Measurement of the Interantral Bone in Implant Dentistry Using Panoramic Radiography and Cone Beam Computed Tomography: A Human Radiographic Study

D Kopecka[1*], A Simunek[1*], J Streblov[2], R Slezak[1], L Capek[3]

ABSTRACT

Objective: *To analyse the dimensions of interantral bone available for dental implant placement in the fully edentulous maxilla.*
Methods: *Interantral bone height (IBH) was measured using panoramic radiography and computed tomography (CT). Interantral bone width (IBW) was measured by means of CT.*
Results: *The difference between both imaging methods in IBH assessment was highly statistically significant ($p < 0.001$) in the canine area, whereas in other areas, it was found to not be significant. Measured in the CT scans, bone is significantly higher in the canine area compared to the area of central and lateral incisors ($p < 0.001$). Significant variations in IBW were found in all three locations: bone in the central incisor area is the widest, in the area of the lateral incisor, the narrowest ($p < 0.001$).*
Conclusion: *Panoramic radiography is a sufficiently accurate method for IBH imaging in the incisor area, but not in the canine area.*

Keywords: Alveolar bone, bone height, dental implants, radiographic study

Medición del Hueso Interantral en Implantología Dental Utilizando Radiografía Panorámica y Tomografía Computarizada de Haz Cónico: Un Estudio Radiográfico Humano

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RESUMEN

Objetivo: *Analizar las dimensiones del hueso interantral disponible para la colocación de implantes dentales en el maxilar completamente desdentado.*
Métodos: *Se midió la altura del hueso interantral (IBH) utilizando radiografía panorámica (ortopantomografía) y tomografía computarizada (TC). Se midió el ancho del hueso interantral (IBW) por medio de la tomografía.*
Resultados: *La diferencia entre ambos métodos de imagen en la evaluación del IBH fue altamente significativa estadísticamente ($p < 0.001$) en el área canina, mientras que en otras áreas no lo fue. Medido en escaneos TC, el hueso es significativamente mayor en el área canina, en comparación con el área de los incisivos centrales y laterales ($p < 0.001$). Se encontraron variaciones significativas en el ancho del hueso (IBW) en las tres zonas; el hueso en el área de los incisivos centrales tiene su parte más ancha; en la zona de los incisivos laterales, la más estrecha ($p < 0.001$).*
Conclusión: *La radiografía panorámica es un método lo suficientemente preciso para obtener imágenes de IBH en el área de los incisivos, pero no en el área de los caninos.*

Palabras claves: Hueso alveolar, altura ósea, implantes dentales, estudio radiográfico

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INTRODUCTION

Reconstruction of lost teeth in the edentulous maxilla is perceived as one of the biggest challenges for dentists. Fixed full arch bridges supported by dental implants are considered to be the best imitation of natural dentition; however, opinions considering the exact positioning of implants for this prosthodontic solution differ considerably. In the majority of concepts used for the treatment of the edentulous maxilla by implants, four to six implants are to be placed in the interantral area (1–4). Usually, two implants are placed bilaterally in the canine areas and two implants are placed symmetrically in the incisor areas.

High success rate of implants depends on their good anchorage in sufficient alveolar bone volume which, unfortunately, is frequently lacking (5). Authors of the present study analysed subsinus bone height of the edentulous maxillae formerly. Their measurements focussed on the premolar and molar areas (6). To the best of the authors' knowledge, the edentulous anterior maxilla, meaning the area of interantral alveolar bone, has not yet been scrutinized in a similar manner.

Interantral alveolar bone borders distally on variously pneumatized maxillary sinuses. According to Kopecka *et al*, interantral space in an edentulous maxilla contains the area of canines and incisors in 96.9% individuals; in 0.7% it spreads into the area of first premolars as well, while in 2.4%, the maxillary sinuses expand mesially leaving only the area of the incisors in bone (6). Cranially, the interantral bone is limited by the nasal floor and, in the midline, it is interrupted by the incisal canal (7). Apart from these anatomical limits, the available bone is reduced both horizontally and vertically by undergoing progressive resorptive changes preceding or following tooth loss (5). Thus, in the edentulous maxilla, reduced interantral alveolar bone volume frequently limits the placement of dental implants.

According to Peñarrocha *et al,* more favourable conditions for interantral implant placement can be awaited in the area of bone pillars: in the paired anterior maxillary buttress (canine eminence), and in the unpaired nasopalatine buttress (8). The anterior maxillary buttress originates in the alveolus of the maxillary canines, following the lateral margin of the piriform aperture, forming the frontal process of the maxilla, and merging with the medial margin of the supraorbital arch. The triangular lower portion is positioned between the nasal cavity and the maxillary sinus (8). The anterior maxillary buttress serves the physiologic transfer of chewing forces in the direction of the skull base and where, before tooth loss, massive canines are anchored. Peñarrocha *et al* claim that the advantage of placing implant into this anatomical structure is the ability to provide bone anchorage in atrophic maxilla without additional grafting procedure (8). A similar but less frequently discussed structure is the nasopalatine buttress (9). It is a reinforced bone structure in the maxillary sagittal plane between the nasal cavity and the alveolar crest. The nasopalatine canal is to be found in the centre of this structure.

Dimensions of dental implants placed have to correspond to the bone volume available. The standard diameter of screw-form implants varies between 3.7 and 4.1 mm, their regular length being more than 10 mm (10–12). These implants are considered standard diameter or length implants, respectively. Their effectivity is richly documented (13, 14). So called short implants usually have a length of at least 8 mm. Considering their effectivity, the present data are somewhat ambiguous; however, the majority of recent reports demonstrate that short implants are a valuable option and should be considered an alternative to bone augmentation surgeries (15).

For good prognosis of an implant, at least 1 mm of supporting bone was suggested to be present around each implant (13). If this bone volume is not available, augmentative procedures are necessary. However, these surgical procedures make the treatment more invasive, more expensive, and more time consuming. Therefore, from the patient's acceptance viewpoint, it is more favourable if there are no augmentative procedures.

There is no doubt that cone beam computed tomography (CBCT) or medical computed tomography (CT) are the most accurate evaluation techniques and set the gold standard for measurement of bone available for dental implants (16). However, due to lower radiation load and examination cost, panoramic radiography is still considered the standard radiographic examination for implant treatment planning (17).

The aims of the present study were to:

- assess the validity of vertical dimensions measurement of the interantral bone in panoramic radiographs;
- compare vertical and horizontal dimensions of alveolar bone in specific areas of the interantral bone; to verify the importance of anterior maxillary buttress and nasopalatine buttress considering the bone volume, and to relate these dimensions to the requirements of standard length implants, short implants and standard diameter implants.

SUBJECTS AND METHODS

In this retrospective study, digital panoramic radiographs and CBCT scans were selected from clinical records of patients at the Unit of Dental Implantology, Department of Dentistry, University Hospital, Hradec Kralove, Czech Republic. The radiographs were obtained during the preoperative examination of consecutive patients during the period from March 2007 to February 2011. The ethical review committee at Faculty Hospital in Hradec Kralove, which works in accordance with the Helsinki convention, approved the present study design (file no. 201101S18P).

All panoramic radiographs were taken with the same panoramic device, Planmeca ProMax Dimax3 Ceph®

(Planmeca Co.), set at 60 to 62 kV and 8 to12 mA with 16 seconds of exposure time, and with standardized positioning of the head and body by the same operator. One investigator (DK) was responsible for selecting the panoramic radiographs and performing the measurements. The following selection criteria were used:

- Each subject was edentulous in the maxilla.
- Interantral alveolar ridge had been edentulous for a period of one to five years.
- With a previously used guide model, it was possible to define the areas of all missing teeth. This guide model contained metal markers at the longitudinal axis of the maxillary central incisor, canine, second premolar and first molar.
- The radiographs clearly showed the anterior border of the maxillary sinus, the nasal floor and the interantral alveolar ridge. In the interantral region, there were no signs of previous sinus or alveolar bone surgery.
- The extraction wounds were radiographically healed.
- Each panoramic radiograph belonged to a different subject.
- All subjects were 18 years of age or older.
- The images of anatomic structures were not incorrectly lengthened in every direction.
- The panoramic image was symmetric, and the cervical spine image was straight at the centre of the radiographs.
- The palatal plate was nearly straight and horizontal, allowing for misalignment of less than 10 degrees.

Radiographs that did not meet these criteria were excluded from further processing. All CBCT scans were taken with the same conebeam device, PaX – Duo3D (Vatech, Republic of Korea) set at 90 kV and 3.2 mA, with 24 seconds of exposure time and field of view (FOV) 120/85 mm, under the standard conditions of the head and body by the same operator. The areas of all missing teeth were defined in the same way as in the panoramic radiographs. One investigator (DK) was responsible for performing the measurements. Only patients obtaining both panoramic radiograph and CBCT examination were included in the examined sample.

Analysis of panoramic radiographs

The images were imported into the PC Dent software (CompuGroup Medical) and analysed with a ten-fold magnifying glass on the computer screen after digital magnification (2X) of the PC Dent software scale. Only one side, which was chosen randomly, was evaluated on each radiograph.

Interantral bone height (IBH) was measured in the region of each interantral missing tooth as the shortest distance between the floor of the nasal cavity and the most apical point of the alveolar crest. Measurements were performed under standard illumination using a caliper (Dental Vernier, Muenchen Design, Dentaurum) and calibrated according to the magnification factor. All values were rounded to the nearest 0.5 mm.

Intra-examiner variation was determined by repeating the measurements on 100 radiographs, with an interval of two weeks separating the first and second measurement. The vertical enlargement ratio of the radiographs was determined from 100 radiographs with dental implants of defined length (10 to 16 mm) in the interantral region. In addition, the validity of IBH measurements based on panoramic radiographs was evaluated in all subjects of this study. The results of measurements based on panoramic radiographs and CBCT were compared at the sites of each missing interantral tooth.

Analysis of CBCT scans

The location of each missing tooth was defined from the guide model in the same way as in the panoramic radiographs. All CBCT measurements of the interantral bone were accomplished with an automated image-measurement tool. Interantral bone height was measured in regions of each interantral missing tooth as the shortest distance between the floor of the nasal cavity and top of the alveolar crest. Interantral bone width (IBW) was measured in the same localizations on a line perpendicular to a line of IBH, 2.5 mm from the alveolar crest (Fig. 1). Obtained values of IBH as well as IBW were rounded off to the nearest 0.5 mm. The intra-examiner variation of IBH and IBW measurements from CBCT scans was determined by repeating the measurements on 100 IBH values and 100 IBW values obtained from CBCT scans, with an interval of two weeks separating the first and second measurement.

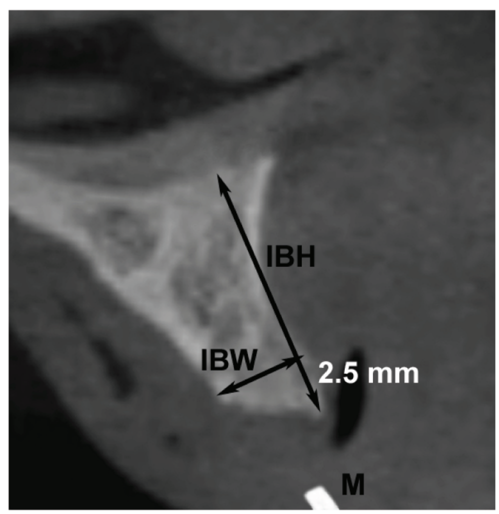

Fig. 1: Interantral bone height (IBH) and interantral bone width (IBW); IBW was measured perpendicular to the IBH line, 2.5 mm cranially from the alveolar crest. M – marker of the guide model.

Statistical analysis

The values IBH and IBW in relation to specific locations were analysed statistically. For statistical analysis, IBH values were divided into three groups: Group L (low, IBH < 8 mm), Group M (middle, IBH 8 to 10 mm), and Group H (high, IBH > 10 mm). Values of IBW were divided into two groups: Group N (narrow, IBW < 5 mm) and Group W (wide, IBW ≥ 5 mm).

Statistical analysis was carried out using NCSS Statistical Software (NCSS, LLC, Kaysville, Utah, USA). The Wilcoxon paired test was employed. The threshold for statistical significance was defined as $p < 0.05$.

RESULTS

A total of 270 panoramic radiographs and 270 CBCT scans of the edentulous maxilla with the guide model were initially considered for the investigation. However, only 264 panoramic radiographs met the selection criteria and were used in the study. These were images of 140 men and 124 women (mean age 54.2 ± 9.6 years; range, 42 to 78 years). All subjects were Caucasian. In all, IBH and IBW values measured in 792 locations were considered in the statistical analysis.

A total of 100 values of IBH on panoramic radiographs, 100 values of IBH on CBCT scans and 100 values of IBW on CBCT scans were measured during the evaluation of intra-examiner variation. The minimal and maximal absolute differences between the first and second measurements were 0 and 1.0 mm (mean 0.3 ± 0.2 mm) for IBH in panoramic radiographs, 0 and 0.5 mm (mean 0.2 ± 0.1 mm) for IBH in CBCT scans and 0 and 1.0 mm (mean 0.3 ± 0.2 mm) for IBW in CBCT scans, respectively. No statistically significant difference was found between replicated measurements.

The vertical enlargement ratio of panoramic radiographs in the interantral region was defined from measurements of the lengths of 242 dental implants. The magnification factor varied between 1.67 and 1.88. A mean magnification factor of 1.8 ± 0.05 was determined. Two hundred and sixty-four sites at the canine area, 264 sites at the lateral incisor area and 264 sites at the central incisors were evaluated during the comparison of IBH gained from panoramic radiographs *versus* CBCT scans. The minimal and maximal absolute differences between the imaging techniques were 0 and 7.5 mm (mean 2.8 ± 1.8 mm) in the canine area, 0 and 1.0 mm (mean 0.1 ± 0.4 mm) in the lateral incisor area and 0 and 1.5 mm (mean 0.2 ± 0.4 mm) in the central incisor area, respectively. The difference between the imaging methods in the canine area was highly statistically significant ($p < 0.001$). The difference in the area of lateral and central incisors was not significant.

Mean bone height measured in CBCT scans and panoramic radiographs and mean bone width measured in CBCT scans in the specified locations are presented in Table 1. Measured in the CBCT scans, bone in the canine area is significantly higher compared to the area of the central and lateral incisor ($p < 0.001$). Comparing the width of the measured bone, significant differences were found in all three locations; bone in the central incisor area is the widest and in the area of the lateral incisor, the narrowest ($p < 0.001$). Cone beam computed tomography analysis of IBH and IBW in relation to particular groups is presented in Table 2. In five (1.9%) cases, the maxillary sinus extended to the canine area, but in not even one case was it found more mesially.

Table 1: Interantral bone height (IBH) and interantral bone width (IBW) values (in mm)

		Canine	Lateral incisor	Central incisor
IBH	Panoramic radiography	17.7 ± 3.6	14.7 ± 3.2	14.8 ± 3.3
	Computed tomography	15.2 ± 3.4	14.7 ± 3.2	14.8 ± 3.4
IBW	Computed tomography	5.7 ± 1.7	5.1 ± 1.5	6.1 ± 1.5

IBH canine *vs* incisors: $p < 0.001$; IBW canine *vs* central incisor *vs* lateral incisor: $p < 0.001$

Table 2: Interantral bone height (IBH) values related to groups H, M and L and interantral bone width (IBW) values related to groups W and N

	Canine	Lateral incisor	Central incisor	Total
Group H (high)	247 (93.6%)	239 (90.5%)	249 (94.3%)	735 (92.8%)
Group M (medium)	13 (4.9%)	22 (8.3%)	13 (4.9%)	48 (6.1%)
Group L (low)	4 (1.5%)	3 (1.1%)	2 (0.8%)	9 (1.1%)
Group W (wide)	192 (72.7%)	152 (57.6%)	222 (84.1%)	566 (71.5%)
Group N (narrow)	72 (27.3%)	112 (42.4%)	42 (15.9%)	226 (28.5%)

Group H: IBH > 10 mm, Group M: IBH 8 to 10 mm, Group L: IBH < 8 mm, Group W: IBW ≥ 5 mm, Group N: IBW < 5 mm

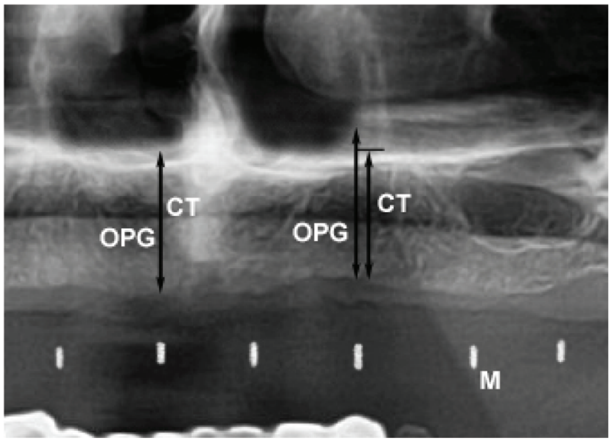

Fig. 2: In the incisor area, interantral bone height (IBH) obtained from panoramic radiograph (OPG) corresponds with IBH obtained from cone beam computed tomography (CBCT). In the canine area, the OPG values are bigger compared to CBCT values. M – markers of the guide model in locations of central incisors, canines, second premolar, and first molar.

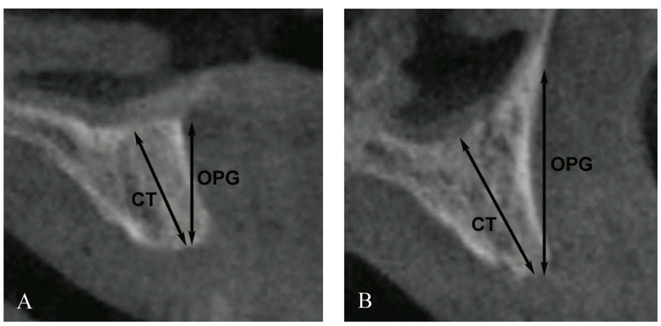

Fig. 3: Explanation of the discrepancy of interantral bone height (IBH) from Fig. 2.
(A) The incisors area: values obtained from panoramic radiograph (OPG) and from cone beam computed tomography (CBCT) are not significantly different.
(B) The canine area of the same patient: OPG values are bigger than CBCT values, because the nasal floor is masked by a bone pillar – part of the anterior maxillary buttress.

DISCUSSION

Arbitrary division of the alveolar bone dimensions originated from the necessity to place implants into a sufficient bone volume. Group H corresponds to standard length implants, group M corresponds to short implants (1, 15). In group L, even short implants are difficult to place and some bone augmentation procedures could be indispensable (1, 18). Regarding the width of the bone, standard diameter implants can be used in group W, whereas bone augmentation procedures are preferred in group N (18). The width of the bone was measured 2.5 mm from the alveolar crest due to the form of the alveolar ridge and a possibility to maximize the bone amount around the implant.

In the present investigation, the obtained IBH dimensions from panoramic radiographs and CBCT scans matched only for the incisor area. In the canine area, measurements differed significantly (Fig. 2). The cause is to be found in the two-dimensional fashion of the panoramic radiograph. The bone used for implant anchorage is situated between the alveolar crest and the nasal cavity floor. In a panoramic radiograph, this anatomic structure is being masked by a compact bone pillar separating the nasal and maxillary cavities. This structure is part of the anterior maxillary buttress, but is to be found more ventrally, thus in a different plane to the placed implants (Fig. 3). The difference between both measurements was mean 2.8 ± 1.8 mm and grossly transgressed the necessary measurement accuracy. Thus, panoramic radiograph cannot be used for bone height measurement in the canine area. This is also the reason why measurements of this area gained solely from CBCT scans were used for further statistical analysis.

Interantral bone height measured in the canine area in CBCT scans was significantly bigger than in the incisor area ($p < 0.001$); however, in mean values, the difference was less than 0.5 mm. Therefore, the frequently declared advantage of the anterior maxillary buttress bone height was shown to be less important from the clinical point of view. Considering the IBW, the widest bone is situated in the central incisor area (6.1 ± 1.5 mm), narrower in the canine area (5.7 ± 1.7 mm), and the narrowest bone is found in the lateral incisor area (5.1 ± 1.5 mm). The differences are again significant ($p < 0.001$) and not to be ignored, especially when comparing central and lateral incisor areas. The difference is 1 mm, confirming both the advantage of anterior maxillary buttress and especially the advantage of parasagittal implant placement into the nasopalatine buttress.

Interantral bone height was sufficient for a standard length implant in 92.8% of interantral locations (group H); the bone was able to include a standard length implant without augmentative procedures. Group L, mostly requiring advanced bone augmentation procedures, formed only 1.1% of obtained values. The most "hostile" interantral location seems to be the lateral incisor area, where bone did not exceed 10 mm height in 9.5% of all cases. Regarding the IBW, the anatomical situation was more discouraging. In 28.5% of patients, bone was primarily insufficient for a standard diameter implant. Differences between specific locations were substantial: while bone augmentation procedure in the central incisor area was indicated in 15.9% and in 27.3% in the canine area, in the lateral incisor area bone was insufficient in 42.4% of cases. The importance of bone augmentation procedures in implant placement in the interantral area of an edentulous maxilla remains undoubted. However, proper use of the present bone volume and the acceptance of short implants can significantly reduce the need for these procedures.

In current literature, CBCT or CT is highly preferred over panoramic radiographs. The disadvantage of the panoramic radiography is solely two-dimensional information with the pitfalls of inaccuracy (5). Visibility on panoramic images is limited and dependent on projection geometry, head positioning and image magnification (6, 19). However, several authors have indicated that panoramic radiographs can be a suitable diagnostic tool for vertical measurements when the patient is correctly positioned (20–24) because the vertical magnification factor, in contrast to the horizontal, is very consistent (6, 16, 19, 23). The present study demonstrates that panoramic radiography is a sufficiently accurate method for interantral bone height imaging in the incisor area, but not for the canine area.

The design of the present study has some limitations. It is known that the alveolar ridge resorption is dependent on the duration of edentulism (25, 26). This imperfection should be compensated by the time limit of one to five years, when the patients ask for dental implants treatment most frequently. A large number of measurements performed could compensate for this imperfection as well. For implants anchorage, not only bone volume, but quality of the bone is also significant (27). Finally, it is necessary to note that presented numeric values evaluate only one half of each maxilla. Bilaterally, presented numeric values are correct only in case of a totally symmetrical maxilla.

The analysis of 264 radiographs of edentulous maxilla rendered the following:

- Panoramic radiography is a sufficiently accurate method for interantral bone height imaging in the incisor area, but not in the canine area, where CBCT or medical CT are inevitable.
- Bone in the canine area was significantly higher than in the central or lateral incisor area ($p < 0.001$). However, the difference was only 0.5 and 0.4 mm, respectively. The mean bone width decreased following locations: central incisor – canine – lateral incisor ($p < 0.001$). The difference between the bone width in the central and lateral incisor area was 1.0 mm.
- Height of the interantral alveolar bone was sufficient for standard length implant placement in 92.8% and for short implant (8 to 10 mm) placement in 98.9%. However, the width of the above mentioned bone was sufficient for standard diameter implant placement in only 71.5% of cases.
- For implant placement in the anterior maxilla, it is appropriate to use the anterior maxillary buttress (particularly for its bone width) and the nasopalatine buttress (for both the height and the width of bone).
- Proper location of implant placement and the use of short implants can reduce the need for reconstructive surgery significantly.

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