Oral Radiol (2010) 26:16–19
DOI 10.1007/s11282-010-0038-5

ORIGINAL ARTICLE

Is linear distance measured by panoramic radiography reliable?

K. Nishikawa · A. Suehiro · H. Sekine · Y. Kousuge · M. Wakoh · T. Sano

Received: 28 January 2010 / Accepted: 23 March 2010 / Published online: 21 April 2010

Abstract
Objectives To re-examine the reliability of distance measurements on clinical panoramic radiographs by comparing them with computed tomography (CT) images, from which the most accurate distance measurement is possible.
Methods Twenty pairs of images from patients examined both with panoramic radiography and CT for dental implant treatment planning in the premolar and molar regions of the mandible were used. The vertical linear distance between the alveolar crest and the closest mandibular canal was measured by three experienced oral radiologists on both images. The distances measured on panoramic radiographs were corrected for the magnification factor at the focal plane. Double-oblique cross-sectional images were used for CT. Pearson's correlation coefficient was calculated between distances obtained from both images. The paired *t* test was performed for statistical comparison. Error levels with the panoramic radiograph versus the CT image were also calculated.
Results Pearson's correlation coefficient showed a significant strong linear correlation ($R = 0.90$; $p < 0.01$). However, the corrected value of distance measured on panoramic radiographs tended to be too small, and a significant difference was observed ($p < 0.05$). The error level was approximately 10% (9.6 ± 7.3%).
Conclusions Distance measurement on clinical panoramic radiographs is less reliable than CT images and cannot be recommended.

Keywords Panoramic radiography · Distance · Measurement · CT

Introduction

Assessment of available alveolar bone is essential in dental implant treatment planning. Although computed tomography (CT) is considered to be the best preoperative imaging technique to evaluate bone morphology and measure distances three-dimensionally [1–3], panoramic radiography is frequently used as a simple, low-cost, and low-dose diagnostic tool [4]. While the efficacy of CT for linear distance measurements at implant recipient sites has been demonstrated in many studies [1, 2, 5–8], many reports argue that panoramic radiography is sufficiently reliable for the evaluation of available bone height [9–11]. The purpose of this study was to re-examine the reliability of distance measurements on clinical panoramic radiographs by comparing them with CT images, from which the most accurate distance measurement is possible.

Materials and methods

Twenty pairs of images from patients examined both with panoramic radiography and CT for dental implant treatment planning in the premolar and molar regions of the mandible were used. All images were obtained with diagnostic stents to decide the position and the inserting direction of implants, and were sequentially selected from

K. Nishikawa (✉) · M. Wakoh · T. Sano
Department of Oral and Maxillofacial Radiology, Tokyo Dental College, 1-2-2 Masago, Mihama-ku, Chiba 261-8502, Japan
e-mail: knishi@tdc.ac.jp

A. Suehiro · H. Sekine · Y. Kousuge
Department of Radiology, Chiba Hospital, Tokyo Dental College, 1-2-2 Masago, Mihama-ku, Chiba 261-8502, Japan

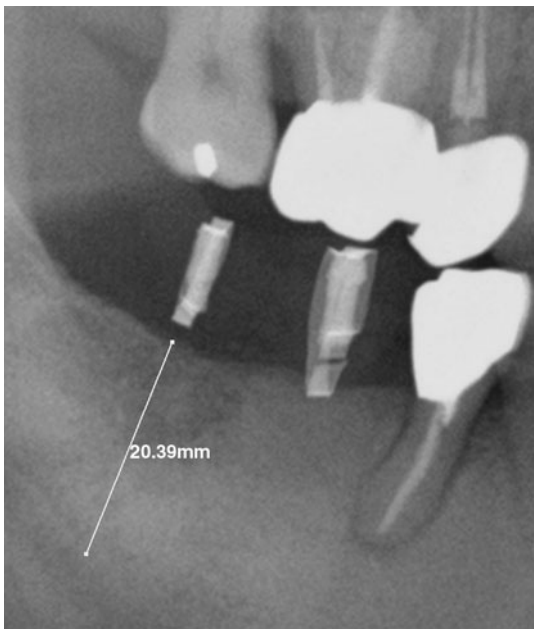

Fig. 1 Measurement of linear distance on a panoramic radiograph

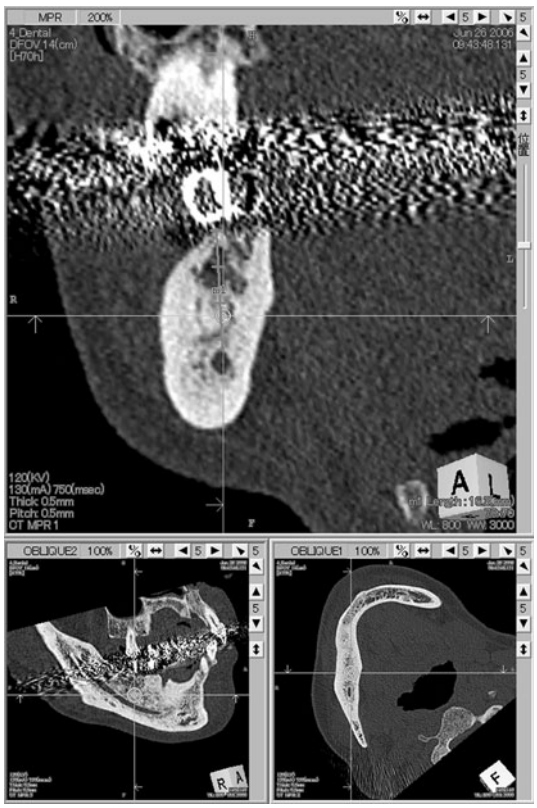

Fig. 2 Measurement of linear distance on a CT image

image inspection records. Panoramic radiographs were obtained digitally with a computed radiography system (FCR5000R plus; Fuji Film Co., Tokyo, Japan) and a panoramic X-ray unit (Veraviewepocs; Morita Co., Kyoto, Japan). The CT images were obtained with a SOMATOM Plus4 VolumeZoom (Siemens AG, Erlangen, Germany). Slice thickness was set at 0.5 mm.

The vertical linear distance between the alveolar crest and the mandibular canal was measured by three experienced oral radiologists on both images. Two measurement points on each image were chosen, referring to the position and the direction of the stent. Measurement on the panoramic radiograph was performed by using a DICOM viewer software (AOC; Array Co., Tokyo, Japan), as shown in Fig. 1. The measured distance was corrected for the magnification factor at the focal plane. According to the manual provided by the manufacturer, the magnification factor of the unit used at the focal plane is constant, at 1.3. This factor was also verified experimentally [12]. The value corrected with the magnification factor at the focal plane was used as the distance obtained from the panoramic radiograph. Measurements on the CT image were performed three-dimensionally, using 3D DICOM viewer software (ExaVision LITE; Ziosoft Inc., Tokyo, Japan), which enables multiplanar reconstruction to be carried out, as shown in Fig. 2. Double-oblique cross-sectional images were used for measurements.

Pearson's correlation coefficient was calculated between distances measured from CT images and distances obtained with panoramic radiographs. The paired t test was performed for statistical comparison between them. Error levels were also calculated with the following formula:

$$\text{Error level} = \left(\left|D_c - D_p\right|/D_c\right) \times 100(\%),$$

where D_c and D_p are distances measured on CT images and distances obtained with panoramic radiographs, respectively. Calculations and statistical analyses were carried out by using Excel 2007 (Microsoft Co., Ltd, Tokyo, Japan).

Results

Figure 3 shows a scatter diagram between distances measured on CT images and distances obtained with panoramic radiographs. Pearson's correlation coefficient showed a significant, strong linear correlation ($R = 0.90$; $p < 0.01$). The distances obtained, however, are not systematically distributed on the same line. Also, the distances obtained with panoramic radiographs tended to be too small. As indicated in Table 1, a significant difference was observed between them ($p < 0.05$). The error level with panoramic radiographs versus CT images was approximately 10% ($9.6 \pm 7.3\%$; Table 2).

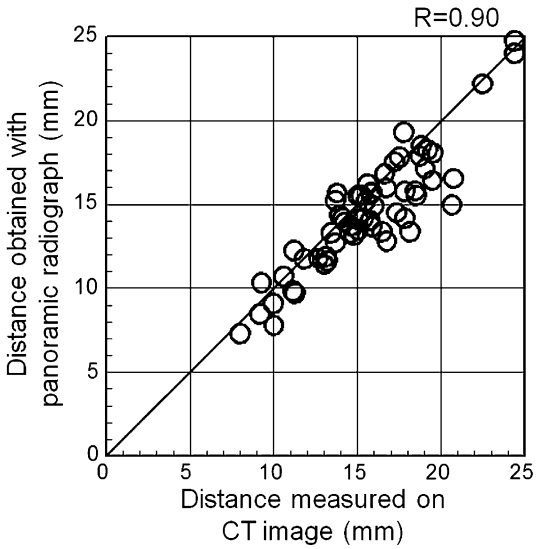

Fig. 3 Agreement of distances measured on CT images and distances obtained with panoramic radiographs

Table 1 Statistical analysis of distances measured on CT images and distances obtained with panoramic radiographs ($p = 0.04$)

	CT image	Panoramic radiograph (corrected value)
Mean (mm)	15.7	14.4
Standard deviation (mm)	3.5	3.4

Table 2 Error level with panoramic radiographs versus CT images

Range (%)	0.1–28.3
Mean (%)	9.6
Standard deviation (%)	7.3

Discussion

Although distances measured on CT images and distances obtained with panoramic radiographs showed a strong correlation, the agreement was poor. The correlation coefficient is an index representing only correlativity between two data sets. A high correlation coefficient in some comparison group versus a control group does not mean consistency. Specifically, a high correlation coefficient between panoramic radiography and CT, with which distance can be measured accurately, does not ensure the reliability of panoramic radiography in terms of distance measurement. In fact, the error level of about 10% is generally unacceptable in measuring a physical quantity. Thus, we do not recommend distance measurements with panoramic radiography because they are not as reliable as those with CT, which is recognized as the most reliable method for distance measurement.

This unreliability is due to two reasons, which can be explained theoretically [13]. The first is the magnification factor, which is position-dependent. The vertical and horizontal magnification factors are identical at the focal plane, but the factors in both directions vary differently at sites other than the focal plane. While the vertical magnification factor varies relatively slowly with distance from the focal plane, the horizontal magnification factor varies rapidly. That is, structures at sites other than the focal plane are not only magnified with a different magnification factor, but are magnified differently in the vertical and horizontal directions. The second is the incident angle of X-rays to structures. X-rays are not necessarily directed perpendicularly to the straight line used to measure distance. In this case, the corrected value of distance becomes smaller than the actual one. The unreliability caused by these two factors cannot be remedied by any correction method. Moreover, variation in positioning of patients further complicates the effects and decreases the reliability of distance measurement on panoramic radiographs [14, 15]. Thus, we conclude that distance measurements from clinical panoramic radiographs are less reliable than those from CT images and are not recommended.

References

1. Tyndall DA, Brooks SL. Selection criteria for dental implant site imaging: a position paper of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000;89:630–7.
2. White SC, Heslop EW, Hollender LG, Mosier KM, Ruprecht A, Shrout MK. American Academy of Oral and Maxillofacial Radiology, ad hoc Committee on Parameters of Care. Parameters of radiologic care: an official report of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2001;91:498–511.
3. de Morais JA, Sakakura CE, Loffredo Lde C, Scaf G. A survey of radiographic measurement estimation in assessment of dental implant length. J Oral Implantol. 2007;33:186–90.
4. Sakakura CE, Morais JA, Loffredo LC, Scaf G. A survey of radiographic prescription in dental implant assessment. Dentomaxillofac Radiol. 2003;32:397–400.
5. Wakoh M, Harada T, Otonari T, Otonari-Yamamoto M, Ohkubo M, Kousuge Y, Kobayashi N, Mizuta S, Kitagawa H, Sano T. Reliability of linear distance measurement for dental implant length with standardized periapical radiographs. Bull Tokyo Dent Coll. 2006;47:105–15.
6. Hedeşiu M, Balog C, Preda DM, Băciuţ G, Băciuţ M, Fildan F, Pop A, Maier M. The accuracy of alveolar crest dimensions measurement for dental implants In vitro study. Rev Med Chir Soc Med Nat Iasi. 2008;112:224–8.
7. Madrigal C, Ortega R, Meniz C, López-Quiles J. Study of available bone for interforaminal implant treatment using cone-beam computed tomography. Med Oral Patol Oral Cir Bucal. 2008;13:E307–12.
8. Peker I, Alkurt MT, Michcioglu T. The use of 3 different imaging methods for the localization of the mandibular canal in dental

implant planning. Int J Oral Maxillofac Implants. 2008;23:463–70.
9. Akdeniz BG, Oksan T, Kovanlikaya I, Genç I. Evaluation of bone height and bone density by computed tomography and panoramic radiography for implant recipient sites. J Oral Implantol. 2000;26:114–9.
10. Frei C, Buser D, Dula K. Study on the necessity for cross-section imaging of the posterior mandible for treatment planning of standard cases in implant dentistry. Clin Oral Implants Res. 2004;15:490–7.
11. Vazquez L, Saulacic N, Belser U, Bernard JP. Efficacy of panoramic radiographs in the preoperative planning of posterior mandibular implants: a prospective clinical study of 1527 consecutively treated patients. Clin Oral Implants Res. 2008;19:81–5.
12. Welander U. A mathematical model of narrow beam rotation methods. Acta Radiol Diagn. 1974;15:305–17.
13. Langland OE, Langlais RP, McDavid WD, DelBalso AM. Panoramic radiography. 2nd ed. Philadelphia: Lea Febiger; 1989.
14. Batenburg RHK, Stellingsma K, Raghoebar GM, Vissink A. Bone height measurements on panoramic radiographs. The effect of shape and position of edentulous mandibles. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1997;84:430–5.
15. Laster WS, Ludlow JB, Bailey LJ, Hershey HG. Accuracy of measurements of mandibular anatomy and prediction of asymmetry in panoramic radiographic images. Dentomaxillofac Radiol. 2005;34:343–9.