RESEARCH

The effects of location of alveolar crest on the vertical bone heights on panoramic radiographs

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Objectives: This study aimed to show that the horizontal relationship between the mandibular canal and the alveolar crest can influence the available bone height (ABH) measurement on panoramic radiographs.

Methods: 92 mandibular edentulous sites of panoramic computed radiographs and reformatted CT images of 77 patients were used. Selected CT images were categorized into four types according to the relative location of the peak of the alveolar crest to the mandibular canal. One oral and maxillofacial radiologist measured the ABH twice on both imaging modalities with an interval of 7 days and compared the measurement differences according to the type.

Results: The absolute average value of the differences in measurement between the values of ABHs on panoramic images and CT images was 0.97 mm. Significant difference was found only between the mean values of ABHs for Type 1 (0.60 mm), where the alveolar crest is located in the buccal side or central area with respect to the mandibular canal, and Type 4 (1.46 mm), where the alveolar crest is in the lingual side to the mandibular canal ($p < 0.05$).

Conclusions: The relative horizontal location of the alveolar crest with respect to the mandibular canal affected the ABH measurement on panoramic radiographs. In particular, ABH is overestimated when there has been resorption of the buccal aspect of the ridge, moving the alveolar crest lingually.

Dentomaxillofacial Radiology (2012) **41**, 117–121. doi: 10.1259/dmfr/76750112

Keywords: panoramic radiography; inferior alveolar nerve; alveolar ridge; X-ray computed tomography

Introduction

Accurate assessment of alveolar ridge morphology and inferior alveolar canal location is critical in the pre-surgical planning phase for dental implant therapy.¹ Panoramic radiography is readily available and provides a view of many structures of the maxilla and mandible at a low cost. However, image magnification and lack of cross-sectional information are the major disadvantages of this image modality for treatment planning. In spite of these disadvantages, panoramic radiography has been the most common single radiographic examination used in the implant treatment planning.² Beason and Brooks³ determined the types of

imaging used for pre-operative implant site assessment in a random sample of the dentists in south-east Michigan, USA. The results showed that more than 95% of the dentists take panoramic radiographs of at least 80% of patients. Over 90% responded that they never prescribe either conventional tomography or CT.⁴ Such dependence on panoramic images should be accompanied by handling the errors of panoramic images. The errors of panoramic images are mostly caused by the inaccuracy of positioning patients.⁵ Therefore, the panoramic radiograph has been considered as a viable tool to measure the available bone height (ABH) only if it is equipped with accurate position and a proper magnifying factor.⁶

However, the hypothesis in this research believes that the errors in ABH on panoramic images are

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Received 20 July 2010; revised 9 December 2010; accepted 21 December 2010

inevitable owing to the upward X-ray beam of a panoramic radiography machine, even if they are well taken with accurate positioning.

This study reports the variance of ABH measurements according to the horizontal relationship of the mandibular canal and the alveolar crest.

Materials and methods

Data acquisition

Among the CT images of the 507 patients (242 male, 265 female) who were taken for implant installation in the Seoul National University Dental Hospital from February 2004 to December 2005, 685 reformatted sagittal CT images for the edentulous mandibular molar area were selected retrospectively for this study, excluding images of extraction socket, retained root and severe alveolar root resorption. All patients were partially or totally edentulous in the mandibular molar regions. Among them, either panoramic images or CT images with blurred images of the mandibular canal or indistinct cortical outlining of alveolar crest were excluded. 92 sites of panoramic computed radiographs (CR) and CT were taken for 77 patients. The imaging protocols of panoramic radiographs and CT in our department are as follows: panoramic radiographs were taken in accordance with the optimum standard provided by the manufacturers. Two types of machines for the panoramic radiographs (Orthopantomograph OP100, Instrumentarium Corp., Tuusula, Finland, and Cranex 3+ PAN, Orion Corporation Soredex, Helsinki, Finland) and one CT machine (Somatom Sensation 10, Siemens AG, Forchheim, Germany) were used in this study. All CR panoramic images were taken using a PSP (photostimulable phosphor) image plate (12 × 10 inch) and were displayed on the FCR system (Fuji Computed Radiography 5000R, Fuji Photo Film Co. Ltd, Dusseldorf, Germany). The acquired digital raw images (2010 × 1670 pixels, 10-bit, 6.7 pixels mm⁻¹) were distributed to PACS (picture archiving and communication system) workstations through the PACS server.

Implant CT images were taken parallel to the occlusal plane of the mandible in the presence of a surgical stent at the installation sites of implant fixtures, and the surgical stent contained indicating rods in the direction of the installations. The implant CT reconstruction images were acquired from the program built in the CT machine. The CT scan procedure was performed with 0.75 mm of axial cross-sectional slice thickness at 0.5 mm slice intervals, 120 kVp and 100 mAs.

Classification of alveolar bone shape

The alveolar ridge morphology was categorized into four types according to the relative horizontal location of the peak of the alveolar crest to the mandibular canal on reformatted cross-sectional CT images (Figure 1).

Figure 1 Four types of locations of the peak point of the alveolar crest with respect to the mandibular canal. A, peak point of alveolar crest; B, vertical line passing through the centre of the mandibular canal and perpendicular to the lower border of each imaging. Type 1: $x \leq 0$ mm, Type 2: $0 \text{ mm} < x \leq 2 \text{ mm}$, Type 3: $2 \text{ mm} < x \leq 4 \text{ mm}$ and Type 4: $x > 4 \text{ mm}$. A negative value of x means that the peak point of the alveolar crest is positioned in the buccal side

Type 1: the peak point of the alveolar crest was positioned in the buccal side or centre in comparison with the vertical line passing through the centre of the mandibular canal and perpendicular to the lower border of each image.

Type 2: the peak point of the alveolar crest was positioned in the lingual side and the distance from the vertical line was less than 2 mm.

Type 3: the peak point of the alveolar crest was positioned in the lingual side and the distance from the vertical line was greater than 2 mm and less than 4 mm.

Type 4: the peak point of the alveolar crest was positioned in the lingual side and the distance from the vertical line was greater than 4 mm.

Measurement

The ABH was defined as the distance between the line tangential to the upper border of the mandibular canal and the line tangential to the peak of the alveolar crest, which are both parallel to the lower border of the image measured on the reformatted cross-sectional CT images (Figure 2) and as the corresponding distance measured on the panoramic radiographs.

The ABHs in the panoramic radiographs were measured with standardization.

The measurement standardization used in this study was as follows:

- A reformatted CT panoramic view was used to find the exact location on the panoramic radiograph corresponding to the location where the ABH was measured on CT.
- The distance from the centre of the root canal of the nearest tooth to the indicating rod at the alveolar crest on the CT panoramic view was multiplied by

Figure 2 The definition of the available bone height (ABH)

1.3, the magnifying factor of the panoramic radiography machine as suggested in the user's manual. The virtual indicating rod on panoramic images was assumed to be located at the magnified distance away from the centre of the root canal of the nearest tooth (Figures 3 and 4).

- The angle between the long axis of the centre of the root canal of the nearest tooth and the parasagittal plane on CT panoramic view allowed observers to measure the ABH on panoramic images which were parallel to the parasagittal plane (Figure 3).

M-view TM PS (Infinit, Seoul, Republic of Korea) was used to measure the distances and angles. One oral and maxillofacial radiologist measured the ABH twice on both imaging modalities with an interval of 7 days and compared the measurement differences according to the type.

Statistical analysis

The relationship between the alveolar bone shape and the degree of difference of the ABHs from the panoramic radiographs compensated for the magnifying factor and those of CTs were verified using ANOVA. Total difference was defined as the absolute average value of the differences between the mean

Figure 3 The location where the available bone height was measured on CT panoramic view

values of two ABHs on panoramic images and on CT images of the total cases. Type 1 difference was defined as the absolute average value of the differences between the mean values of two ABHs on panoramic images and on CT images of Type 1. Type 2–4 differences were defined in the same manner as Type 1 difference.

Type 1–4 differences were used to determine whether there was statistically significant discrepancy by using ANOVA. Statistical analysis was performed using SPSS for Windows (version 12.0, SPSS Inc., Chicago, IL) and $p < 0.05$ was considered to indicate statistical significance.

Results

The total 685 reformatted sagittal CT images consisted of 105 cases for Type 1, 195 cases for Type 2, 253 cases for Type 3 and 132 cases for Type 4. The selected 92 cases consisted of 20 cases for Type 1, 20 cases for Type 2, 31 cases for Type 3 and 21 cases for Type 4. Type 1 difference was 0.60 mm, Type 2 difference was 0.88 mm, Type 3 difference was 0.94 mm and Type 4 difference was 1.46 mm. Total difference was 0.97 mm (Table 1). Significant difference was found only between Type 1 difference and Type 4 difference ($p < 0.05$).

Discussion

Although the gantry angle and the mandibular positioning affect the alveolar height and width of dental implant sites in reformatted cross-sectional CT scans,^{7–9} the accuracy of measurements of the ABHs on the CT images has been ascertained in other references.^{10–12} In this study, the measurements of the ABHs on the CT images were set to the reference standard. In the case when there was a relatively large difference between the measurements on the CT images and panoramic images, the panoramic images were determined to be erroneous. Total difference in this study was 0.97 mm, which was similar to the result of a previous study.¹³ This result verifies that the magnification of the vertical plane in the panoramic image was relatively consistent with the object. This study showed a rather small magnitude of total differences since the measurement of the ABH on the panoramic images employed the parasagittal plane on the CT panoramic view, which was identical to the sagittal cut on CT. When the angle between the long axis alveolar bone and the vertical line approaches 0°, the difference between the ABH measurements of panoramic images and those of CT decreases. The X-ray beam of a panoramic radiography machine usually faces about 7°–10° upward, which causes even horizontally paralleled mandibular canals or alveolar crest to appear vertically misaligned in panoramic radiographs.¹⁴ In other words, ABHs in Type 1

Figure 4 (a) A panoramic view of the same patient as Figure 3. (b) (Cropped image of Figure 4a) the location of available bone height (ABH) measured on the panoramic radiograph corresponding to that of ABH on CT in Figure 3

were underestimated and ABHs in Type 4 were overestimated. In this study, the majority of cases in Type 1 (Type 4) had smaller (larger) ABHs on panoramic images than those on CT, where types do not make a significant difference in the ABH measurements.

A couple of clinical methods can be suggested to deal with the error of ABH measurements. One is to decrease the vertical angles of the panoramic machine, which may severely distort the images of the maxillary areas. Assessment of the area for implant installation by palpation can also be suggested.¹⁵ Short implants for mandibular posterior areas may be employed.^{16,17}

Park and Kim¹⁸ reported that the edentulous mandibular molar area had an inward and forward atrophic change. Bolin and Eliasson¹⁹ reported that the differences in maxillary alveolar bone height recorded

by the two techniques, panoramic radiographs and tomographic radiograph, were greater in edentulous regions than in dentate regions and the differences increased in regions where the available bone height was small. Type 4 showed the largest ABH differences and was inferred to have the longest edentulous period among the four types based on the result by Park and Kim.¹⁸ Therefore, the cases with long edentulous duration and small ABH can be expected to have the considerable errors in the ABHs measured on the panoramic radiographs.

Morphologically, the alveolar bone of the molar area of the mandible was mainly slanted in the lingual direction and the mandibular canal seems to be located in the buccal position in view of the alveolar bone, although it was at the centre of the bone. Consequently, we should take into account that there may be a discrepancy between the ABH measurement on panoramic radiographs and the real ABH of the mandibular molar area, especially for Type 4 bones.

This study focused on the analysis of variations in measuring the ABHs on the panoramic images. The variations rely on whether the peak point of the alveolar crest was located in a buccal, lingual or centre position. This study was limited to the mandibular molar area and the mandibular canal generally lay in the lingual side to the centre of the mandibular basal bone, which prohibited exploration of the effects of the location of the mandibular canal on the variations in the ABHs in panoramic radiographs. Recommended future work includes the research on the effects of the bucco-lingual location of the mandibular canal within the bone on the measurement discrepancy.

The conclusion of our study is that the relative location of the alveolar crest with respect to the mandibular canal affected the ABH measurement on panoramic radiographs. In particular, ABH is overestimated when there has been resorption of the buccal aspect of the ridge, moving the alveolar crest lingually.

Table 1 The mean values and standard deviations of differences between available bone heights (ABHs) on panoramic images and CT images for Type 1, 2, 3 and 4

Difference	n	Mean	Standard deviation	
Type 1	20	0.60*	0.36	$ABH_{\text{pano}} < ABH_{\text{CT}}$
Type 2	20	0.88	0.58	$ABH_{\text{pano}} < ABH_{\text{CT}}$
Type 3	31	0.94	0.69	$ABH_{\text{pano}} > ABH_{\text{CT}}$
Type 4	21	1.46*	1.72	$ABH_{\text{pano}} > ABH_{\text{CT}}$
Total	92	0.97	0.99	

n: number of selected cases.

*Statistically significant for $p < 0.05$ (ANOVA).

Type 1: the peak point of the alveolar crest was positioned in buccal side or centre in comparison with the vertical line.

Type 2: the peak point of the alveolar crest was positioned in lingual side and the distance from the vertical line was less than 2 mm.

Type 3: the peak point of the alveolar crest was positioned in lingual side and the distance from the vertical line was greater than 2 mm and less than 4 mm.

Type 4: the peak point of the alveolar crest was positioned in lingual side and the distance from the vertical line was greater than 4 mm.

$ABH_{\text{pano}} < ABH_{\text{CT}}$, Smaller ABHs on panoramic images than those on CT images; $ABH_{\text{pano}} > ABH_{\text{CT}}$, Larger ABHs on panoramic images than those on CT images.

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