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The Reliability of Panoramic Radiographs for Different Recipient Sites in Dental Implant Treatment Planning

Dental İmplant Tedavi Planlamasında Panaromik Radyografinin Farklı Bölgelerdeki Güvenilirliğinin Değerlendirilmesi

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ABSTRACT Objective: Width, height, density and morphology of alveolar bone must be carefully examined before the surgical intervention for a successful implant treatment. The panoramic radiography (OPG) is the most frequently used method that is employed by large majority of dentists in dental implant planning. The purpose of this study is, to evaluate the consistency of OPG and cone beam computed tomography (CBCT) alveolar height measurements at different recipient sites in dental implant planning. **Material and Methods:** The present study was carried out on the OPG and CBCT images of 206 patients. Using the radiological data of subjects, 752 edentulous implant sites were specified. These areas were classified into 3 groups based on the proximity to certain anatomical landmarks, which were "maxillary sinus (MS)", "mental foramen (MF)" and "nasal floor (NF)". Bone distances between anatomical points and alveolar crest were measured on the OPG and CBCT cross-sectional images. **Results:** In MS group, the correlation between OPG and CBCT was 0.968 ($p<0.001$). The correlation between OPG and CBCT was 0.860 in MS-II subgroup ($p<0.001$). The correlation between OPG and CBCT was 0.950 in MF-I subgroup ($p<0.001$) and 0.932 in MF-II subgroup ($p<0.001$). The correlation between OPG and CBCT was 0.965 in NF group ($p<0.001$). **Conclusion:** OPG is a safe method in measuring the vertical bone distance on maxillary sinus region for implant planning. However, it might not be safely used on the mental foramen and nasal floor regions.

Keywords: Dental implants; CBCT (Cone-Beam Computed Tomography); panoramic radiography

ÖZET Amaç: İmplant cerrahisi öncesi alveolar kemiğin genişliği, boyu ve yoğunluğu dikkatli bir şekilde değerlendirilmelidir. Diş hekimlerinin büyük çoğunluğu implant planlamasında panoromik radyografileri (OPG) kullanmaktadır. Bu çalışmanın amacı dental implant planlamasında farklı alıcı bölgelerin boyutunun değerlendirilmesinde OPG ve konik ışınlı volumetric tomografi (KIVT) arasındaki uyumun değerlendirilmesidir. **Gereç ve Yöntemler:** Bu çalışmada 206 hastanın OPG ve KIVT görüntüleri kullanılmıştır. Radyolojik arşivinden, 752 dişsiz implant bölgesi çalışma için seçilmiştir. Bu alanlar ilgili anatomik bölgelere yakınlığına göre maksiller sinus (MS), mental foramen (MF) ve nasal taban (NT) olarak üç gruba ayrılmıştır. Anatomik noktalar ile alveolar kret arası mesafe OPG ve KIVT üzerinde ölçülmüştür. **Bulgular:** MS grubunda OPG ve KIVT arasındaki korelasyon 0,968 olarak bulunmuştur ($p<0,001$). MS-II alt grubunda ise OPG ve KIVT arasındaki korelasyon 0,860 olarak bulunmuştur ($p<0,001$). MF I ve II grubunda ise OPG ve KIVT arasındaki korelasyon sırasıyla 0,950 ve 0,932 olarak bulunmuştur ($p<0,001$). NF grubunda OPG ve KIVT arasındaki korelasyon 0,965 olarak bulunmuştur ($p<0,001$). **Sonuç:** MS bölgesinde implant planlamasında OPG tek başına güvenle kullanılabilir. Ancak, MF ve NT bölgesinde sadece OPG ile ölçüm yapılması güvenli olmayabilir.

Anahtar Kelimeler: Dental implant; CBCT (Konik Işınlı Bilgisayarlı Tomografi); panoromik radyografi

The rehabilitation of edentulous regions is an important issue for the dental practitioners. Nowadays, the most actual approach suggested for treatment of edentulous patients is the dental implants. For a successful implant treatment, the width, height, density and morphology of the alveolar bone must be examined before the surgical intervention, the accurate determination of the position of anatomical structures is also very important. A successful and accurate planning before implant surgery enables the

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placement of optimum number of implants at optimum sizes. The information such as the positions of mandibular canal, maxillary sinuses (MS), and nasal floor (NF) and the volume and angulation of the bone in alveolar crest are a prerequisite for planning an appropriate implant treatment.[1]

The panoramic radiography (OPG) is accepted as the most frequently used 2D radiographic method that is employed by large majority of dentists in examining the orofacial complex from general aspect.[2] OPG images are used for initial examination of implant site adequately since they give a general overview about the jaws, besides that American Academy of Oral and Maxillofacial Radiology (AAOMR) recommended that the examination of potential implant site should incorporate the cross-sectional imaging that is orthogonal to the site of interest.[3] OPG may be considered to be a quick, simple, low-cost and low-dose method for pre-surgical diagnosis. However, OPG provides no information about angulation, buccolingual thickness and volume of the bone, since it offers 2-D imaging. The buccolingual aspect of alveolar bone can be monitored only by using the conventional cross-sectional tomography, the computed tomography (CT) or the cone beam computed tomography (CBCT). The CBCT method yields images with high diagnostic quality and short scanning duration, as well as lower level of radiation in comparison to the CT examination.[4,5] Which imaging method provides better information about the planning is still being discussed in literature and there is no consensus on this subject.[6] Moreover, the objective is to prefer a radiographic method giving sufficient information for planning the treatment that involves the lowest doses of radiation and cost (ALARA principle: as low as reasonably achievable). In order to avoid complications and achieving long-term success in implant treatment, the most important factors are to determine the actual bone volume to prefer appropriate implant length and width. In the studies, which were carried out to date, the efficiency of cross-sectional images in evaluating the implant sites and placing the implant in ideal position was discussed in comparison with the efficiency of standard OPG.[7-9] In literature, the number of studies indicating in which regions the OPG can be used without the need of CBCT is not enough.

The purpose of this study is to evaluate the consistency of OPG and CBCT alveolar height measurements at different recipient sites in jaws.

MATERIAL AND METHODS

This study has been carried out in accordance with the principles of Declaration of Helsinki on medical protocol. The study protocol was approved by the Ethics Committee of Ondokuz Mayıs University (Protocol no: 2016/251). Patient consent forms were obtained from all patients. In this retrospective study, the cases were randomly selected from a total of 678 patients who have applied to Ondokuz Mayıs University Faculty of Dentistry, between 2012 and 2016 and had both OPG and CBCT images. Seven hundred and fifty two implant sites of 206 cases (106 male and 100 females with mean age of 60.0±9.4 years) were enrolled in the study. Inclusion criteria were as follows; having minimum one tooth loss in maxillary incisor, mandibular premolar, molar or maxillary posterior region, sufficient image resolution for examination of the jaws, maximum 6 months between OPG and CBCT imaging. The images including intraosseous pathologies hindering the examination of mental foramen, nasal floor, and maxillary sinus, having artifact due to movement of patient during scanning, and unsuitable resolution for examination were excluded from the study. Three groups were created based on the proximities of edentulous sites to the anatomic regions. The patients who lost their maxillary posterior teeth were gathered in "Maxillary Sinus (MS)" group, those who lost their teeth in mental foramen region in "Mental Foramen (MF)" group and those that lost their maxillary anterior teeth in "Nasal Floor (NF)" group. The distribution of 752 implant sites is presented in (Table 1).

The CBCT images of the patients were taken by using CBCT device (GALILEOS Comfort Plus, Sirona Dental Systems, Bensheim, Germany) operating with 98 kV and 15-30 mAs. The CBCT images were prepared based on the following parameters; 0.25 mm^3 of isotropic voxel, 12-bit grey scale, 15 mm X 15 mm of FOV amplitude 14 seconds of scanning

TABLE 1: Number of recipient implant sites in each group.

Groups	Number of recipient sites
Maxillary sinus	329
Mental foramen	274
Nasal floor	149

time, 2-6 seconds of radiation duration, and 204° of rotation. The panoramic radiographs were taken by using digital panoramic X-ray device (Morita, Veraviewepocs 2D CPX 550, J. Morita Corporation, Japan) with the parameters recommended by the manufacturer (65 kVp, 5 mA, and 7.4 seconds).

The measurements on CBCT images were performed by using image analysis software (SIDEXIS XG 2.56, Sirona Dental Inc., Bensheim, Germany) and measurements on OPG were performed on screen view of digital panoramic image. All analysis and measurements of OPG and CBCT images were performed by a maxillofacial surgeon.

Before starting the measurements, the "auto calibration" feature of digital panoramic image viewer program was activated. By using this feature, without any need for dividing the obtained numerical values to the magnification value specified by the manufacturer, the actual dimensions of objects in OPG were determined. And then, by using "caliper" feature of program in "labels" section, the shortest distance between the alveolar crest and bottom point of maxillary sinus floor in MS group was measured (Figure 1A). In MS group, the slicing window feature of CBCT program was used in order to determine bottom point of maxillary sinus floor. Then, the shortest distance between the bottom point of maxillary sinus floor and the alveolar crest on cross-sectional image of CBCT was measured by "caliper" feature of CBCT program (Figure 1B). Additionally, the distance between the maxillary sinus floor and the alveolar crest which was measured as 5 mm or less, was evaluated separately within the named as MS-II subgroup. The shortest distance between the alveolar crest and the top point of mental foramen was measured in MF group on OPG (Figure 1C). In MF group, the slicing window was again put onto the top point of mental foramen and the distance between the point, where the nerve leaves the mandible, and alveolar crest was measured on cross-sectional image (Figure 1D). Then the obtained value was recorded in MF-I subgroup. Moreover, in the same cross-section, the distance between the top point of curvature of mental nerve before leaving mandible and the alveolar crest was measured and recorded in MF-II subgroup. The shortest distance between the bottom point of nasal floor and alveolar crest in NF group were measured in OPG (Figure 1E). Then, the measurements were made on CBCT images (Figure 1F). All measurements were repeated 1 week later, and the mean values were recorded.

For the statistical analysis, MED Calc 15.2 software (MedCalc Software, Ostend, Belgium) was used. The descriptive statistics for numerical values were expressed in mean, standard deviation and those for categorical variables were expressed in number and percentage. Taking CBCT measurements as golden standard, Bland-Altman Method was used for examining the consistency of values obtained from OPG with CBCT values. In case of no relationship between differences and mean values, the consistency between both measurements was examined using intraclass correlation coefficient (ICC), correlation and regression analysis, mean value of differences ($\bar{d}$), and standard deviation (SD).

RESULTS

The mean values, standard deviations, mean and standard deviations of measurement differences, and intraclass correlation coefficients for CBCT and OPG are presented in Table 2. In MS group, minimum -1.2 mm and maximum 1.6 mm differences were found between the measurements performed using OPG and CBCT (Figure 2). The correlation between OPG and CBCT was 0.968 in MS group ($p<0.001$). Minimum -1.5 mm and maximum 3.3 mm differences were found between the measurements performed using OPG and CBCT in MF-I subgroup (Figure 3). The correlation between OPG and CBCT was 0.950 in MF-I subgroup ($p<0.001$). Minimum -4.3 mm and maximum 1.2 mm differences were found between OPG and CBCT in MF-II subgroup (Figure 4). The correlation between OPG and CBCT was 0.932 in MF-II subgroup

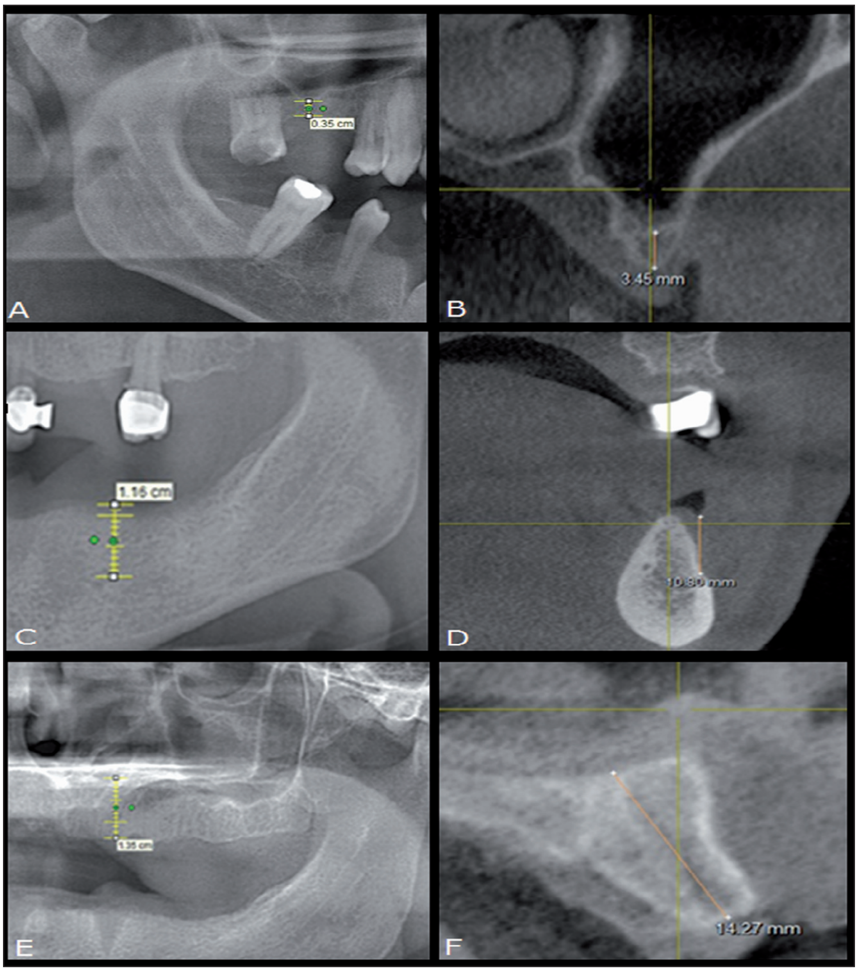

FIGURE 1: A) In MS group, vertical linear measurements were taken from the bottom point of the maxillary sinus to alveolar crest on OPG; **B)** In MS group, vertical linear measurements were taken from the bottom point of the maxillary sinus to alveolar crest on CBCT cross-sectional image; **C)** In MF group, vertical linear measurements were taken from the top point of the mental foramen to alveolar crest on OPG; **D)** In MF group, vertical linear measurements were taken from the top point of the mental foramen to alveolar crest on CBCT cross-sectional image; **E)** In NF group, vertical linear measurements were taken from the bottom point of the nasal floor to alveolar crest on OPG; **F)** In NF group, vertical linear measurements were taken from the bottom point of the nasal floor to alveolar crest on CBCT cross-sectional image.

TABLE 2: Mean, standard deviation and ICC values of measurements made on OPG and CBCT belonging to all groups, mean and standart deviation of differences of measurement between OPG and CBCT.

		Measurements			CBCT-OPG Difference		
		Mean	**SD**	**ICC**	**$\bar{d}$**	**SD**	**p***
MS	CBCT	7.21	3.07	0.973	0.22	0.72	<0.732
	OPG	7.00	3.05	(0.966-0.978)			
MF-I	CBCT	10.87	3.94	0.950	0.92	1.23	0.041
	OPG	9.95	3.79	(0.937-0.960)			
MF-II	CBCT	8.39	3.46	0.924	-1.57	1.41	<0.001
	OPG	9.95	3.79	(0.905-0.940)			
NF	CBCT	14.33	3.31	0.964	0.50	0.87	0.029
	OPG	13.83	3.20	(0.951-0.974)			
MS-II	CBCT	4.06	1.10	0.854	0.36	0.56	<0.008
	OPG	3.70	0.95	(0.789-0.900)			

ICC: Intraclass correlation coefficient, OPG: Panoramic radiography, CBCT: Cone beam computed tomography, MS: Maxillary sinus, MF: Mental foramen, NF: Nasal floor, p: Significance value, SD: Standart deviation, $\bar{d}$: Mean of differences.

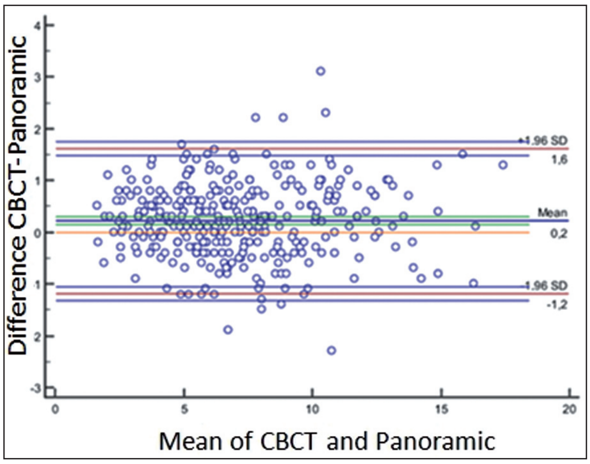

FIGURE 2: Bland-Altman graph showing the scatter plot of the differences of the measurements versus mean of the measurements made on OPG and CBCT in MS group. Minimum -1.2 mm and mnimum 1.6 mm measurement difference between OPG and CBCT is shown by graph.

(p<0.001). In NF group, minimum -1.2 mm and maximum 2.2 mm differences were found between the measurements performed using OPG and CBCT (Figure 5). The correlation between OPG and CBCT was 0.965 in NF group (p<0.001). Minimum -0.73 mm and maximum 1.45 mm differences were found between the measurements performed using OPG and CBCT in MS II subgroup (Figure 6). The correlation between OPG and CBCT was 0.860 in MS-II subgroup (p<0.001).

DISCUSSION

Implant selection with an acceptable size and position is the fundamental step for a successful treatment planning. OPG is considered to be one of the most widely used method in examining the jaw prior to the implant surgery.[10] In 2002, European Association of Osseointegration (EAO) Guidelines recommended OPG for planning oral implant placement in the upper jaw.[11] In a study of Vazquez et al., OPG was reported to be a reliable imagining method in measuring the alveolar bone height prior to the insertion of posterior mandibular implants (safety margin was accepted to be minimum 2 mm).[12] On the other hand, others reported the use of OPG to be less reliable than CT or CBCT, especially in identifying the mental loop and mandibular canal.[13-15] The present evidences suggest that the cross-sectional imaging (CT/CBCT) can be used as the gold standard in planning the implant treatment.[16-20]

Various parameters might negatively affect the reliability of OPGs. The most important point for the success of scanning is the accurately positioning the patient, since the failure in positioning will result in discrepancy and distortion of shape.[21] Besides, the OPG method provides 2D image of 3D subjects; the superimposition of adjacent anatomical structures, makes it more difficult to make an accurate diagnosis.[22] The shadows from soft tissues and the air around these tissues decrease the quality of OPGs.

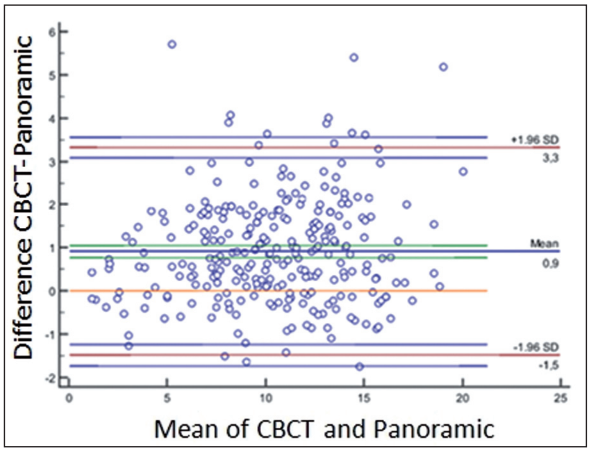

FIGURE 3: Bland-Altman graph showing the scatter plot of the differences of the measurements versus mean of the measurements made on OPG and CBCT in MF-I group. Minimum -1.5 mm and minimum 3.3 mm measurement difference between OPG and CBCT is shown by graph.

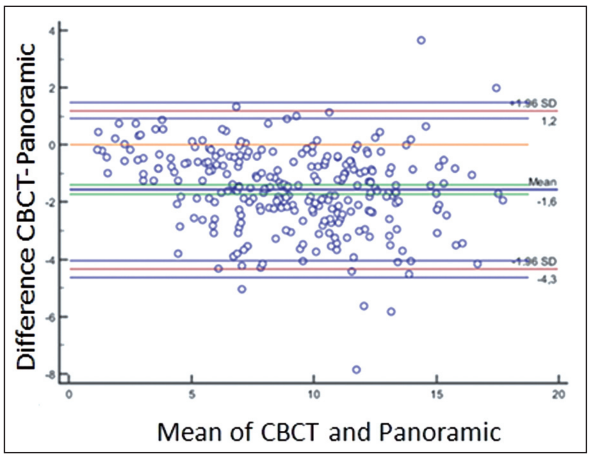

FIGURE 4: Bland-Altman graph showing the scatter plot of the differences of the measurements versus mean of the measurements made on OPG and CBCT in MF-II group. Minimum -4.3 mm and minimum 1.2 mm measurement difference between OPG and CBCT is shown by graph.

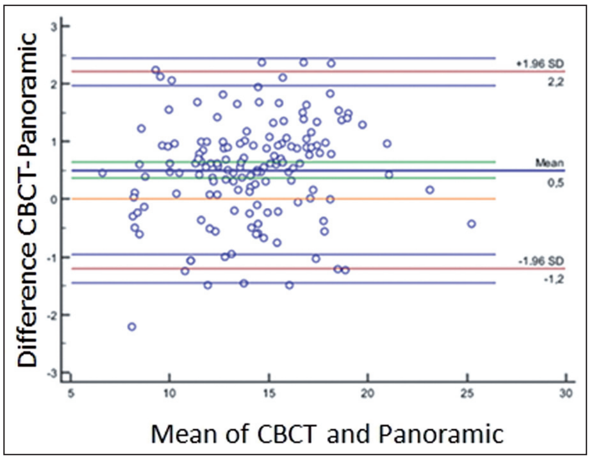

FIGURE 5: Bland-Altman graph showing the scatter plot of the differences of the measurements versus mean of the measurements made on OPG and CBCT in NF froup. Minimum -1.2 mm and minimum 2.2 mm measurement difference between OPG and CBCT is shown by graph.

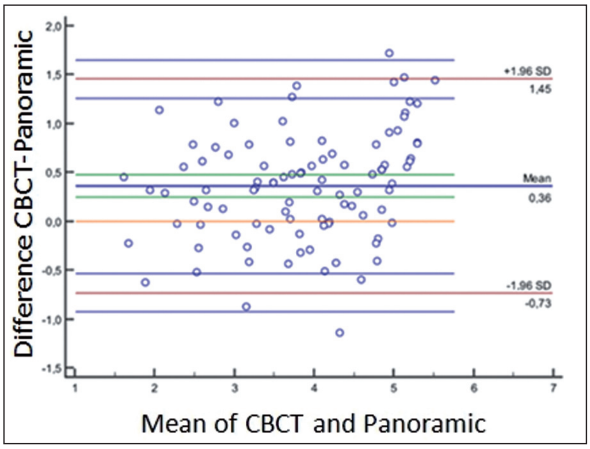

FIGURE 6: Bland-Altman graph showing the scatter plot of the differences of the measurements versus mean of the measurements made on OPG and CBCT in MS-II group. Minimum -0.73 mm and minimum 1.45 mm measurement difference between OPG and CBCT is shown by graph.

The shadowy images of spine and mandible also decrease the diagnostic quality of these radiographs. The magnification of OPGs range between 10% and 30%, while the horizontal magnification is more inconsistent and less reliable.

Literature data reveals that in mandibular canal or mental foramen region, the measurements performed using OPG do not offer results as reliable as CBCT does, and that it might lead the surgeon to select an improper implant length. Furthermore, the upper border of mandibular canal and mental foramen cannot be well-observed with OPG and that the vertical measurement cannot be safely performed in these regions.[23] Kamrun et al. reported that OPG offered better option for visualizing the bottom border of mandibular canal than its upper border, and that the visibility of mandibular canal decreased while approaching to posterior to mental foramen in both of CBCT and OPG images.[23] Angelopoulos et al. divided the distance between mandibular foramen and mental foramen into 3 segments, and then examined the visibility of mandibular canal.[14] They reported that the visibility of mandibular canal was better with CBCT in all three regions when compared to OPG. In the same study, they also reported that the visibility of canal decreased from posterior to the mental foramen in both imaging methods. Consistently with the literature, we found a low correlation between the vertical measurements performed on CBCT and OPG in mental foremen region. Various explanations were made regarding why it is difficult to visualize the mental foramen on radiographs. Yosue and Brooks emphasized that some of the reasons hindering the observation might be the difficulty in distinguishing foramen from trabecular pattern and thin structure of mandibular bone providing no radiographic contrast, excessively dark radiographs, as well as the lingual cortical plate of bone that is excessively thick and the foramen that doesn't decrease the density of the bone to the sufficient level for detection on radiographs.[24] The data obtained from the previous studies as well as our study concluded that, planning in mental foramen region by using only OPG might cause complications such as mandibular nerve damage, and hemorrhage. For this reason, it should be better to examine the area with CBCT especially in critical sizes. It also enables 3-D examination of the present bone and identification of mental foramen and mandibular canal variations.[25]

Kopecka et al. reported that, OPG doesn't give accurate results in alveolar bone height measurements in the maxillary canine region when compared to CBCT.[26] They concluded that it offers more consistent results with CBCT in maxillary incisor region. In the present study, we also found a weak correlation between two methods in NF group. The reason for this might be the inability of clearly visualizing the borders of nasal floor because of the intersection line of maxillary sinus cavity, which crosses in this region and intense compact bone that covers nasal cavity. Nasal mucosa perforation, hemorrhage, post-operative infection, and rhinosinusitis might occur if the accurate and careful measurement is not performed in nasal floor region.[27] In this study, considering the differences between the mean values of measurements, it was seen that the 2 mm safety margin was exceeded in some of the cases. In complex cases, that have insufficient vertical bone distance in maxillary anterior region, CBCT can be considered as a safe method for the surgeon in order to prevent possible complications that affect vital structures.

Dagassan and Berndt et al. reported a significant difference between the mean value obtained from OPG and CBCT in measuring the height of the vertical alveolar bone in mandibular and maxillary molar and premolar regions.[28] The region with the highest level of difference was reported to be maxillary premolar region. The authors emphasized that the reason might be the inability of constantly and clearly visualizing the bottom border of maxillary sinus. Inconsistent with the results of Dagassan and Berndt et al., we found, a strong relationship between OPG and CBCT at the maxillary sinus region. We advise to use OPG as a safe and easy-to-implement technique for implant planning in maxillary posterior region. In cases with sinus pneumatization that have 5 mm or less alveolar height, we create a subgroup to evaluate the reliability of OPG measurements in deciding close or open sinus lift operation. Interestingly, we found a low correlation between the measurements made on OPG and CBCT in this group though there was a strong correlation in total MS group. The possible reason of this condition might the changes in the 3 dimensional architecture of the pneumatized sinus cavity. Alveolar ridge resorption was higher in frontal part of the maxillary sinus according to maxillary resorption pattern. A concave area occurs at the vestibular aspect of the maxillary alveolar crest that could only be seen at transverse cross sections of the CBCT which may lead inconsistency in the measurements of CBCT and OPG.

The advantages of using OPG rather than CBCT include easy access to the equipment, decreased cost and radiation exposure. Both modalities have less radiation than CT.[29,30] The CBCT scanners deliver a smaller radiation dose (2 to 5%) than medical scanners; however, they can deliver up to 15 times more radiation per exposure than 2D imaging.[31-33] It has been demonstrated that decreasing the field of view (FOV) helps reducing radiation dose.[34] Studies have shown that increase in voxel size does not affect the accuracy of measurements in the maxillofacial region.[35,36] In a study of Luangchana et al., linear measurements of five voxel sizes from two CBCT machines were compared with the physical measurements and showed a high correlation with each other.[36] In a study of Torres et al., 0.3 and 0.4 mm^3 voxel size was recommended for linear measurements during implant planning owing to low radiation doses.[35] Practitioners who use CBCT routinely should pay particular attention to minimize the dose by altering the FOV, the kilovolt peak, and the milliamper-second. In the present study the voxel size was 0,25 mm^3.

CONCLUSION

OPG is still frequently used in implantology and routine dentistry practice. Besides that, CBCT gradually gains more place in actual practice of dentistry. In the present study, it was determined that, in vertical measurements performed in maxillary posterior implant sites which have 5 mm or more vertical height, OPG might be used alone under favor of lower radiation level and more affordable costs. In vertical measurements performed in mental foramen, nasal floor and extensive maxillary sinus pneumatization regions, OPG didn't yield results that are as safe as those given by CBCT. In cases in which the available bone is limited due to the close proximity with anatomical landmarks, preoperative CBCT examination is recommended to avoid complication risk. Surgeons should make imaging method preferences by evaluating the complexity of case and possible complication, as well as the radiation that the patient will be exposed to.

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During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that pro-

vides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

***Idea/Concept:** Burcu Baş, Haluk Yener Ünsal; **Design:** Burcu Baş, Haluk Yener Ünsal; **Control/Supervision:** Burcu Baş; **Data Collection and/or Processing:** Haluk Yener Ünsal; **Analysis and/or Interpretation:** Burcu Baş, Haluk Yener Ünsal; **Literature Review:** Haluk Yener Ünsal;**Writing the Article:** Burcu Baş, Haluk Yener Ünsal; **Critical Review:** Burcu Baş; **Materials:** Haluk Yener Ünsal.*

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