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Cone beam computed tomography as a method of quantitative and qualitative analysis of alveolar crest in the frontal mandibular area

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Abstract

New radiographic maxillofacial techniques, cone beam computerized tomography (CBCT) are a necessity in the assessment of jaw bone offer to effectively evaluate the treatment. *Aim*: To quantitatively and qualitatively evaluate anterior mandibular area on CBCT comparing to orthopantomography (OPG). *Material and Methods*: Fifty-one dental patients, aged between 20 and 77 years, were quantitatively analyzed and 81 dental patients, aged between 20 and 79 years, were qualitatively analyzed. ANOVA and Mann–Whitney tests were used for statistical analyses. *Results*: Strong statistical significant differences were recorded between CBCT and OPG assessments for all groups of teeth (p<0.001), when evaluation was performed on distances to mandibular base. When assessing the distance to the incisive canal, the differences were recorded only for the left canine zone. Mean densities of central incisor, lateral incisor and canine regions, were 1,400–1,425 HU, 1,212–1,224 HU, and 1,150–1,175 HU, respectively. There was a marginal statistical evidence that bone density was lower in canine zone comparing to central incisor area (p=0.08). *Conclusions*: Measurements on CBCT are more accurate when compared with OPG. Bone density of central incisor region is higher. Therefore, CBCT permits the clinician to have all necessary information when planning dental implants.

***Keywords*:** mandible anatomy, tomography, quantitative analyses, bone density.

Introduction

Interpretation of X-rays provides information that can build a diagnosis. A good clinician should have interpretive skills to identify normal structures. Moreover, the dentist has to differentiate the radiographic deviations in shapes and density of normal values [1].

More recent radiographic imaging techniques, such as digital radiography, computed tomography (CT), magnetic resonance imaging (MRI) become necessities in the assessment of jaw bone offer to evaluate preoperatively the treatment effectiveness and to decrease the recovery interval [2–5].

Computed tomography has revolutionized the bone analysis and treatment planning. With a single scan and using a low dose of radiation, images of both bone and soft tissues are analyzed. CT creates a three-dimensional reconstruction of the patient's skull or of any maxillofacial region. Moreover, this technique is able to produce images in axial, sagittal, frontal planes [6, 7].

European Academy of Dentomaxillary Radiology set ground rules in use of CBCT by dental practitioners, radiology specialists, and producing companies of radiological equipment [8]. The dental CBCT is recommended for: assessment of bone support for the application of dental implants; TMJ's analysis to diagnose degenerative bone changes; examination of teeth and facial structures to start orthodontic treatment; proximity viewing of wisdom molars to lower mandibular canal, prior extractions; diagnosis of cysts, tumors or infections of the teeth and jaw bones [9]. Effective dose of irradiation for CBCT is between 6 and 477 μSV and equipment cost is relatively low related with the benefits obtained by this imaging technique [10].

The purpose of this study is to assess different methods of quantitative and qualitative frontal mandibular alveolar bone analyses, aiming improvement of the dental implant preoperative evaluation.

Patients and Methods

All patients were recruited from a Radiological Center in Bucharest. For all subjects, personal data were collected by interview. Both sexes were analyzed. All subjects were partial edentulous.

Quantitative analysis

For quantitative analysis of alveolar crest, 51 clinical cases were randomly selected from a total of 700 patients to whom their dental practitioners recommended both OPG and CBCT, aprior the dental implant plan. The measurements were made between dental apices and two landmarks: the incisive canal considered as mandibular canal's extension, the mandibular base. Evaluations were made on panoramic radiographs (controls) and on the reconstructed panoramic sections and cross sections of CBCT. Measurements were made for each anterior mandibular tooth present on the jaw by a single researcher, to eliminate differences that might be statistically significant between several evaluators [11]. These were carried out with a digital sliding calliper (PowerFix, PagetTrading Ltd., London, UK) with an accuracy of 0.01 mm and were repeated three times at an interval of four weeks, to obtain the reproducibility of values by the same assessor. Averages were then calculated.

All radiographic examinations were carried out using Orthopantomography Auto IIIN CM. Furthermore, images were produced via a Kodak cassette and 15×30 cm Kodak dental films, with an automatic regenerator AGFA–Gevaert and a processing time of 4 minutes.

The CBCT unit used was NewTom VGi. Image detector was an amorphous silicon flat plate of 20×25 cm dimensions. The CBCT parameters were 110 kV, 1–20 mA, the emission of X-rays during 18 seconds, and the effective dose was 100 μSV. To achieve sagittal sections, CBCT reconstructions were set for a thickness of 1 mm.

Qualitative analysis

For qualitative analysis of the alveolar ridge color assessments have been done. Bone density was evaluated only on three-dimensional reconstructions of the CBCT. Eighty-one patients were randomly selected from patients referred to the Radiological Center. Color evaluations were made visually after a classification into 22 codes corresponding to Hounsfield Units (HU), at 250 HU interval.

Data were processed using a computer Pentium IV. The 3D reconstruction program uses standard Open GL, version 1.2, and HDD of 500 GB. The operating system was Windows® XP Pro.

Mean values and standard deviations (SD) of measurements were calculated; one-way ANOVA test was used to assess mean differences between evaluations obtained by the methods mentioned above. Mann–Whitney test was used to compare bone densities expressed by codes in different anterior mandibular areas. Stata 11C statistical software (StataCorp LP, Texas, USA, version 2009) was used for data analysis. A p-value ≤ 0.05 was considered statistically significant.

Results

Quantitative analysis

Quantitative analysis of alveolar crest was performed on 51 patients, aged between 20–77 years, the average being 48 years (SD=14). Distribution by sex was balanced, being more males (50.98%) than females (49.02%). The descriptive analysis of the measurements of anterior mandibular teeth is shown in Tables 1 and 2.

Table 1 – ***Measurements from apices of anterior inferior teeth to basal mandible***

Variables	Observations	Mean [mm]	Standard deviation	Min. [mm]	Max. [mm]	*p*-values*
Right CI on panoramic	50	24.25	4.49	14.91	33.23	
Right CI on panoramic section of CT	50	17.11	2.65	11.85	22.05	<0.0001
Right CI on sagittal section of CT	50	18.64	2.79	12.62	24.83	
Right ILI on panoramic	50	27.27	5.12	17.48	40.03	
Right ILI on panoramic section of CT	50	19.02	2.75	12.56	25.33	<0.0001
Right ILI on sagittal section of CT	50	20.73	3.41	13.51	30.33	
Right ICI on panoramic	48	28.48	5.15	20.23	4306	
Right ICI on panoramic section of CT	48	20.29	2.92	13.23	26.53	<0.0001
Right ICI on sagittal section of CT	48	21.95	3.47	14.72	29.62	
Left ICI on panoramic	48	28.95	5.01	20.04	41.09	
Left ICI on panoramic section of CT	48	20.28	2.91	12.33	26.53	<0.0001
Left ICI on sagittal section of CT	48	21.49	3.28	15.61	27.71	
Left ILI on panoramic	50	27.56	5.03	19.21	41.03	
Left ILI on panoramic section of CT	50	18.86	2.34	13.66	23.89	<0.0001
Left ILI on sagittal section of CT	50	20.44	3.1	13.42	27.13	
Left CI on panoramic	48	24.26	3.92	17.08	33.49	
Left CI on panoramic section of CT	48	17.4	2.73	10.33	22.29	<0.0001
Left CI on sagittal section of CT	48	18.29	2.66	13.56	23.96	

*One-way ANOVA test.

Table 2 – ***Measurements from apices of anterior inferior teeth to incisive canal***

Variables	Observations	Mean [mm]	Standard deviation	Min. [mm]	Max. [mm]	*p*-values*
Right CI on panoramic	23	7.82	4.3	0.29	20.11	
Right CI on panoramic section of CT	50	6.84	2.17	2.03	11.49	=0.08
Right CI on sagittal section of CT	50	8.05	2.45	2.42	13.73	
Right ILI on panoramic	23	8.02	3.44	2.2	12.9	
Right ILI on panoramic section of CT	50	8.46	3.13	2.73	15.03	>0.05
Right ILI on sagittal section of CT	50	9.87	2.11	4.62	14.03	
Left ILI on panoramic	16	8.46	3.10	3.63	12.09	
Left ILI on panoramic section of CT	50	8.12	2.37	3.73	12.61	>0.05
Left ILI on sagittal section of CT	50	9,19	3.00	3.55	14.36	
Left CI on panoramic	19	8.83	3.34	3.62	17.05	
Left CI on panoramic section of CT	48	7.47	2.04	3.53	12.82	=0.05
Left CI on sagittal section of CT	48	8.1	2.36	3.42	13.23	

*One-way ANOVA test.

Ninety-eight mandibular canines (CI), 100 lateral mandibular incisors (ILI) and 96 central mandibular incisors (ICI) were measured from apices to the mandibular base. Forty-two CI and 39 ILI were measured from their apices to the incisive canal; due to lack of visibility of incisive canal on OPGs, statistical analysis could not be performed for ICI.

Testing mean differences of measurements from apices to the mandibular base revealed statistical differences for all groups of anterior inferior teeth, when comparing measurements performed on panoramic radiographs with those on panoramic or sagittal sections of CBCT (p<0.0001). Scheffe test shows statistically significant differences (p<0.0001) between means of all measurements performed by OPGs, and both panoramic and sagittal sections of CBCT. When CBCT sagittal and panoramic sections measurements were compared. No statistical significant differences were recorded, except the right CI (marginal statistical significant difference, p=0.08) (Table 1).

Testing mean differences of measurements from apices to the incisive canal revealed statistical differences only for canine regions, when comparing measurements performed on panoramic radiographs with those performed on panoramic or sagittal sections of CBCT (p <0.05) (Table 2).

Table 3 shows the prevalence of the incisor canal's detection in the mandibular anterior group, assessed on OPGs, and CBCT panoramic and sagittal sections. Among the CI that were analyzed, the incisive canal was visible only for 28 teeth on OPGs. From the same reasons, only 24 ILI could be assessed regarding the distances from their apices to the incisive canal (Table 3).

Table 3 – ***Percentage of visibility of incisive canal in anterior mandibular region***

Variables	Observations [n]	Visible observations [n']	Percentage of visible observations [%]
ICI on panoramic	96	1	1.04
ICI on panoramic section of CBCT	96	4	4.17
ICI on sagittal section of CBCT	96	16	16.67
ILI on panoramic	100	24	24
ILI on panoramic section of CBCT	100	59	59
ILI on sagittal section of CBCT	100	74	74
CI on panoramic	98	28	28.57
CI on panoramic section of CBCT	98	76	77.55
CI on sagittal section of CBCT	98	86	87.76

Qualitative analysis

Qualitative analysis (bone density) was performed on alveolar crest of 81 patients, who were total or partially toothless, aged between 20–79 years, average being 50 years (SD=14). There were evaluated 40 females (49.38%) and 41 males (50.62%). Results of bone density obtained in mandibular anterior area are presented in Table 4.

Table 4 – ***Bone density of anterior mandibular teeth***

Variables	Observations	Mean (HU)	Standard deviation	Min. (HU)	Max. (HU)
ICI	46	8.38 (1,559–1,564)	3.91 (729)	1–249	2,720–2,999
ILI	39	10.11 (1,212–1,224)	2.3 (277)	1–249	2,001–2,249
CI	35	10.36 (1,150–1,175)	1.78 (200)	250–499	1,750–1,999

Mann–Whitney test showed marginal evidence of statistical significant difference (p=0.08) between bone density of inferior central incisor and inferior canine areas.

Discussion

Dental Implantology is on an upward evolution, being an alternative to prosthetic solutions. The ethical attitude of the dentist towards patient is the presentation of his morpho-functional dento-maxillo-facial data and to offer alternative solutions of recommended treatment, including dental implants. All these issues are solved by recommending a comprehensive preoperative imaging analysis performed by CBCT.

Radiation exposure used for CBCT, even if it is different from one unit to another, is less than the required values for CT. CBCT has also a superior spatial resolution and is compatible with dental implants simulation programs. However, due to the low-density resolution scanning techniques, soft tissue of the face and neck have a low contrast [12].

It is evident that panoramic radiography cannot illustrate the width of the bucco-lingual alveolar ridge or the angle for the future dental implants and also distorts the images. However, it cannot be eliminated, being recommended in cases without complications, when the number of future dental implants is low [13]. No doubt, if it is found, after clinical examination, sufficient height of alveolar ridge, OPG or retro-alveolar radiographs are considered enough as preoperative examination documents for application of dental implants [14, 15].

Hanssens JF (1996) proved that the exact offer of bone and the relationships between different bone structures could be determined by three-dimensional analysis [16]. The results of our study confirm that measurements performed with aid of OPG are overestimated, comparing with those obtained by CBCT sagittal sections, with 6–7 mm. Therefore, an accurate quantitative evaluation in this mandibular area could be only obtained with CBCT. Our study showed that even rarely, the image of incisive canal is viewed on OPG in anterior mandibular region. These findings are in agreement with those of Arzouman MJ *et al.* [17], who showed that the incisive canal, as a continuation of the mandibular canal, was observed in the incisor region, with values between 2 and 6.95 mm. Most times, however, vascular-nervous package for each anterior tooth crosses the spongious mental region without being radiologically visible on OPGs.

The location and configuration of the mandibular canal are various, the importance of these anatomical formations requiring careful observation on reformed CBCT images (Figures 1 and 2) [18, 19].

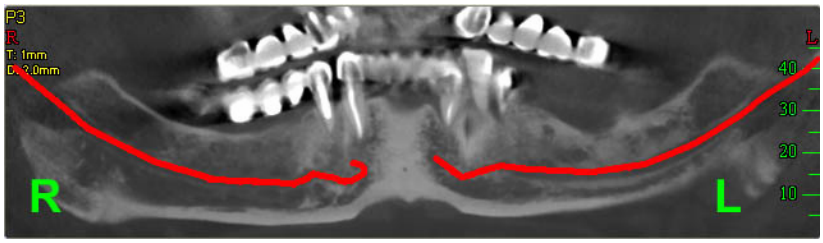

Figure 1 – ***Incisive canal view on reformatted panoramic CBCT (turning curve shape).***

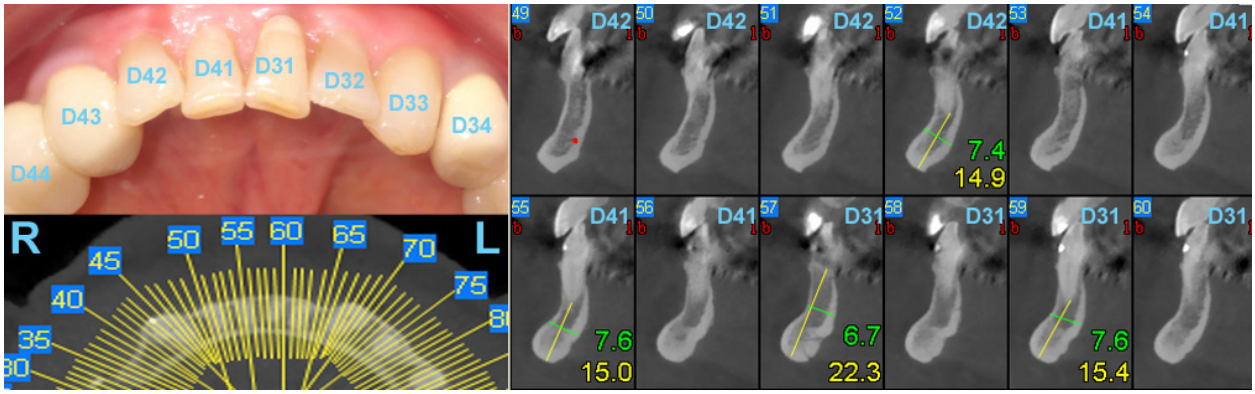

Figure 2 – ***Anterior mandibular area, 1 mm slices: (A) genii tubercles; (B) lingual foramen; (C) mental crest; (D) inferior mandible margin; (E) mental fossa; (F) alveolar crest.***

There are studies showing both mandibular canal and inferior alveolar nerve have different topographies than anatomical findings [20]. Sagittal images of CBCT did not have magnification or overlapping of neighboring structures, which are inherent problems in OPG, allowing views of the upper floor of mandibular canal [21].

Considering the incisive canal as anterior extension of the mandibular canal, OPG does not always offer accurate identification of it. Thus, a CBCT scanning is the only proof for the clinician to have documentation in case of malpractice. If the topography of incisive canal is not well radiographically evaluated, by applying the mandibular dental implants, the terminal branch of the inferior alveolar nerve could be easily harmed and sensitive disorders may occur (hypoesthesia, hyperesthesia, paresthesia). Previous studies have demonstrated that bleeding or nerve disruption can occur following implants application, because of the unrecognized presence of incisive canal [22, 23].

This study shows the presence of incisive canal CI (87.76%) > ILI (74%) > ICI (16.67%). Therefore, on OPGs his visibility is lower than on CBCT images: CI (28.57%) > ILI (24%) > ICI (1.04%).

Regarding bone density in central mandible areas, our results were consistent with those of the Turkyilmaz I *et al.* (2007) [24] where the qualitative analysis were anterior mandible (738–1152 HU) > anterior maxillar

(526–906 HU) > posterior mandible (447–985 HU) > posterior maxillar (231–779 HU).

Other findings still revealed the peak bone densities of both jaws in mandibular central area, but the values were lower than ours were [mandibular central (955–1759 HU) > maxillar frontal (900–1622 HU) > mandibular lateral (753–1655 HU) > maxillar lateral (765–1571 HU)] [25].

Conclusions

The assessment of incisor canal confirms previous results, i.e. the visibility is much lower on panoramic radiographs compared to panoramic sections and sagittal sections of CBCT. Moreover, the frequency of incisive canal's visibility is higher in the inferior canine area, followed by the inferior lateral incisive and inferior central incisive areas.

Density and bone structure are carefully analyzed before application of a dental implant. Bone density of anterior mandible regions is higher corresponding to central incisive region, comparing with the canine and lateral incisive regions.

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