buccal surface and inferior border.

The height (the distance between the crest and inner surface of the cortex of inferior border of mandible) and width (the maximum distance between the buccal and lingual inner surfaces of the cortex of mandible) at each site of interest was measured. A digital caliper with 0.01 mm accuracy (Guilin Guanglu Measuring Instrument Co., China) was used for measurements on the mandible (as the gold standard) to achieve real measures. It was also used to measure the distances on tangential radiographs. CBCT images were evaluated using the built-in measurement software (Sirona Dental Systems Inc.,Germany).

The measurements were performed by two expert Dentomaxillofacial Radiologists independently, and without matching the tangential images with CBCT images for each site of interest. The reproducibility of the measurements was assessed by repeating the measurement after a 2 weeks interval to eliminate memory bias. The results of tangential technique were corrected by the magnification factor calculated for the technique (described before).

The SPSS (Statistical Package for Social Science software; SPSS Inc., Chicago, IL, USA) 11.5 was used for analyzing the data. The intraobserver reliability was assessed by intraclass correlation coefficients. Inter observer reliability, and also the agreement between the mean of four measurements in each method and real measures were assessed by

interclass correlation coefficients(ICC). The mean measurement error (ME) was defined as:

Measurement error = Absolute value ([measurements of a particular method – real measures]/real measures).[18] Thus, ME is a ratio with no units of measurement (power of study >0.90).

RESULTS

The agreements between each technique and real measures, and the MEs of the techniques are presented in Table 1. The ICC values range from 0.00 to 1.00. A higher ICC reveals that the two values were more similar. The ICCs in this study are almost the same for the two techniques.

The intraobserver and interobserver reliability are presented in Table 2.

The ICC between the mean of four measurements (from two observers, each measured twice) and real measures from the bone are shown in Figures 3-6. The dots indicate that how a measurement on bone (vertical axes) is reported on the particular radiograph (horizontal axes). The lines indicate the ICC between the two measurements. A 45° line shows a complete (100% or 1.00) agreement. An increased or decreased degree indicates less agreement.

DISCUSSION

This study evaluates the use of tangential projection for preimplant assessment. The evaluation was in comparison to CBCT as an accurate and widely used technique.

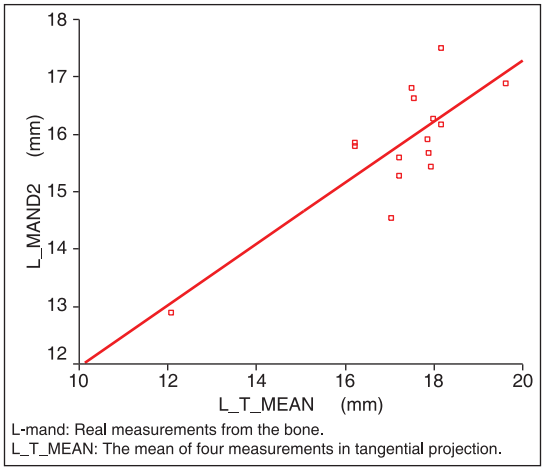

Figure 3: The interclass correlation co-efficience between the measurements of the length in tangential projection and bone.

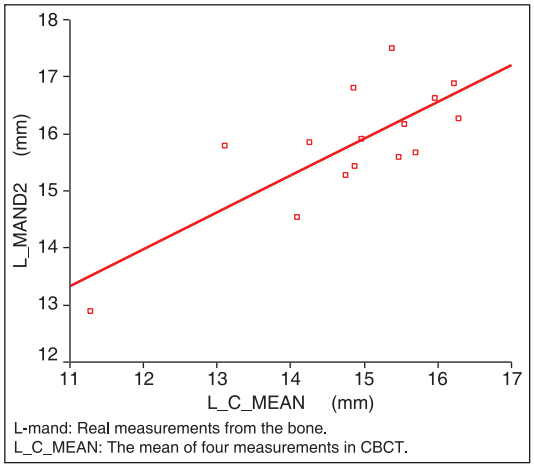

Figure 4: The interclass correlation co-efficience between measurements of the length in cone beam computed tomography and bone.

Table 1: ICC between tangential and CBCT techniques and real measures for length and width and ME

Measurement	Technique	ICC	ME			
			Min	Max	Mean	SD
L	T	0.92	0.01	0.17	0.08	0.04
	C	0.89	0.01	0.17	0.06	0.05
W	T	0.87	0.01	0.34	0.12	0.08
	C	0.91	0.00	0.14	0.04	0.03

L: Length; W: Width; T: Tangential projection; C: CBCT; ICC: Interclass correlation coefficient; ME: Measurement error; Min: Minimum; Max: Maximum; SD: Standard deviation; CBCT: Cone beam computed tomography.

Table 2: Inter and intraobserver reliability

Measurement	Technique	Interobserver	Intraobserver	
			Observer 1	Observer 2
L	T	90	95	96
	C	78	78	97
W	T	94	89	83
	C	80	85	90

L: Length; W: Width; T: Tangential projection; C: CBCT; CBCT: Cone beam computed tomography.

In contrast to other studies, the measurements were achieved as the distances between the inner surfaces of the cortex of the mandible rather than the outer surface, which requires much superior image quality, sharpness and detail. It is much easier to find the outer surfaces of the cortex rather than finding the interface between the cortical and medullary bone (the inner surface). It influences the results achieved by both techniques when compared to other studies.[19-22] Despite this fact, the agreements between each technique and real measures were high. The ME

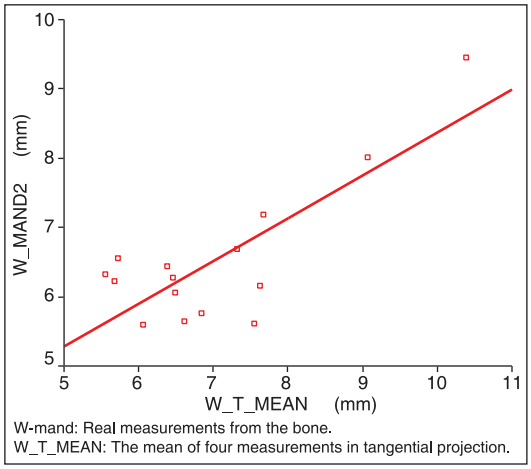

Figure 5: The interclass correlation co-efficience between measurements of the width in tangential projection and bone.

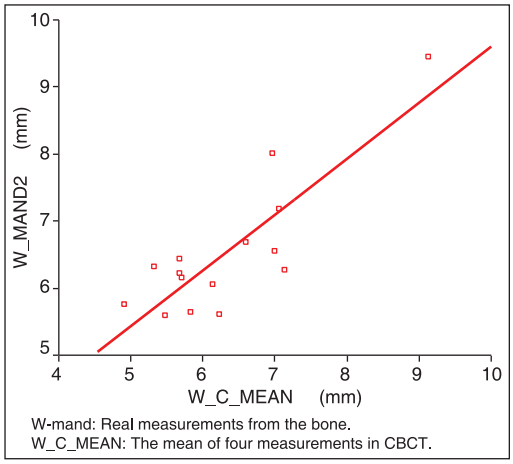

Figure 6: The interclass correlation co-efficience between measurements of the width in cone beam computed tomography and bone.

was also reasonably small in both techniques when compared to other studies examining the accuracy of CBCT. It was reported that the ME of CBCT scans in different studies was <0.5 when obtained from the outer surface of bone.[4] It emphasizes the accuracy of tangential projection, since its ME showed a maximum of 0.34 in this study.

The thickness of the cortical plate of the mandible differs in different anatomic parts, so the maximum and minimum height of the ridge in this study was in different areas compared with other studies, which measured the height and width as the distances between the outer surfaces of the cortexes. For instance, Madrigal *et al*. evaluated the agreement between panoramic and CBCT images for preimplant measurements in interforaminal implant placement in 50 patients.[23] Regardless of the width of the crestal part of the ridge, they reported the maximum height in the midline, and the minimum near the mental foramen. However, as a result of thick cortical borders in the mental region, the midline had the minimum height in this study.

Furthermore in this study, only a small piece of Gutta-percha was used over the crest to indicate the sites of interest. This study did not use markers such as wire around the entire ridge, nor made holes in the cortex, because these would facilitate finding the cortical boundaries of the ridge.[1] The observers, in this study, had to find the height, the width, and also the inner surface of the cortical bone by their own judgment, as they do in clinical practice.

There are not many studies about using the tangential projections for preimplant assessment. Sewerin suggested the technique as a complement for frontal views for localization of supernumerary teeth and lesions, and also for planning of insertion of dental implants.[15] Sewerin and Skov[16] compared the technique with panoramic radiography for measuring the height of the ridge in mandible. They found it effective, and reported that it also reveals the true morphology of the mandible as seen in cross-section views. Sano *et al*. introduced a film holder for this technique. They clinically evaluated its efficacy and suggested it for preimplant evaluations.[17] Shelley and Horner[14] also evaluated this projection. They reported that it can successfully be used for preimplant assessments in the midline areas in mandible, and also suggested it for near midline regions.

This study found only a small difference between the accuracy of the two methods in preimplant measurements, while tangential projection was more reliable. It is somehow in agreement with the findings of Wakoh *et al*.[18] They investigated the accuracy and reliability of film based periapical radiographs, panoramic radiographs, conventional tomography, and CT in linear measurements in implantology. They reported that periapical radiograph was the most reliable, and the same as or better than CT in the accuracy of measuring the length of implants. This can be mainly due to the superior sharpness and resolution of intraoral films, in addition to the blurring related to tomographic nature of other techniques. The same reasons can be mentioned for CBCT not to be superior to tangential projection.

Another reason that CBCT is not more accurate than tangential projection can be the fact that CBCT

slightly underestimates the linear measurements. Some studies had reported this point, but they did not find it significant in peripheral parts of the skull, such as the jaw bones.[19,22,24-26] The findings of the present study also indicate that CBCT measurements were always smaller than the real measures. On the other hand, tangential projections slightly overestimated the distances in most measurements, even after correction of the values by magnification factor. This can be due to an error in either projecting the lead ball or calculating the magnification factor.

In CBCT images noise is also a significant factor that affects the quality of the image.[2,25]

The radiation dose in CBCT projection is a considerable issue. It is important to note that while the radiation dose from a CBCT scan may be less than from low-dose CT, the dose is still significantly higher than other modalities of dental radiographic examination.[11] The dose of a unit with a field of view that involves both mandible and maxilla had been measured to be between 3 and 10 times higher than that of a panoramic radiograph, according to the method of measurement and the characteristics of CBCT unit.[13,19] The radiation dose in tangential projection had been estimated to be 2-3 times more than a parallel periapical radiograph,[14] which is less than a panoramic radiograph.

CONCLUSION

Considering the low cost, low radiation dose, simplicity and availability, tangential projection would be proper for preimplant assessment in edentulous patients when limited numbers of implants are required in the anterior mandible, and there is no need for more complicated image modalities. However, if multiple implants are going to be placed, or in complicated cases, or when other regions of the jaws have to be assessed, CBCT would be the technique of choice according to cost-benefit considerations.

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