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Image analysis for dental bone quality assessment using CBCT imaging

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Abstract. Cone beam computerized tomography (CBCT) is one of X-ray imaging modalities that are applied in dentistry. Its modality can visualize the oral region in 3D and in a high resolution. CBCT jaw image has potential information for the assessment of bone quality that often used for pre-operative implant planning. We propose comparison method based on normalized histogram (NH) on the region of inter-dental septum and premolar teeth. Furthermore, the NH characteristic from normal and abnormal bone condition are compared and analyzed. Four test parameters are proposed, i.e. the difference between teeth and bone average intensity (**s**), the ratio between bone and teeth average intensity (**n**) of NH, the difference between teeth and bone peak value (**Δp**) of NH, and the ratio between teeth and bone of NH range (**r**). The results showed that n, s, and **Δp** have potential to be the classification parameters of dental calcium density.

1. Introduction

Recent development in technology of medical imaging has a new perspective in medical diagnosis and therapy planning. The X-ray based imaging equipments are also employed in the cases of dental treatment for functional and aesthetic purposes. The periapical and panaromic dental imaging are the type of 2D imaging. For 3D imaging, cone beam computed tomography (CBCT) is recently widely used for dental maxillofacial radiography application. CBCT uses much lower radiography percentage, faster scan time, and safer to use in maxillofacial region than conventional multidetector CT scan. For assesment of bone quality, CT image has relatively straightforward because a gray value is proportional with energy attenuation of bone material. Unlike CT scan, CBCT image has problem on variability of gray values due to limited field size, relatively high amount of scattered radiation and limitations of currently applied reconstruction algorithms. However, to support pre-operative dental implant planning, 3D CBCT data has potential to be applied if the problem on variability of gray values can be suppressed. To overcome this problem, we proposed an image analysis scheme, based on relative comparison between quantitative data on the different location of region of interest (ROI) on the same slice orientation. The dental expert defined the locations of ROI that are predicted as normal and abnormal condition. On the 3D CBCT data, an image plane could be selected based on the slice that used for further analysis and diagnosis.

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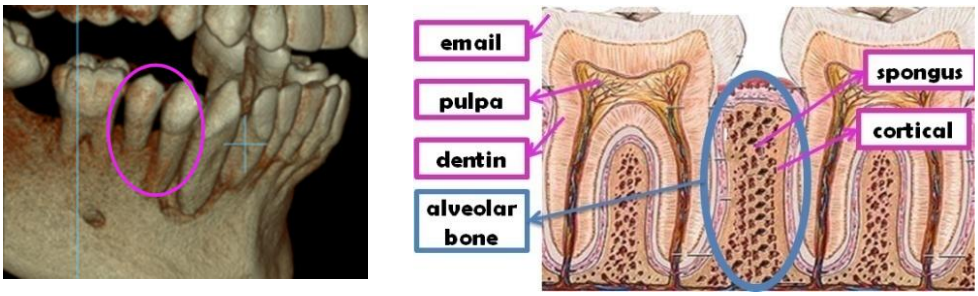
2. Material and Methods

2.1. Material

In this work, sponges of alveolar bone in the lower jaw is selected as ROI. These selected teeth are shown in 3D reconstruction CBCT image in figure 1(a). Alveolar bone that used as ROI was inter septal bone that located between two teeth as described by blue circle in figure 1(b). The alveolar bone is consist of spongus and cortical, where spongus bone calcium density was lower than cortical bone calcium density.



(a) (b)

Figure 1. (a). Right lower jaw premolar teeth. The blue circle represent the permolar teeth (b). Teeth and alveolar bone structure.

In the research, ten sets of 3D CBCT data was acquired using CBCT (EPX-Impla, E-WOO Tech-Department of Dentomaxilofacial Radiology, Faculty of Dentistry, Padjadjaran University). Each set of CBCT data contain 256 axial slices of human. Each slice is a 12 bit DICOM (Digital Imaging and Communication in Medical) image. These sets were used to build 3D image and another orthogonal slice such as coronal and sagittal slices by *EPX-IMPLA* software. ROI were recognized by identifying dental structure from 3D images and orthogonal slices. The dentist makes preliminary diagnosis in order to classify the set of 3D CBCT data. The dentist also decides that five sets of 3D CBCT data are normal and the rest of data sets are abnormal.

2.2. Methods

Based on 3D CBCT reconstruction, the slice orientation that is proper for the representation of the premolar teeth and interseptal bone image was selected. Sagittal orientation was chosen for image plane (see figure 2-left). Furthermore, the image area that is used for further processing is selected. On the pre-processing step, contrast stretching is applied to normalize the contrast range of images.

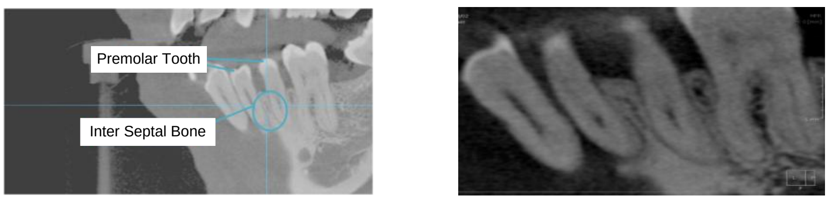


Figure 2. Sagittal plane of premolar teeth and inter septal bone (left) and the pre-processing image for further analysis (right).

The bone condition could be diagnosed based on the calcium density of bone that is represented as grayscale on the images. We propose comparison method based on normalized histogram (NH) on the ROI inter-dental septum and premolar teeth. Under the guidance of the dentist, ROI is selected and marked by several points around the targeted area. Then, based on selected points, a close curve is reconstructed using spline interpolation (see figure 3).

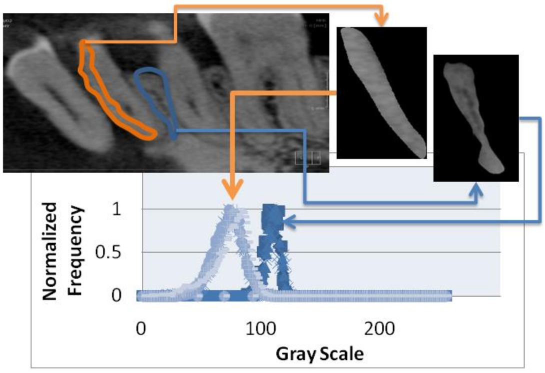


Figure 3. Proposed scheme of image analyis bone condition.

The probalistic density function of each selected ROI is determined based on NH, that is represented as

$$h(k) = \frac{p(I_k)}{p(I_k)_{\max}} \tag{1}$$

where $p(I_k)$ was number of pixel on one grayscale value, k was a grayscale value. Each histogram was normalized by its maximum value to minimize CBCT inconsistency effect that influences the data. Furthermore, the NH characteristic from normal and abnormal bone condition are compared and analyzed. Five sets of NH of normal data and five sets of NH of abnormal data are used on the research. Each set of data contains four sagittal slices of premolar tooth and alveolar bone that located between two premolar teeth.

Four test parameters are used to analyze the prediction of bone condition based on two NH distributions (figure 3). The first test parameter is the difference between teeth and bone peak value (**Δp**) of NH. This variable was also recognized as the difference between bone and tooth gray scale mode.

The second parameter is the ratio between range of NH tooth and NH bone **(r).** NH range is calculated based on the difference between maximum and minimum of grayscale intensity in the NH. The third parameter is the difference between average of grayscale distribution on NH tooth and NH bone **(s)**. The fourth parameter is the ratio between bone grayscale intensity averages and tooth grayscale intensity averages **(n)**.

Sets of four test variables ({Δp, r,s,n}**)** are analyzed with averaging four axial slice histogram values in each data. Analysis was conducted by comparing five normal and five abnormal data to observe the difference between groups. This comparison was done by two methods, directly and analyzing its variance.

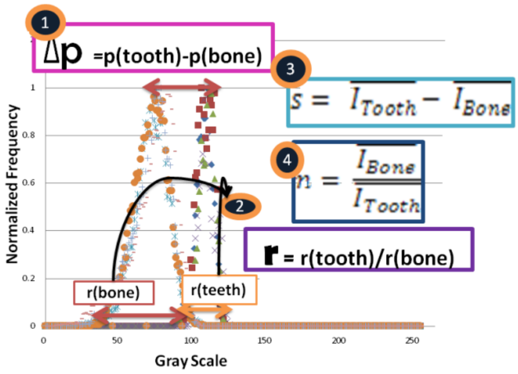


Figure 4. Four test parameters are used to analyze prediction bone condition based on two NH distribution.

Analysis of variance (ANOVA) was a general method to overlook the variance of data inside group and inter groups. If the variance inside the group is significantly smaller than inter group, then it means we can observe the difference between groups clearly. F-test was used to evaluate the diference between group, where F value determined by ratio between intergroup variability (Va) and group variability (Vg). The significant of four test variables to determine bone condition is evaluated based on comparing F value of data and F critical (F_{crit}) value.

3. Results

Based on the sets of CBCT jaw image data (five normal and five abnormal), the range of **Δp** value from left and right jaws data was shown in Figure 5. These results directly showed that **Δp** value could differentiate normal and abnormal teeth clearly.

Figure 5. The range of Δp value from right and left jaws.

ANOVA of this data Δp showed that F of this data is 22.93, which is much larger than its F critical of 3.96. These mean that the first variable, **Δp**, has potential to be a test variable for teeth classification. From their trends, normal teeth **Δp** values tend to be smaller than abnormal teeth **Δp** values. The same procedure to determine range of **Δp**, the range of **r** value from left and right jaws data was shown in figure 6.

Figure 6. The range of **r** value from right and left jaws.

The result of the left jaws **r** values showed that r could differentiate normal and abnormal teeth. But the result of the right jaws **r** values showed that normal teeth **r** area covers all abnormal **r** area. That fact showed **r** could not differentiate normal and abnormal teeth **r** group. ANOVA of this data **r** showed that F of this data is 0.69, which is much smaller than its F critical of 3.96. These mean that the second variable, **r**, has no potential to be a test variable for teeth classification. Furthermore, the third parameter, **s**, left and right jaws showed in figure 7. These results directly showed that **s** value could differentiate normal and abnormal teeth on both jaws.

Figure 7. The range of **s** value from right and left jaws.

ANOVA of this data **s** showed that F of this data is 53.01, which is much larger than its F critical of 3.96. Those two facts have give us indication that the third variable, **s**, has potential to be a test variable for teeth classification. From its trend, normal teeth **s** values tend to be smaller than abnormal teeth **s** values. Finally, the fourth parameter,**n**, left and right jaws showed in Figure 8. Calculation of the fourth variable, **n**, left and right jaws showed in figure 8.

Figure 8. The range of **n** value from right and left jaws

These results directly showed that **n** value could differentiate normal and abnormal teeth as two different groups. ANOVA of this data n showed that F of this data is 70.11, which is much larger than its F critical of 3.96. Those two facts have give us indication that the fourth variable, **n**, has potential to be a test variable for teeth classification. From its trend, normal teeth n values tend to be bigger than abnormal teeth **n** values.

4. Conclusion

The proposed image analysis method has potential for the assessment of dental bone quality using CBCT images. Four test parameters are proposed, i.e. the difference between teeth and bone average intensity **(s)**, the ratio between bone and teeth average intensity **(n)** of NH, the difference between teeth and bone peak value (**Δp**) of NH, and the ratio between teeth and bone of NH range **(r)**. The results showed that **n**, **s**, and **Δp** have potential to be the classification parameters of dental calcium density.

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