Dimension distortion of digital panoramic radiograph on posterior mandibular regions

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Abstract

Objectives: To determine the accuracy of the vertical and horizontal measurements on digital panoramic radiographic images using implants in the posterior mandibular regions and to compare the vertical and horizontal distortions of digital panoramic radiographic images.

Materials and methods: 74 implants in 21 females and 20 males at mean age of 57 years with postoperative panoramic radiographs were taken with KODAK 9000 C (Eastman Kodak Company, Rochester, NY). The length and width of placed implants in the posterior mandibular regions were measured by digital caliper of Synapse® software. The difference in width and length between the implant radiographic images and the actual implant was presented by magnification rate. The distortion of vertical and horizontal measurement was also analyzed.

Results: The magnification rate of the width and length of implant radiographic images was 111.36 ± 5.81% and 104.86 ± 2.87%, respectively. The magnification rate of the width and length of the implant radiographic images was significantly higher than the actual implant ($P<0.05$). There was difference between the magnification rate in width and length of about 6.50 ± 6.26% that was significant ($P<0.05$).

Conclusions: Digital panoramic radiographic images had distortions in both vertical and horizontal dimensions. The horizontal distortion was higher than the vertical distortion and there was significant difference. Our findings may be useful in informing clinicians to practice using digital panoramic radiographic images with caution for determining the pre-operative implant width and length in posterior mandibular regions.

Keywords: digital panoramic radiographic images, dental implant, horizontal distortion, vertical distortion

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Introduction

Radiographs are important for dental practitioners to diagnose and evaluate many oral diseases. Moreover, dental practitioners use radiographs for treatment planning in many dental fields. There are various types of intraoral and extraoral radiographs used in dentistry such as periapical radiograph, bitewing radiograph, occlusal radiograph, lateral cephalometric radiograph, panoramic radiographs, etc.

Panoramic radiographs present a comprehensive overview of the maxillofacial complex and are accessible and impartial to a low radiation dose, while providing the best radiographic survey[1,2]. Panoramic radiographs serve as an additional examination tool for diagnosis and screening[3]. This technique is also applied in many dental fields such as orthodontics, oral maxillofacial surgery, prosthodontics, and general dentistry.

Panoramic radiographs, as standard radiographic examination tools, are widely used in order to plan an implant treatment to evaluate the bone quality, bone quantity, anatomical limitations and dimensions of potential implant site[4-6]. Pre- and postoperative panoramic radiograph are often *described*.

There are two types of panoramic radiographs used in dentistry: conventional and digital panoramic radiographs [1]. The basic principle of digital panoramic radiography is similar to the technique used in conventional machines. A radiographic image of curved plane approximating to the jaws is produced on a narrow two-dimensional detector by linking the rotation of the narrow X-ray beam and the detector around the patient's head. The movement of the charge-carrier is synchronously controlled in such a way that the speed is matched to the speed of objects within the central plane of the image layer. Objects located outside the center of the sharply depicted plane are reproduced with characteristic distortions. An object situated between the central plane and the effective rotation center is magnified, while the one located between the central plane and the film is a minified. Distortion arises because the degree of magnification varies in the horizontal and vertical planes[2]. Owing to varying magnification, reference objects with known dimensions are required to determine the exact magnification in a particular area.

For conventional panoramic radiographs, dental implants of known length are easily measured with a sliding caliper to determine the unit's magnification factor[1]. With digital panoramic radiography, the dentist can measure the size of the dental implant in two methods, using software application that is installed with radiography (panoramic unit proprietary measurement software[1,2], such as KODAK 9000 (Eastman Kodak Company, Rochester, NY), and extra-source workstation imaging viewer software such as IMPAX® (Agfa, Belgium), Synaspe® (Fujifilm, USA), which dentists are more likely to use to measure the size of implant because digital panoramic radiographs are widely used at present.

The distortion of digital panoramic radiographic images may affect the determination of the pre-operative implant placement. If there is an error in the estimated implant size, it may damage the critical anatomical structure such as the mandibular canal and the floor of maxillary sinus. Finally, given this, patients tend to have complications after procedure. There are many studies evaluating the accuracy of vertical and horizontal measurements in panoramic radiographs, however, they have yielded controversial results[2,7-14]. One study[7] mentioned about the measurement accuracy on the distortion or magnification in both vertical and horizontal measurements of digital panoramic radiographs using implant. To our knowledge, there is no study using the Synapse® software imaging tool in hospital computerization to

measure the length and width of the implant for determining radiographic image distortions. This study is aimed to determine the accuracy of the vertical and horizontal measurements on digital panoramic radiographic images using implants in the posterior mandibular regions and to study the vertical and horizontal distortions of digital panoramic radiographic images.

Materials and methods

This study was a retrospective study, conducted in the Department of Advanced General Dentistry, Faculty of Dentistry, Mahidol University, Thailand. The sample group was gathered from the digital panoramic radiographic images with implant in posterior mandibular regions.

Patient and radiograph selection

Enrolled patients were selected from the SSB HIS software database (dental implant record) at the Advanced General Dentistry clinic, Advanced Center clinic, Implant Center clinic, and Oral and Maxillofacial clinic at the Faculty of Dentistry, Mahidol University, Thailand. All patients obtained implant placement on the posterior mandibular regions with bone level implant during January 1, 2014 and December 31, 2015. Implant's diameter and length had been recorded in OPD cards. Moreover, post-operative digital panoramic radiograph with healing abutment or cover screw of posterior mandibular implants had also been recorded. The digital panoramic radiographic equipment used was the KODAK 9000 C (Eastman Kodak Company, Rochester, NY). All digital panoramic radiographs were taken by technicians according to standard protocol provided by the manufacturer. Panoramic radiographic images with pathologic bone lesion, artifact or blur and healing abutment or cover screw that may interfere with reference points for implant measurement by Synapse image tool's ruler were excluded from this study.

The total number of implants included in this study was 74, with 21 females and 20 males and a mean age of 57 years. The 18 implants (24.32%) were inserted in the premolar region whereas others (56, 75.68%) were implanted in the molar region. The 39 implants (52.7%) were located in the left posterior segment and 35 implants (47.3%) on the right posterior segment of the mandible. 19 patients had single implant, 15 patients had 2 implants, 4 patients had 3 implants, 2 patients had 4 implants, and 1 patient had 5 implants. Table 1. showed the seven brands implant that included Astratech, Strauman, Ostem, Zimmer, Intralock, AnyRidge, and PW plus systems and number of patients in each system. Included implant's widths and lengths were described in Figure 1. and 2.. All radiographic images were analyzed under standard conditions by one observer (AR) who was her training in advanced general dentistry. Measurements of the dental implant size in digital radiographic image were done three times for each implant and there was repeated measurement after one week to ensure the accurate results.

Evaluation of radiographic implants

The length and width of the placed implants in posterior mandibular regions were measured by digital caliper of Synapse® software. The vertical distance was measured from the upper to the lower border of the implant fixture and the horizontal distance was measured from

Table 1 Implant's brands of enrolled patients in this study.

Amount	Implant's brands							
	Astratech	Strauman	Osstem	Zimmer	Intralock	AnyRidge	PW plus	Total
Implant	30	16	10	6	5	5	2	74
Patient	16	9	8	3	2	1	2	41

the topmost of the first thread level to the bottommost of this level (Figure 3.).

Figure 3 This image is a digital panoramic radiograph. It displays on computer screen and shows implant maesurement. Implant's width of tooth no. 37 area and implant's length of tooth no.45 area were measured by digital caliper of Synapse® software. The scale was labeled with a millimeters (mm) unit. The length was measured from the upper to the lower border of the implant fixture and the width was measured from the topmost of the first thread level to the bottommost of this level.

Statistical analysis

The magnification rate (MR) was calculated for each implant using the following formula:

$$\text{The magnification rate of length (\%)} = \left(\frac{\text{The length of implant on digital radiographs}}{\text{The length of actually placed implant fixture}}\right)\times 100$$

$$\text{The magnification rate of width (\%)} = \left(\frac{\text{The width of implant on digital radiographs}}{\text{The width of actually placed implant fixture}}\right)\times 100$$

Statistical analysis was conducted with SPSS version 18 (SPSS Inc, Chicago, IL). Student t-test was used to examine if the width or length of the implant radiographic images was statistically different from the width or length of the actual implant. In addition, to examine if the difference of MRs of width was statistically different from the difference of MRs of length, the pair t-test was applied. Implant radiographic images were measured six times by one observer (AR). Intra-observer reliability was estimated by using intra-class correlation coefficient (ICC).

Results

The width of the implant on radiographs was significantly higher than the width of the actual implant fixture with about 0.51 mm (±0.27mm, $P<0.0001$). The length of the implant on radiographs was significantly higher than the length of the actual implant fixture with about 0.48 mm (±0.25 mm, $P<0.0001$) (Table 2).

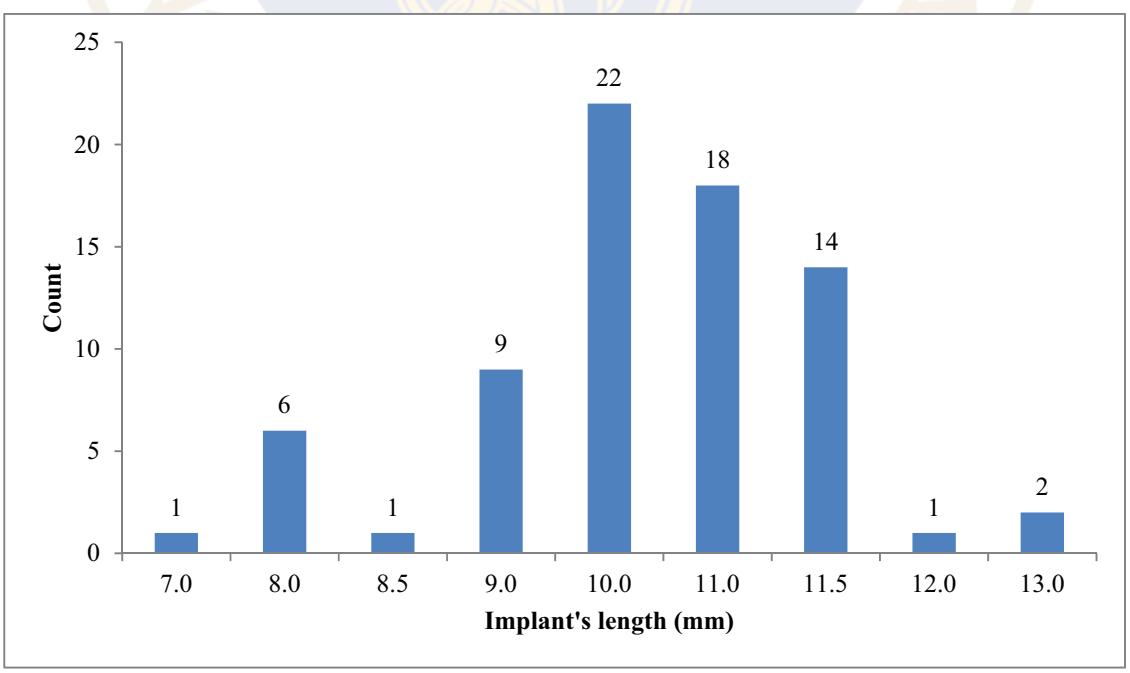

Figure 1 Number of implants in each length of the implant.

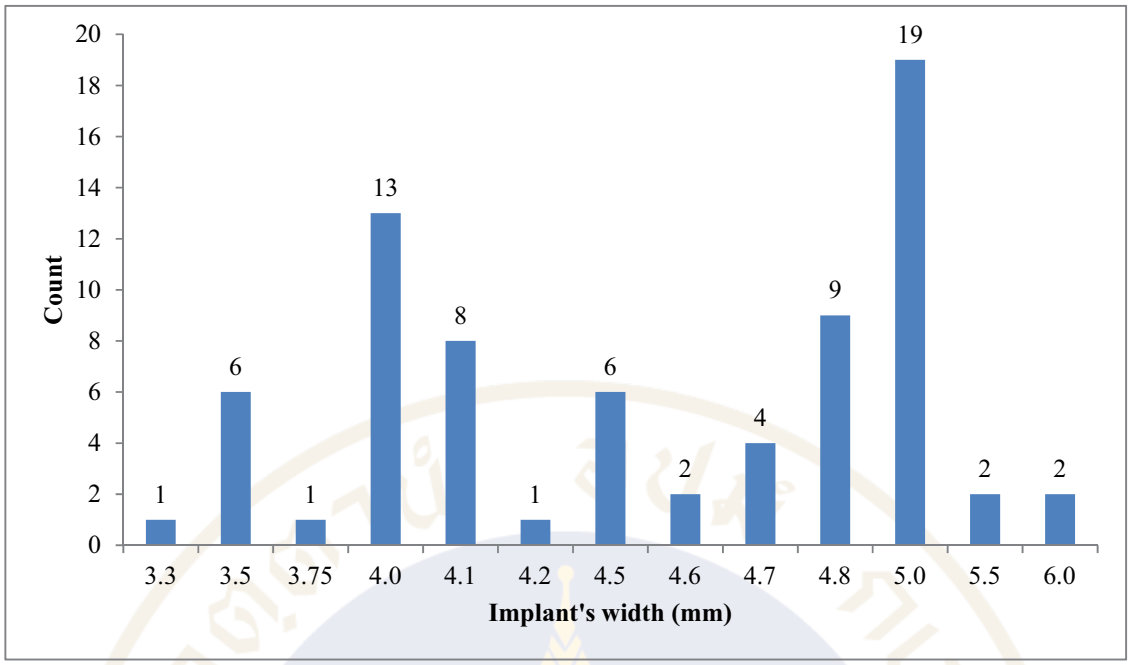

Figure 2 Number of implants in each width of the implant.

Figure 3 Implant's width of tooth no. 37 area and implant's length of tooth no.45 area were measured by digital caliper of Synapse® software. The scale was labeled with a millimeters (mm) unit.

Table 2 Mean difference of width and length in implant radiographic images.

Radiographic measurement	n	Mean difference (mm)	SD	*p* value
Width	74	0.51	0.27	<0.0001
Length	74	0.48	0.25	<0.0001

MR of the width and length of the implant radiographic images was 111.36 ± 5.81% and 104.86 ± 2.87%, respectively (Table 3.). MR of the width and length of the implant radiographic images was significantly higher than actual implant (P<0.0001). There was the difference between magnification rate of width and length about 6.50 ± 6.26% that was significantly (P<0.0001).

Intra-observer reliability of radiographic implant width is the same value as length which were shown with 0.99, (95% CI) high reliability of the measurement done six times.

Discussions

Panoramic radiography is often the first choice method for the placement of implants because it provides information on the overall shape of the jaws, the position of the maxillary sinus floor and the nasal cavity floor, and the proximal distal as well as vertical position of the mandibular canal and the mental foramen. In addition, it provides information on the presence or absence of residual dental roots or asymptomatic lesions in the dental root apex, lesions within the bone, the interval between remaining teeth, etc.[7].

Factors causing the distortion of images on panoramic radiography include the head position, tooth location within the dental arch, shape of the dental arch, and type of panoramic equipment[12]. Positioning errors commonly occur in panoramic radiography. The focal plane (image layer) in panoramic radiography has limited dimensions. Therefore, minor positioning errors can cause image distortions such as unequal vertical and horizontal magnifications, the appearance of overlapping teeth, and the loss of image sharpness[15]. If images are taken properly, by adjusting the position of patients, panoramic radiographs are sufficiently accurate for the measurement of the vertical dimensions and can reduce the magnification of panoramic radiograph[7,14]. Studies of accuracy of digital panoramic radiographs to pre-operative assessment tool in the implant size placement were represented by the magnification factor (MF) or the magnification rate (MR) or the distortion ratio (DR). Park[5] reported that the MF was 126.8 ± 8.1% in vertical plane. Vazquez L, et al.[13] reported that the vertical MF was 1.27 ± 0.01 and also they also performed vertical DR with 0.99[1]. Kim YK, et al.[7] reported that the magnification rate of the width and length of the inserted implants, seen in the digital panoramic radiographs, was 127.28 ± 13.47%, and 128.22 ± 4.17%, respectively. Previous four studies[1,7,5,13] concluded that digital panoramic radiographs showed sufficient accuracy for pre-operative implant length evaluation in the posterior mandibular regions (P<0.05). In this study, the horizontal MR was 111.36 ± 5.81% and the vertical magnification rate was 104.86 ± 2.87%. Moreover, the MR of the width and length of the implant radiographic images was significantly higher than the actual implant (P<0.05). Our results could imply that the accuracy of the vertical and horizontal measurements of implants in digital panoramic radiographic images was not appropriate to determine the pre-operative implant width and length in posterior mandibular regions. The conclusion of our study corresponded to Yim, et al.[12] that concluded that adapting a single

Table 3 Magnification rate of horizontal and vertical measurement.

Radiographic measurement	n	MR (%)	SD	p value
Width	74	111.36	5.81	<0.0001
Length	74	104.86	2.87	<0.0001

magnification ratio for evaluating panoramic radiography in implant treatment planning is not appropriate and thus the magnification ratio must be adapted according to the respective standard value of the implant site. Also, the use of the recently well-developed CBCT is recommended for greater accuracy. Their study also reported MRs that the two types of panoramic equipment were 1.27 (Ortho stage) and 1.17 (Promax). However, MR varied according to the tooth location and the type of panoramic equipment used. Previous studies can be applied for each specific tooth area and panoramic equipment.

In recently, some studies [12,16] recommended using CBCT for evaluation of the pre-operative implant size because magnification of images did not occur and CBCT improves the ability of predicting the actual implant length and reduces inaccuracy in surgical dental implant planning.

Our study presented that implant radiographic images were significantly wider than implant actual width with 0.51 mm (±0.27mm, $P<0.05$) and they were longer than the implant actual length of 0.48 mm (±0.25 mm, $P<0.05$). Both values are clinically insignificant because dentists often perform the procedure by leaving distance between the implant and critical anatomical area to avoid complication. Greenstein G and Tarnow D[17] created clinical guidelines to avoid nerve injury during surgery in the foraminal area. The guidelines were developed based on the literature with respect to verifying the position of the mental foramen and validating the presence of an anterior loop of the mental nerve. These guidelines included leaving a 2 mm zone of safety between an implant and the coronal aspect of the nerve; observation of the inferior alveolar nerve and mental foramen on panoramic and periapical films prior to implant placement; and use of CT scans when these techniques do not provide clarity with respect to the position of the nerve. In order to identify the location of inferior alveolar nerve (IAN), most clinicians use conventional radiography (e.g., panoramic views, periapicals), which is sufficient for most cases[18]. Panoramic radiographs can be used safely for most cases but with some limitations. A 2 mm safety zone between the apical part of the implant and the upper border of the IAN canal is strongly recommended by most implant manufacturers and practitioners. The magnification of the X-ray machine must be known; some recommend placing an object of known dimension in the mouth before taking the radiograph. This technique allows accurate calculation of the dimensional changes in the panoramic radiograph[19].

In conclusion, Digital panoramic radiographic images had distortions in both vertical and horizontal dimensions. The horizontal distortion was higher than the vertical distortion and there was significant difference. Our findings may be useful in informing clinicians to practice using digital panoramic radiographic images with caution for determining the pre-operative implant width and length in posterior mandibular regions.

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