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Radiographic Assessment of Alveolar Bone Thickness by Two Plains Radiography (Pre-clinical study)

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ABSTRACT

Aim of the study: is to investigate the use of 2D radiographs to assessment the alveolar bone thickness (width) and modify the standard Rinn-XCP film holding device to improve the imaging technique.

Material and Method: the thickness of the alveolar bone of thirty six edentulous regions (8 anterior and 10 posterior for each jaw) in the maxilla and mandible of three dry skulls at the selected edentulous sites measured directly by digital caliper. Intraoral periapical radiograph by modified paralleling technique made for each site with the use of modified Rinn-XCP film holder.

Results: the statistical analysis by t-test showed a non-significant difference between the direct and radiographic alveolar bone thickness ($p \geq 0.05$).

Conclusion: Three-dimensional information could be obtained from a periapical radiographs taken with modified horizontal projections of the x-ray beam. The film holding device recommended using for standardization, reproduction and simplicity of technical application.

Key Words: modified paralleling technique, film holder, radiographic stent, alveolar bone.

INTRODUCTION

The increasing acceptance of dental implant has been attributed in part to the increasing sophisticated imaging techniques used in implant treatment[(1)]. The diagnostic phase of dental implant therapy and, the proper choice of radiographic examination are important to the long-term success of a dental implant [(2)]. The accuracy of image measurement is an essential requirement of any radiographic technique used for dental implant diagnosis[(3)]. Intraoral periapical radiograph produce a high resolution (more than 20 line pairs / mm) planar image[(4,5,6)]. A paralleling technique of intraoral radiography will provide an accurate high resolution image of bone height. The use of identical standardized intraoral radiographs with proper positioning techniques, periapical radiographs give minimum magnification and distortion and the reproducibility of these radiographs is high [(7)]. The aim of study is to investigate the use of 2D radiographs to assessment the alveolar bone thickness (width) and modify standard Rinn-XCP film holding device to improve the imaging technique.

MATERIALS AND METHODS

Three dry skulls, borrowed from Human Anatomy Class / Basic Science Department / College of Dentistry / University of Mosul, containing edentulous regions (an alveolar bone with removed teeth) have been used for this study. The thickness of the alveolar bone of thirty six edentulous regions (8 anterior and 10 posterior for each jaw) in the maxilla and mandible of dry skull was measured superio-inferiorly by digital caliper at four points started at the crestal part of the alveolar bone with 5mm distance separates the one point from the next (Figure 1).

Figure (1): Direct measurements of the bone thickness by the digital caliper.

The points of measurement were demarcated by pencil. To represents the soft tissue layer, the edentulous regions of maxilla and mandible of dry skulls covered by a layer of soft wax with 2mm thickness. A stainless steel metallic ball with 3.88 mm of diameter placed occlusally at each selected site to use as a caliber for linear measurements (Figure 2) [8,9].

Figure (2): The edentulous regions of the jaws of dry skulls covered by a layer of soft wax and stainless steel metallic ball placed occlusally at each selected site.

FABRICATION OF RADIOLUCENT STENT

For each edentulous site that selected for examination, a simple design of radiolucent stents was fabricated from self-cure acrylic resin material in a U-shape form extend bucco-lingually. Four pairs of orifices were made vertically in the stent with stainless steel prosthetic fissure bur, the buccal (labial) orifice opposing directly the other orifice on the lingual (palatal) side. Five millimeters of distance separate one pair of orifices from the next one. Stainless steel wires with gauge 0.7mm used as radiopaque markers inserted in the holes[10, 11]. The stent replaced in its site, and the radiopaque markers pushed through the holes and penetrate the wax layer till to touch the bone (Figure 3 – A and B).

Figure (3): Radiolucent stents with stainless steel wires gauge 0.7mm used as radiopaque markers. A- Mandible, B- Maxilla

RADIOGRAPHICAL EXAMINATION

Modified Paralleling Technique used for intraoral periapical radiographic examination of anterior and posterior segments of the dental arch. The principles of right angle paralleling technique modified, by changing the horizontal angulation of primary x-ray beam. In order to determine the appropriate horizontal angulation of the x-ray beam, the white cardboard used where a horizontal base line was draught and from the midpoint of this line a perpendicular line was drawn, then on both sides of perpendicular line different angle determined with use of protractor starting from 10º – 60º angles. The examined arch should be placed on the cardboard where the long axis of the ridge compensates the drawn horizontal base line[12, 13] (Figure 4).

The XCP-film holding device for digital sensor size 2 adult CCD digital image sensor (Dixi-type, Finland) that used to support the image receptor to be parallel to the examined ridge, its extension arm extends along the drawn perpendicular line. The cone of x-ray beam was adjusted to be on the aiming ring of the film holder, the examined region was exposed by Dental x-ray machine type Planmeca Intra (Helsinki, Finland) operated at 70 kVp, 8 mA and exposure time range 0.025 – 0.05 sec. This view represents the standard principles of right angle paralleling technique (90º horizontal angulation), and then the examined region re-exposed where the cone of x-ray machine was shifted horizontally with different angles (10, 20º, 30º, 40º, 50º, and 60º, angles respectively) from the standard direction with maintained vertical angulation[14] (Figure 4). The radiographs examined to identify the most appropriate one with minimal distortion and maximum separation between the ends of radiopaque markers of radiographic stent [15], thus the most appropriate radiograph was depended that was projected with the 30º angle (θ = 30º) of horizontal angulation. This modification in the horizontal beam angulation was considered to compensate the requirements of the present study.

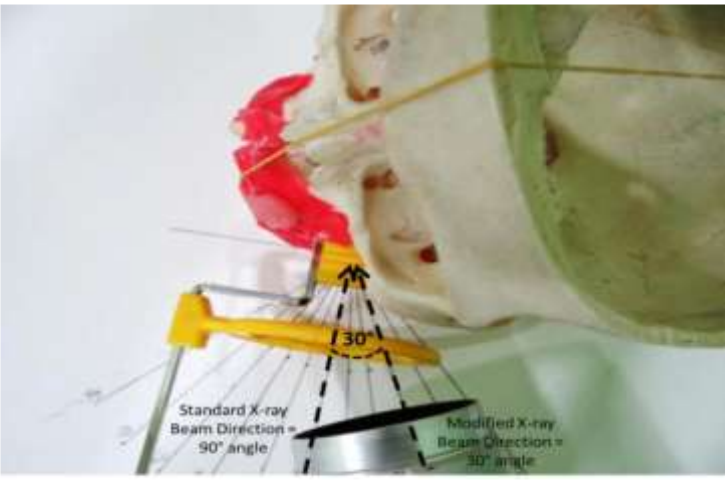

Figure (4): Determination of the horizontal beam angulation of modified paralleling technique.

THEORY OF TECHNICAL MODIFICATION

The shifted horizontal angulation leads to depict distorted image of the object thickness (shortened). According to trigonometry principles where the angle of inclination of any line (primary beam direction) to any plain (object thickness) called (Θ1), which determine the angle between the true line in space (object thickness) and its projection on the plain (image receptor) called (Θ2). These principles represented diagrammatically by AutoCAD software version 2012. In order to determine the value of Θ2, the following hypothesis was depended;

An object (O-Ō) with 20mm thickness was projected at 90º angle of vertical angulation and 30º angle of horizontal angulation (Θ1). The shadow of the object (S-Ś) cast on the image receptor with distorted or shortened image size 11.54mm. Line (A-B) represents the image size of the object in the space, a circle with radius same as the real object thickness (20mm) was drawn at point (A) as a center. A perpendicular line (B-C) drawn from point (B) to intersect the circumference of the circle at point (C). Thus we have a right angle triangle (ABC) [16] (Figure 5).

According to the trigonometry principles, the cosine function of Θ2 can be used to identify the value of this angle [16], as the following;

In the right angle triangle (ABC);

- The hypotenuse (AC) = 20mm.
- The adjacent (AB) = 11.54mm.

Cosine function of Θ2: cos. (Θ2) = adjacent / hypotenuse.

By replacement: cos. (Θ2) = AB / AC.

$$\therefore \cos.(\Theta 2) = 11.54 / 20.00 = 0.577$$

From the table of values: the value 0.577 represents the cosine of 55º angle.

$$\therefore \Theta 2 = 55^{o}$$

This trigonometric function is true for any object thickness, if Θ1= 30º angle. Thus the value of Θ2 absolutely depends on the value of Θ1.

The following equation is applied to calculate the real radiographic size of the object thickness from the distorted image[17];

Real Object Thickness = Apparent Radiographic Thickness / Cos. θ_2

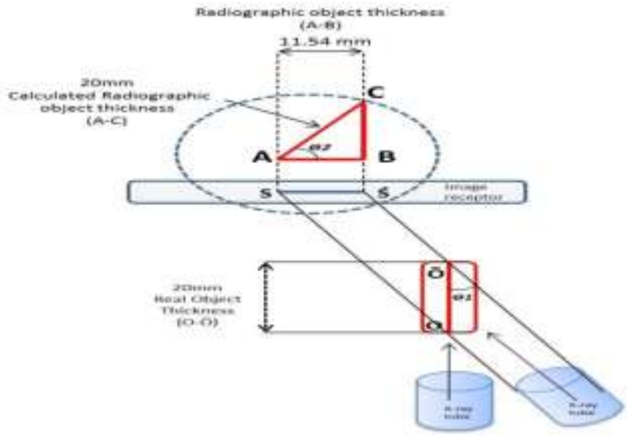

Figure (5): Diagrammatic representation of the modified paralleling technique principles.

RADIOGRAPHICAL MEASUREMENTS

The digital radiographic images were imported separately to the Dimax Classic imaging software. Vertical line was traced to tangent the inner end of each radiopaque marker, then another horizontal line traced to connects between each two opposed vertical lines at the level of each pair of markers. The linear measurements calibrated by measuring the diameter of metallic ball in the horizontal plain, which considered as a reference distance[1,4,5]. The length of the horizontal line was measured to represents the radiographic distance between the selected radiopaque markers (Figure 6 – A and B). In order to obtain the real radiographic distance between the markers (radiographic alveolar bone thickness) dividing each value to the 0.3775, this represents the cosine of 55º angle.

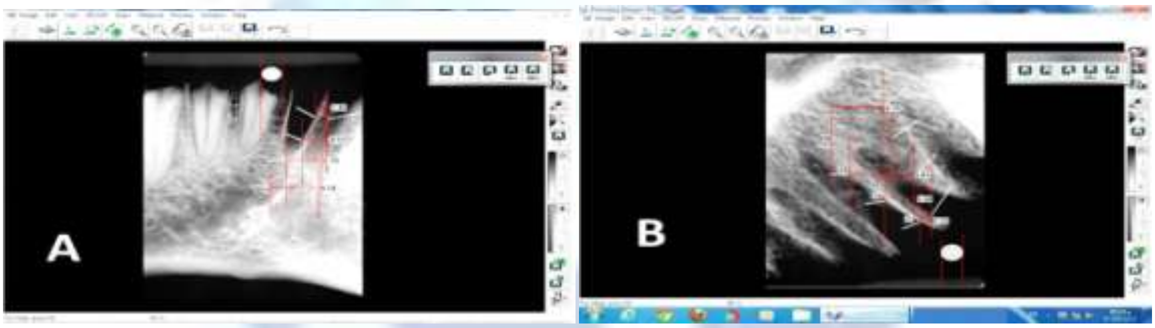

Figure (6): Radiographic measurements of the alveolar bone thickness projected by modified paralleling technique.

A- Mandibular arch. B- Maxillary arch.

FILM HOLDER FOR MODIFIED PARALLELING TECHNIQUE

The standard design of the Rinn – XCP film holder was used including; mechanical film supporting part, bite block and an x-ray beam – aiming device[18]. A certain modification includes; adding an accessory stainless steel arm with square section of 3.33 mm dimension to hold the x-ray beam aiming device was used. This accessory arm has two right angled bending and joined with the main extension arm of the film holder by joining part. The joining part was made from self-cure acrylic resin which maintain divergence of the two arms from each other with a 30º angle, to determine the horizontal beam angulation (Figures 7 – A, B and C).

Figure (7): Modified Rinn XCP film holder. A- The 30º angled accessory arm. B- The orientation of the ring aiming device. C- The application of modified paralleling technique on dry skull.

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RESULTS

The statistical analysis of the results by t-test showed no significant difference ($p \geq 0.05$) in the comparison of the bone thickness measurements (D1, D2, D3, and D4) between the modified paralleling radiographic technique and direct bone measurements in both the maxillary and mandibular anterior and posterior regions. The p- value of the D1, D2, D3, and D4 in the maxillary anterior region are 0.122, 0.067, 0.306 and 0.347 respectively. Where, the p-value of the D1, D2, D3, and D4 in the mandibular anterior region are 0.147, 0.246, 0.256 and 0.266 respectively (Table 1). While the p-value of the D1, D2, D3, and D4 in the maxillary posterior region are 0.556, 0.509, 0.605 and 0.622 respectively. Where, the p-value of the D1, D2, D3, and D4 in the mandibular posterior region are 0.490, 0.557, 0.479 and 0.621 respectively (Table 2).

Table (1): shows the comparison between the direct and radiographic bone thickness measurements with modified paralleling technique in the anterior regions.

Arch	Distance	Technique	N	Mean (mm)	SD	SE mean	df	t-value	p-value
Maxillary	D1	Direct	8	4.195	0.49365	0.17453	14	1.646	0.122
		MPT	8	3.795	0.47854	0.16919			
	D2	Direct	8	5.955	0.37283	0.13181	14	1.986	0.067
		MPT	8	5.583	0.37485	0.13253			
	D3	Direct	8	8.363	0.82519	0.29175	14	1.062	0.306
		MPT	8	7.948	0.73480	0.25979			
	D4	Direct	8	11.332	0.86492	0.30579	14	0.919	0.374
		MPT	8	10.931	0.88226	0.31193			
Mandibular	D1	Direct	8	3.942	0.47234	0.16700	14	1.534	0.147
		MPT	8	3.580	0.47280	0.16716			
	D2	Direct	8	5.258	0.62695	0.22166	14	1.210	0.246
		MPT	8	4.867	0.66568	0.23535			
	D3	Direct	8	7.131	0.59650	0.21089	14	1.185	0.256
		MPT	8	6.763	0.64258	0.22719			
	D4	Direct	8	9.593	0.69007	0.21089	14	1.158	0.266
		MPT	8	9.198	0.67442	0.23844			

Table (2): shows the comparison between the direct and radiographic bone thickness measurements with modified paralleling technique in the posterior regions.

Arch	Distance	Technique	N	Mean (mm)	SD	SE mean	df	t-value	p-value
Maxillary	D1	Direct	10	6.731	1.61504	0.51072	18	0.600	0.556
		MPT	10	6.303	1.57550	0.49822			
	D2	Direct	10	9.355	1.71841	0.54341	18	0.674	0.509
		MPT	10	8.990	1.74137	0.55067			
	D3	Direct	10	12.381	1.71585	0.54260	18	0.526	0.605
		MPT	10	11.973	1.75062	0.55359			
	D4	Direct	10	14.722	1.78310	0.56387	18	0.501	0.622
		MPT	10	14.320	1.80341	0.57029			
Mandibular	D1	Direct	10	6.367	1.20623	0.38144	18	0.705	0.490
		MPT	10	5.992	1.17164	0.37271			
	D2	Direct	10	9.355	1.41587	0.44774	18	0.598	0.557
		MPT	10	8.991	1.30445	0.41250			
	D3	Direct	10	11.485	1.45544	0.46025	18	0.723	0.479
		MPT	10	11.022	1.40917	0.44562			
	D4	Direct	10	12.552	1.84757	0.58425	18	0.502	0.621
		MPT	10	12.120	1.99520	0.63094			

DISCUSSION

Exposing human being to ionizing radiation for research study is a quite refuseable technique, and for reasons of standardization of exposure technique, keeping the same relation of the object to the film and x-ray beam and obtain real direct measurements of the examined site, thus all the exposures carried out throughout the pre-clinical study have been made on the maxilla and mandible of dry human skull to investigate the suggested radiographic techniques with their constructed film holding devices(19, 20).

MODIFIED PARALLELING TECHNIQUE

The principles of modified paralleling technique follow the basic principles of long cone right-angle paralleling technique which include the alignment of the long cone x-ray beam (30 cm) to be perpendicular to the paralleled plains of the examined object and image receptor.(12,13) The long cone paralleling technique for taking periapical radiographs is the technique of choice for the following reasons: reduced skin dose, less magnification, a true relationship between the bone height and adjacent teeth was demonstrated, and easy to reproduce. It should be remembered that to get the most from the long cone paralleling technique it should be performed with a film-focal distance of approximately 30 cm.(21)

The modified horizontal angulation (30º angle) of basic right-angle paralleling technique was considered in the present study, its capable of assessing the bone quantity by measuring the thickness of the alveolar bone at a specified region in a two dimensional plain in any direction related to the visible landmarks (radiopaque markers of stent) in the oral cavity. Since there is no additional equipment or cost involved, the technique explained here can be used as an adjunct to implant practice(4).

The theory of tube shifting (10-20º angle of horizontal tube shifting) was followed by Clark's localization technique, which used to localize an object in the third dimension according to its relationship to the selected reference point.(13,22) But the present study follow the theory of tube shifting to measure the distance between two selected points with increased horizontal angulation to 30º angle.

Thirty degree angled horizontal angulation selected from the different angulation that tested in the present study because it was represent adequate separation between the ends of radiopaque markers with minimal image distortion and avoid the overlapping of the adjacent structures like abutment teeth over the examined region.(1,23) Image size distortion (enlargement or reduction) is a well-known phenomenon in radiography. Geometrically the resultant radiographic images from the modified technique suffering from distortion "shortening" (8,13), this distortion corrected by the geometric principles of trigonometry, from these principles mathematic equation derived and applied to obtain the real radiographic thickness of the alveolar bone by dividing the radiographic bone thickness to the cosine of 55º angle.

According to the literatures, this modification in the principles of right-angle paralleling technique and the application of the mathematic equation to correct the distorted radiographic measurements are firstly applied in the present study.

The idea to use more than one intraoral periapical radiographs with modified horizontal angulation of the paralleling technique described and supported by many authors; Sahiwal and co-workers(14) in (2002), they identify threaded endoseous implants from their radiographic images. Radiographs were made of these implants at 0°, 30°, 60°, and 90° horizontal rotation combined with –20°, –10°, 0°, +10°, and +20° vertical inclination relative to the radiographic beam and film. Thirty degree shifted horizontal angulation between two periapical radiographs used by Berketa and his group(1) in (2010) to evaluate and clarify the threat design of dental implant.

Modified Film Holding Device

An additional stainless steel arm added to the basic design of the Rinn – XCP film holder was used to hold the ring aiming device, this arm have two right angled bending were made to insure that the alignment of mechanical film supporting part to be located along the center of the ring aiming device by providing transitional shifting of the x-ray beam with the maintained 30º angle of horizontal angulation. This design depends on the mathematical principles; if two lines (CD and EF) are cut by a transversal (GH) and the alternate interior angles (ϴ1 and ϴ2 = 90º) are matching, the lines are parallel. A transversal is a line that intersects two or more lines in the same plain. Therefore, if two parallel lines (CD and EF) are cut by a transversal (AB), the corresponding angles are compatible (ϴ3 and ϴ4 = 30º angle)(24) (Figure 8).

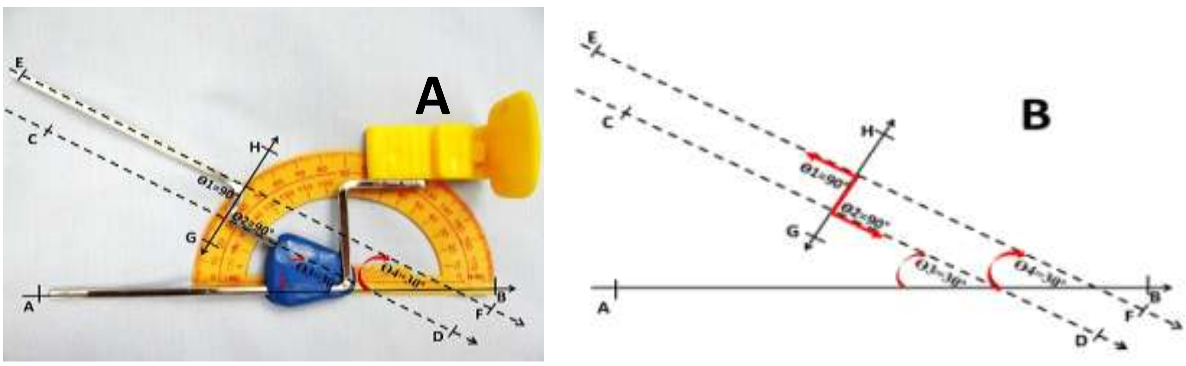

Figure (8): Geometrical alignment of the arms of the modified film holding device for modified paralleling technique. A- Picture of the film holder. B- Diagram of theory.

IMAGE CALIBRATION

Image size distortion (enlargement or reduction) is a well-known phenomenon in radiography. The accuracy of image measurement is an essential requirement of any radiographic technique used for dental implant diagnosis. Image analysis has been widely used in research and is based on calibrating images using a radiopaque reference device of known dimensions (metallic ball) that was included in the image during exposure of the radiograph of the implant patient.(4) The metallic balls prefer to use because the radiographic image of a metal ball is not influenced by the geometrical conditions and parameters associated with an exposure (projection geometry) due to the symmetrical shape of the sphere (1,8). The method recommended by Mupparapu, and Singer(25) in (2004), and Anil and Al-Ghamdi,(4) in (2007) they predetermined the magnification factor by using a radiographic stent with ball bearings embedded in acrylic and imaged in the patient's mouth.

RADIOPAQUE MARKERS

The advantage of radiopaque markers in their position during radiographic examinations, which were used as references points to measure the distance between each two opposing markers (26).

This method of measurement sustained by study of Iplikcioglu and others(27) (2002) they recommended the use of stent with radiopaque markers used for radiographic evaluation during treatment planning for the implant patient. Radiopaque markers are helpful guides to evaluate the bone in the recipient area provide an accurate transfer of the two-dimensional information to the three-dimensional stent throughout the entire procedure.

Padmanabhan and Gupta(28), in (2010) they evaluate the crestal bone loss around an implant; were used the radiopaque implant length, implant shoulder and the alveolar crest as a measuring reference points. Measurements of the distance between reference points were performed at mesial and distal aspects of implant digitally. Where in (2010) Talwar and co-workers,(29) they used gutta percha as a radiopaque marker with stent, because it has property of thermoplasticity, was easy to compact in the drill channel, does not produce artifacts as metal markers do and can be easily removed while conversion of stent from diagnostic to surgical use.

Radiographical Measurements

Dimax Classic imaging software used to perform the linear measurements to enhance the image visualization through using software to adjust image contrast, density and sharpness. The linear measurements calibrated by using the real diameter of metallic ball placed in the radiographic stent close to the implant site as a reference distance (1,5,9).

In order to obtain an accurate calibration and more precise measurements; the diameter of the metallic ball corresponding to the direction of the x-ray beam shifting was depended, that mean the horizontal diameter was used, corresponding to modified horizontal angulation of x-ray beam.(30)

According to mathematic rule "A straight line is the shortest distance between two points in the same direction"(31), the shortest radiographic distance between the selected radiopaque markers was selected by tracing a vertical line to tangent the inner end of each radiopaque marker, then another horizontal line traced to perpendicular and connects between each two opposed vertical lines at the level of each pair of markers(8). The length of the horizontal line was measured to represents the alveolar bone thickness.

The comparison between the corrected radiographic measurements with modified paralleling technique and direct alveolar bone thickness (D1, D2, D3, and D4) show there was no significant difference between the two methods of measurements ($P \geq 0.05$) in anterior and posterior segments of both maxillary and mandibular arches (Tables 1 and 2).

These results related to that the intraoral periapical radiography using the parallel technique provides planar image at least twice the resolving power of extraoral radiography. It was recommended method for a high accuracy in measurements can be obtained.[32]

Accurate measurement can be hampered by the presence of distortions on intraoral periapical radiographs. Distortions can be in the form of elongations or foreshortenings.[26] The apparent radiographic measurements of alveolar bone thickness by modified paralleling technique suffering from distortion as shortening. Because the shape distortion can be occur if the center of the x-ray beam was directed at right angles to the object but the object is not parallel to the image receptor, then an elongated image was produced. If the center of the beam was directed at right angles to the image receptor but was angled in relation to the object, then a distorted, foreshortened image will be produced.[33] Therefore, the amount of distortion in the linear measurements corrected mathematically by dividing their values to the cosine 55° angle, in order to obtain the real radiographic bone thickness.

This method come in agreement with the mathematical correction of the radiographic measurements suggested by Yunus[5] study in (2009) by evaluates the difference of radiographic imaging of dental implant size which is going to be placed in patient before and after correction by using the panoramic, periapical, and occlusal radiographic techniques. A metal ball with 6 mm in size is used for correcting the radiographic results. The difference is appeared as a correction parameter value and it is used as a subtracted value. The size of dental losing area which is measured in certain radiographic method is subtracted with the difference value or correction parameter value to get the real size of alveolar bone space.

To derive three-dimensional information, two or more periapical radiographs can be taken with different horizontal projections of the x-ray beam, while the receptor must be parallel to the alveolar ridge axis in order to produce a perpendicular radiographic slice. However an oblique x-ray beam direction makes the anatomic details of jaw bone look blurred.[34] The radiographic images taken with modified paralleling technique suffering from inherent poor resolution and they are used for linear measurements only, because the distortion practically obliterated the regular shape of the objects. This effect has great importance in visualization and detection of the trabecular pattern of bone, which may become unclear due to three-dimensional distortions.[35]

One way of minimizing distortions was the parallel placement of radiographic film and object (implant site) which controlled by the film holding device.[26] For this reason, the modified Rinn – XCP film holder which designed for this study used to control the amount of the horizontal x-ray beam inclination (30 °angle) and maintain the parallel relationship between the examined site and the image receptor.

The use of thirty degree shifted horizontal angulation between two periapical radiographs proposed by Berketa and his group[1] in (2010) to evaluate and clarify the threat design of dental implant. Also, Hishikawa et al., (2010) recommended that intraoral radiographs should be taken at different horizontal x-ray beam angles (-30° to +30°) to reduce the risk of missing furcation involvement.

CONCLUSION

Three-dimensional information could be obtained from two or more periapical radiographs taken with different horizontal projections of the x-ray beam, while the receptor must be parallel to the alveolar ridge axis in order to produce a perpendicular radiographic slice. The film holding device designed for the modified technique recommended to use for standardization, reproduction and simplicity of technical application.

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