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Research Article

Subjective Evaluation of Maxillofacial Landmarks with Different Resolutions of Cone Beam Computed Tomography

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Abstract

Introduction: There are some anatomical considerations that are important while selecting a dental treatment plan, such as measurement of height, width, quality, and density of the alveolar bone for placement of the implant, identification of the possible pathologies, and observation of the periodontal ligament around the impacted teeth to determine the presence or absence of ankylosing. With the advances in technology, the size of the voxels in cone beam computed tomography (CBCT) has reduced and the resolution of the images has increased. Since this increase in resolution also increases the radiation dose to the patient, we aimed to investigate the accuracy of detection of the anatomical landmarks in implantology with different CBCT resolutions and the possibility of minimizing patient radiation dose by decreasing the resolution.

Method: In this study, the CBCT information archive in a private center was used and images of 30 patients who were referred for implant placement or for examination of impacted teeth as well as their information in DICOM format were investigated. The images were stored in two different resolutions: 0.32 and 0.16. Three radiologists examined the images on two different days and assessed the ability to detect the different landmarks and measurements specified in the relevant forms.

Results: In the measurement of the distance between the alveolar crest and the mandibular canal, the mean difference (based on consensus between observers 1, 2, and 3) between the two sets of images with resolutions of 0.16 and 0.32 was less than 0.4 mm. The mandibular canal limits were visible in 72.9% of the images (Kappa coefficient = 0.434). The mandibular canal site was visible in 88.6% of the images (Kappa coefficient = 0.495). The mental foramen borders were visible in 85% and mental foramen site in 98.2% of the images. The lamina dura was visible in 87.1% of the images (kappa coefficient = 0.286).

Conclusion: Based on the results of this study, the use of CBCT images at a resolution of 0.32 rather than 0.16 appears to provide sufficient accuracy for the detection of the abovementioned anatomical landmarks.

Keywords: *CBCT; Resolution; Anatomical Landmarks*

Introduction

Locating and accurately tracking anatomical landmarks is the first step in a patient's dental treatment plan, which provides an accurate understanding of the treatment type and options available for patient management. To reduce the risks during treatment, it is important to know the exact location of the anatomical landmarks. Cone beam computed tomography (CBCT) can be used to assess the location and characteristics of the chin hole, the anterior loop and the mandibular incisive canal, the lower alveolar canal, infraorbital hole, the length and width of the dental arch, cephalometric measurements such as the anterior nasal spine, posterior nasal spine, prothion, gonation, pogonion jenion, and corion; determination of the location of impacted teeth [1,2]; determination of bone displacements by orthognathic surgery [3,4]; growth modification [5]; 3-dimensional (3D) analysis of facial, soft tissue, and airway asymmetries; angle determination; root analysis [6,7]; and determination of the location of the condylar head in patients with temporomandibular problems.

The benefits of CBCT include the high quality of the information obtained, the short scan time, the effect on the diagnosis and treatment plan, ease of use, and cost-effectiveness [8-10].

Despite all these benefits, there are still many concerns regarding the use of this technique, particularly in children, since radiation exposure of the patient in this technique, though considerably less than that in conventional CT, is more than that in common dental radiography [11]. According to the principles of As Low As Reasonably Achievable (ALARA), which seek to gain as much information as possible while subjecting the patient to the lowest risk possible, CBCT is considered to be the preferred choice for evaluating surgical patients, since it uses allow radiation dose, the irradiation time is short, and the diagnostic accuracy is high. In fact, some of the pioneers of this field, such as Prof. Ganz, consider this method not only a typical imaging modality but also a surgical strategy [12].

Aim of the Study

The aim of this study was to determine the accuracy of evaluation of anatomical landmarks in implantology with different CBCT resolutions and to minimize the patient radiation dose by reducing the resolution as much as possible.

Materials and Methods

In this study, the CBCT information archive in a private center for maxillofacial radiology was used. The images of 30 patients referred for implant placement or examination of impacted teeth and their information in the DICOM format were reviewed. Imaging was performed using a CBCT device (Planmeca, promax 3D, Helsinki, Finland, Flat panel 8 x 8 cm, resolution 0.16 mm, 84 kVp, 16 mA). In accordance with ethical guidelines, patients scheduled for implant placement or examination of impacted teeth were exposed to radiation only once (0.16 mm resolution).The images acquired were restored and saved at two different resolutions of 0.16 mm and 0.32 mm in JPEG format (Figure 1 and 2) using Romexis Viewer 2.9 software. Three radiologists reviewed the images on two different days at an interval of 1 week and evaluated the visibility of different landmarks and measurements specified in the data collection forms. Images were placed in Romexis Viewer 2.9 software for radiologists and reviewed at a resolution of 0.16 mm on one day and at a resolution of 0.32 mm on the other day. The landmarks evaluated were as follows:

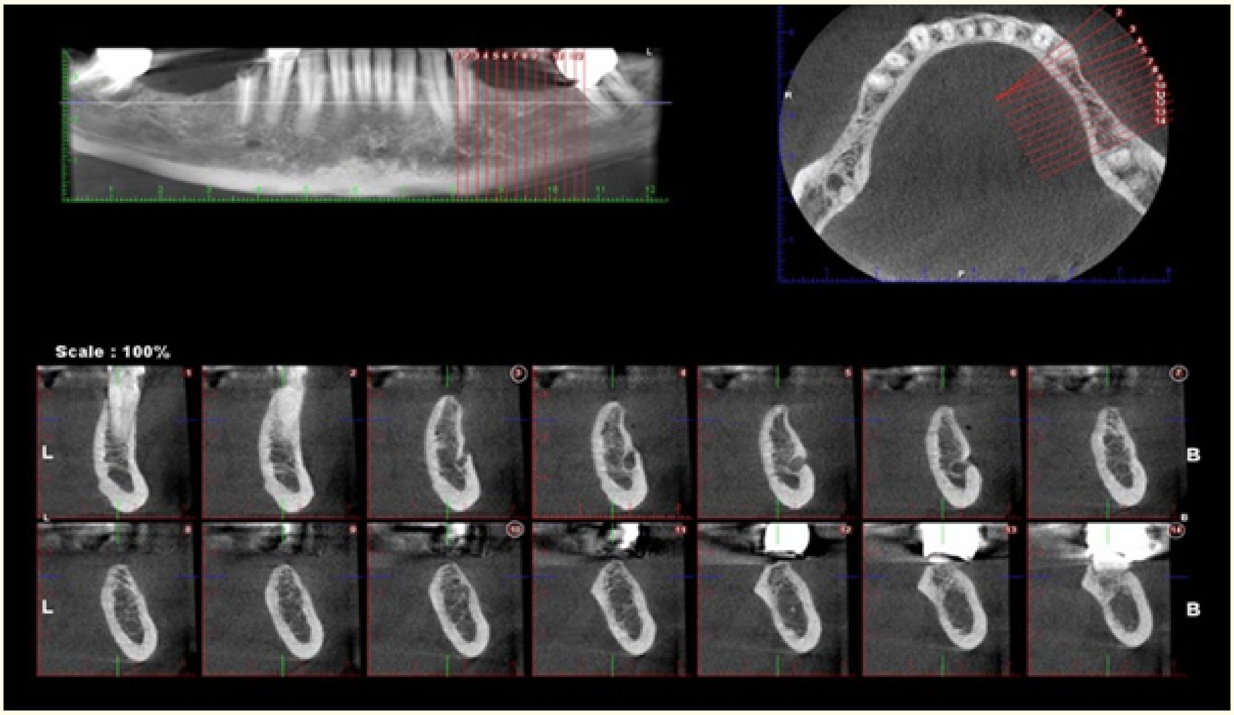

Figure 1: *Image with Resolution 0.32 mm.*

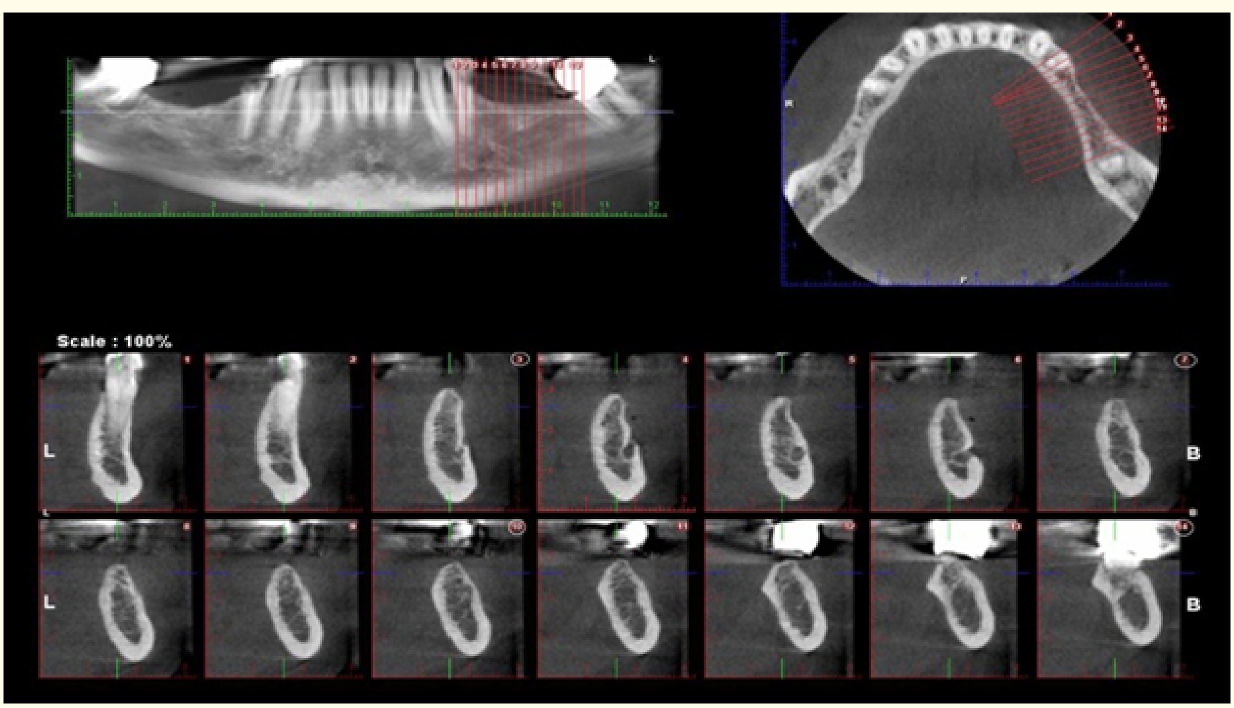

Figure 2: *Image with Resolution 0.16 mm.*

- Presence or absence of the mandibular canal
- Presence or absence of the mental foramen
- Presence or absence of the lamina dura around the impacted teeth
- Measurement of the distance between the alveolar crest and the mandibular canal or between the mental foramen and incisive canal.

The data recorded in the related forms were entered into SPSS version 17. Statistical analysis was performed using t-tests.

Results

Based on the objectives of the present study, after acquisition of data and statistical analysis, the following results were obtained, which will be explained and interpreted in the following sections. The results are as follows.

Landmark	Average sensitivity (%)	Average specificity (%)
Around the mandibular canal	71.4	80
Observing mandibular canal	88.2	94.5
Around the mental foramen	85.8	-
Observing mental foramen	99.1	-
Observing Lamina Dura	81.7	54

Table 1: *Status of detection of landmarks studied by CBCT at two resolutions (0.16 and 0.32).*

The distance between the alveolar crest and the mandibular canal was measured by CBCT at resolutions of 0.16 mm and 0.32 mm, and compared using the paired t test.

Observer	Resolution	Mean	Number	Standard deviation	Average standard error
Observer 1	0.16	6.44	72	2.879	0.339
	0.32	6.236	72	2.990	0.352
Observer 2	0.16	6.594	71	2.791	0.331
	0.32	6.586	71	2.665	0.316
Observer 3	0.16	6.277	70	2.648	0.316
	0.32	6.397	70	2.533	0.302

Table 2: *Paired samples statistics in measuring the distance in millimeter between the alveolar crest and the mandibular canal.*

Observer X at resolutions 0.16 and 0.32	Number	Correlation Coefficient	Significance level
Observer 1	72	0.969	0.000
Observer 2	71	0.983	0.000
Observer 3	70	0.980	0.000

Table 3: *Paired sample correlations in the distance between the alveolar crest and the mandibular canal.*

The average distance between the mandibular canal and the alveolar crest as determined by Observer 1 was 6.44 mm at a resolution of 0.16 mm and 6.236 mm at a resolution of 0.32 mm. The correlation coefficient between the two sets of measurements was 0.969.

The average distance between the mandibular canal and the alveolar crest as determined by Observer 2 was 6.594 mm at a resolution of 0.16 mm and 6.586 mm at a resolution of 0.32 mm. The correlation coefficient between the two sets of measurements was 0.983.

The average distance between the mandibular canal and the alveolar crest as determined by Observer 3 was 6.277 mm at a resolution of 0.16 mm and 6.397 mm at a resolution of 0.32 mm. The correlation coefficient between the two sets of measurements was 0.980.

The difference between the two sets of measurements (at resolutions of 0.16 mm and 0.32 mm) for the distance between the alveolar crest and the mandibular canal was 0.73 mm, 0.51 mm, and 0.53 mm for Observers 1, 2, and 3, respectively.

Discussion

CBCT can accurately display anatomical structures and relationships between craniofacial complex using DICOM software.

A combination of volumetric reconstruction and multidimensional vision can provide valuable information to dentists, orthodontists, and maxillofacial specialists regarding hard tissue, dentation, and airway conditions. Non-standard items such as impacted teeth, dental odontomas, or unexpected radiological observations such as pathologic lesions or accidental findings are best visualized by a 3D CBCT scan. In addition, CBCT is indicated when routine radiographs show the near relationship between the third mandibular molar and the lower alveolar canal, or for obtaining cross-sectional images before implant placement.

Images with a good diagnostic quality are crucial for successful management of dental patients. Precise linear measurements in cross-sectional CBCT images are important to avoid injury to the critical anatomical structures, such as the lower alveolar canal, mental perforation, maxillary sinus floor, and nasopalatine canal.

The radiation dose to which the patient is exposed is one of the main concerns in CBCT. Although the effective dose in CBCT is less than that in medical CT, there are concerns regarding it, especially in children. Therefore, it is important to know the patient dose for all CBCT devices and protocols to reduce the associated radiological risk by optimizing the imaging conditions.

The imaging modality with the highest diagnostic accuracy and the lowest possible radiation exposure should be used, and hence, the CBCT protocol needs to be optimized.

According to the clinical indications including kVp, mA, field of view (FOV), exposure time, and image resolution, CBCT equipment should offer an option that uses the smallest volumetric size and exposes the patient to lesser radiation while adapting to clinical needs [13].

With the change in the resolution of the image, the patient's exposure dose also changes. We decided to carry out this study with the aim of carrying out a subjective evaluation of maxillofacial anatomical landmarks by CBCT with different resolutions of 0.16 and 0.32. According to the goals of this study, the following results were obtained:

- The mean sensitivity for observation of the area around the mandibular canal was 71.4% at a resolution of 0.32 mm in comparison to a resolution of 0.16 mm.
- The mean specificity for observation of the area around the mandibular canal was 80% at a resolution of 0.32 mm in comparison to a resolution of 0.16 mm.

- The mean sensitivity for the detection of the mandibular canal was 88.2% at a resolution of 0.32 mm in comparison to a resolution of 0.16 mm.
- The mean specificity for the detection of the mandibular canal was 94.5% at a resolution of 0.32 mm in comparison to a resolution of 0.16 mm.
- The mean sensitivity for observation of the area around the mental foramen was 85.8% at a resolution of 0.32 mm in comparison to a resolution of 0.16 mm.
- The mean sensitivity for the detection of the mental foramen was 99.1% at a resolution of 0.32 mm in comparison to a resolution of 0.16 mm.
- The mean sensitivity for the detection of the lamina dura around the impacted teeth was 81.7% at a resolution of 0.32 mm in comparison to a resolution of 0.16 mm.
- The mean specificity for the detection of the lamina dura around the impacted teeth was 54% at a resolution of 0.32 mm in comparison to a resolution of 0.16 mm.
- The mean difference in the distance from the alveolar crest to the mandibular canal between resolutions of 0.16 mm and 0.32 mm was 0.59 mm.

Ganguly., *et al.* in a study used three protocols with different voxel sizes (0.16, 0.3, and 0.2), and concluded that using 0.3 mm voxel size without exposing the patient to excessive radiation is reasonable and sufficient for evaluation of implant sites. In other words, selecting a lower resolution (0.3 mm voxel size) has no significant adverse effect on the detection of anatomical landmarks [14]. In the present study, the resolution of 0.32 mm showed a sensitivity and specificity comparable to the resolution of 0.16 mm, which is consistent with the results of the above study.

Damstra., *et al.* examined the accuracy of linear CBCT measurements with 0.4 mm and 0.25 mm voxel sizes and concluded that there was no difference between CBCT measurements with the given resolutions and the actual measurements. A voxel size of 0.4 mm is suitable for measuring craniofacial structures, and increasing the resolution of the voxel does not make any difference in the accuracy of surface models [15].

In the present study, there was no difference in distances between the crest and the mandibular canal between resolutions of 0.32 mm and 0.16 mm, and the measurements of both resolutions were highly correlated with each other. Thus, our results are consistent with those of the abovementioned study.

Patcas., *et al.* in a study examined the accuracy of CBCT at two resolutions with voxel sizes of 0.4 mm and 0.125 mm, and found that bone measurements obtained from CBCT were precise and had a very low difference with the actual measurements. Measurements obtained at the two resolutions were not significantly different from each other, and the results of this study are consistent with those of our study [16].

MGG., *et al.* examined the accuracy of CBCT measurements with different voxel sizes of 0.4, 0.3, 0.2 and 0.25 mm and concluded that voxel sizes of 0.3 and 0.4 mm should be used for linear measurements to plan implant therapy to reduce the patient's radiation dose [17].

In the study mentioned above, lower resolution measurements were also found to be adequate for the implant treatment plan, which is consistent with the results of the present study.

Zhang., *et al.* in a project titled "detection accuracy of condylar defects in CBCT", studied resolutions and different units of 42 temporomandibular joints (TMJs) from 21 human skulls at a normal resolution of 0.32 and a high resolution of 0.16 mm, and ProMax 3D and DCT PRO scanners. It was concluded that high-resolution images are not superior to normal resolution images for the evaluation of condylar defects. These results are in line with the results of the current study [18].

Hassan., *et al.* in a study entitled "Influence of scan setting selections on root canal visibility in CBCT", to assess the effect of choosing settings including the high and low FOV and the number of images and modes of scan on the observation of the root canal with CBCT, examined mandibular canines with 6 different FOVs of 4 * 4, 6 * 6, 8 * 8, 10 * 10, 14 * 10, and 17 * 12, and with 180° and 360° images at a high resolution of 0.16 mm and normal resolution of 0.32 mm and 10 observers. They concluded that for endodontic purposes, the smallest FOV and 360° projection should be used, and the use of standard instead of high resolution had no negative effect on the detectability of the root, which is again in line with the results of this study [19].

Kamburoğlu., *et al.* examined occlusal caries by using CBCT at different voxel resolutions and using an intraoral sensor. They evaluated 130 mandibular molars with three voxel sizes: 0.1, 0.2, and 0.3 mm. They found that all resolutions can be used for the diagnosis of occlusal caries and it can be concluded that lower resolutions can be used to reduce the patient dose [20]. In the present study, the resolution of 0.32mm had an acceptable sensitivity and specificity in the detection of anatomical landmarks, which is consistent with the results of the above study.

Feragalli., *et al.* investigated the quality and dose of radiation of CBCT images for five different protocols and examined the exposure dose of different protocols for sensitive organs. They concluded that a low-dose protocol with larger FOV and normal resolution allows for the evaluation of mandibular structures at high-quality and low radiation dose. It provides a complete evaluation of dental and maxillofacial assessments for a treatment plan. This is consistent with the results of this study [13].

Ponder., *et al.* in a study for quantifying external root resorption by low- and high-resolution CBCT and periapical radiography examined the roots of teeth with root defects by micro CT and CBCT at resolutions of 0.2 and 0.4 mm and periapical radiography. They concluded that in examining the root defects, the high resolutions produce a more accurate lateral volumetric analysis of the lateral root analysis that is in disagreement with the results of the present study [21].

The lack of consistency between the results of this study and those of the above study can be attributed to the difference in the method of execution, such as differences in the device used and the selected resolution.

Kamburoğlu and Kursun in a study entitled "Comparison of the diagnostic accuracy of CBCT images of different voxel resolutions used to detect simulated small internal resorption cavities" concluded that CBCT devices with high and very high resolutions provide better diagnostic sensitivity compared to low-resolution images, which is inconsistent with the results of the present study [22].

The lack of consistency between the results of this study and those of the above study can be attributed to the difference in the methodology, such as the difference in the studied landmarks and the selected resolution.

Conclusion

According to the results of the present study, use of CBCT images with a resolution of 0.32 mm has sufficient accuracy to detect specific anatomical landmarks.

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