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ORIGINAL ARTICLE

Mineral Density Distribution Differences in Enamel and Dentin Tissues in the Teeth Array According to the HU Scale

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ABSTRACT

Objective: To evaluate the mineral density of enamel and dentin tissues of healthy individuals using three-dimensional cone-beam computed tomography. **Material and Methods:** CBCT images of 15 healthy individuals, previously obtained for various reasons, were used in this study. In HU measurements, mineral density measurements were made from three different regions of enamel and three different regions of dentin, and the values obtained were compared. Enamel and dentin mineralization density measurements were measured from six regions, namely the crown cutting edge, buccal middle and cervical region for enamel, and the crown cutting edge, cervical region and root apex for dentin. In the comparisons of groups, the parametric One-Way ANOVA variance analysis method was applied. In the paired comparisons between the groups, the Tukey HSD test was applied as the multiple comparison post hoc test. A value of $p<0.05$ was accepted as statistically significant. **Results:** Mineralization density of tooth enamel and dentin tissues was quantitatively different in the maxilla and mandible in anterior and posterior teeth. **Conclusion:** In all the teeth, there were statistically significant decreases in the mineral density values of enamel and dentin tissue from occlusal towards the cemento-enamel junction. Statistically significant decreases were observed in the mineral density values of enamel and dentin tissue from the anterior region towards the posterior region in the teeth in both the upper and lower jaws.

Keywords: Diagnostic Imaging; Tomography; Dental Enamel; Dentin; Minerals.

Introduction

A significant problem frequently encountered is dental decay, which starts in the enamel outer layer of the tooth. Therefore, it is important to know the mineral content of dental enamel tissue and the underlying dentin tissue, which is in contact with oral flora and saliva [1].

Dental enamel tissue is the hardest and most mineralized tissue in the human body. Approximately 96% of dental enamel is inorganic mineralized material and the remainder consists of organic material and water [2]. It is known that the mineral section is formed of hydroxyapatite crystals tightly bound to each other within prisms [3]. The enamel prisms are perpendicular to the enamel–dentin junction and extend toward the outer surface [4,5].

Research into the analysis and density measurements of mineralized tissues is important in dentistry. The introduction of the use of cone-beam computed tomography (CBCT) in dentistry allowed researchers to make quantitative measurements of the mineral density of mineralized tissues, such as enamel, dentin, and bone, without destroying any tissues in living subjects or experimental samples. This created the possibility of comparing dental tissues in different groups of teeth, in different patient groups, and developmental mineralization disorders in the teeth. For example, mineral losses in the tissues in periapical lesions can be compared with mineralization after treatment [6-9].

CBCT presents many possibilities to dentists in scientific studies. One of these is the use of the Hounsfield Unit (HU) scale, developed by Godfrey Newbold Hounsfield in 1972, which is a method by which mineral density can be measured quantitatively on CBCT images.

Using the HU scale, the density of mineralized tissues such as bone and teeth can be measured with numerical values and examined quantitatively. According to the HU scale on CBCT scans, tissue status has values between -1000 and +3000 HU [10-13]. When examining the mechanical properties of bone, enamel, and dentin tissue, mineral density is an important evaluation criterion [14].

There is a parallel, positive relationship between mineral density and the mechanical properties of dental enamel tissue. In other words, however low the mineral content of enamel is, so there is a parallel low rate of resistance and hardness of the enamel. It has been reported that as a decrease in enamel mineral content causes a decrease in the mechanical properties of the enamel, this can result in the failure of restorations applied [15]. The mineral density of enamel can contribute to the long life of restorations to be applied, the selection of appropriate restorative material, and the evaluation of remineralization agents and the associated mechanisms [14].

Unwanted image distortions such as super-positioning or magnification do not occur on CBCT images, and separate measurements can be obtained at real dimensions on the images. These can be examined two or three-dimensionally in micron thickness ranges in horizontal, frontal, and sagittal planes of the skull. Healthy enamel and dentin can be differentiated from lesions at the initial stages of decay according to the mineral density measured with the HU scale [16,17].

As a result of the advantages presented in dentistry, CBCT has started to be increasingly used in many areas such as orthodontics, orthognathic surgery, implant planning, examination of alveolar bone, pathological formations, and the temporomandibular joint, diagnosis and treatment of craniomaxillofacial fractures, the measurement of dental and bone density, dental age estimation, the determination of embedded tooth position, the dimensions of periapical lesions, and the determination of damage formed in bone tissue [18-20].

This study aimed to investigate the feasibility of mineralization density measurements of dental enamel and dentin tissues with CBCT and to examine whether differences in mineralization density in 3 different areas of enamel and dentin tissue in the teeth array showed variability according to the HU scale.

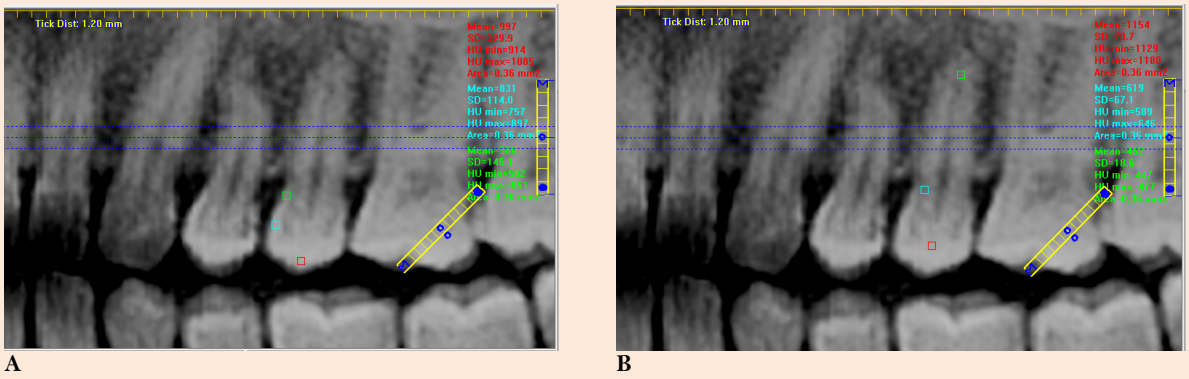
Material and Methods

Ethical Clearance

Approval for the study was granted by the Ethics Committee of Dicle University Dentistry Faculty (decision no: 2022-13, dated:30.03.2022). All procedures were applied in compliance with ethical principles.

Data Collection

Measurements of HU values on bucco-lingual sagittal slices of CBCT panoramic images were obtained using a CBCT device (Imaging Science International, Hatfield, USA) and the standard I-CAT Vision™ program. The measurements of dentin HU values on bucco-lingual sagittal slices of CBCT images are shown in Figure 1A and Figure 1B, and enamel HU measurement examples of all the teeth are shown in Figure 2.



A B

Figure 1. (A) Example of measurement of enamel HU values on bucco-lingual sagittal slice. (B) Example of measurement of dentin HU values on bucco-lingual sagittal slice.

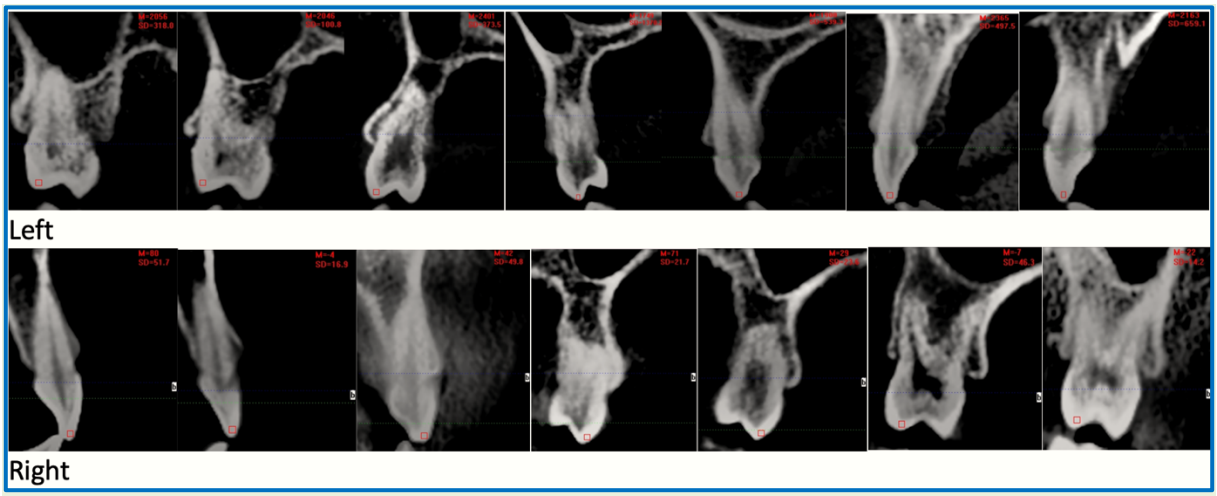


Figure 2. Examples of measurements of enamel HU values of all the teeth in the right and left upper jaw.

On all the 3D CBCT images, the HU values of an area mean of 1mm² were measured on bucco-lingual slices with an I-CAT Vision™ unit. The enamel measurements were obtained by selecting an area mean of 1mm² from 3 regions of the teeth (crown incisor/occlusal edge, buccal, and cement-enamel junction [CEJ]) on the CBCT images, and the dentin HU measurements from 3 regions (crown incisor/occlusal edge, CEJ, and root). These procedures were applied at two different times and the mean values were used in the analyses.

The image data were obtained from CBCT scans taken with 12 KvP, 5 mA, and 0.3 voxel size at 8.9 seconds. Each image was obtained with a single 360° revolution of the device around the patient, and all the images were recorded in Digital Imaging DICOM format. The data of 15 adult patients with CBCT scans previously taken for various reasons were used in the study.

The enamel and dentin mineralization values obtained from 3 different regions of the teeth were compared according to the measurement localization, tooth localization, and jaws.

Data Analysis

Descriptive statistics were stated as mean and standard deviation values. The data showed normal distribution, and the parametric One-Way ANOVA variance analysis method was applied in the comparison of groups. In the paired comparisons between the groups, the Tukey HSD test was applied as the multiple comparison post hoc test. A value of $p<0.05$ was accepted as statistically significant in all the analyses.

Results

The mean values of enamel and dentin mineralization density are shown in Tables 1 and 2, respectively.

Table 1. The mean values of enamel mineralization density.

Region	Enamel Mineral Density Measurement Averages*
Enamel Cutting/Occlusal Edge	2113,39
Enamel Buccal	1808,52
Cole	1235,07

*(p<0.05).

Table 2. The mean values of dentin mineralization density.

Region	Dentin Mineral Density Measurement Averages*
Dentin Cutting/Occlusal Edge	1430,65
Cole	1220,36
Apex	1026,46

*(p<0.05).

The mean values of enamel and dentin mineralization density obtained from upper, lower, right and left localizations according to the numbers of the teeth examined are shown in Table 3 and Figures 3 and 4.

The mean values of enamel and dentin mineralization density obtained from the upper and lower teeth of the samples compared in the study are shown in Table 4.

Table 3. The mean values of enamel and dentin mineralization density obtained from upper, lower, right and left teeth according to the teeth numbers.

Tissue	Tooth													
	17+47	16+46	15+45	14+44	13+43	12+42	11+41	21+31	22+32	23+33	24+34	25+35	26+36	27+37
Enamel	1618,66	1597,5	1762,58	1764,08	1744.62	1780,95	1817,83	1810,70	1841,58	1768,29	1667,12	1699,75	1666,66	1575,33
Dentin	1093,91	1135,12	1186,16	1226,20	1275,83	1265,58	1309,37	1368,37	1319,58	1296,91	1207,87	1222,54	1166,54	1087,62

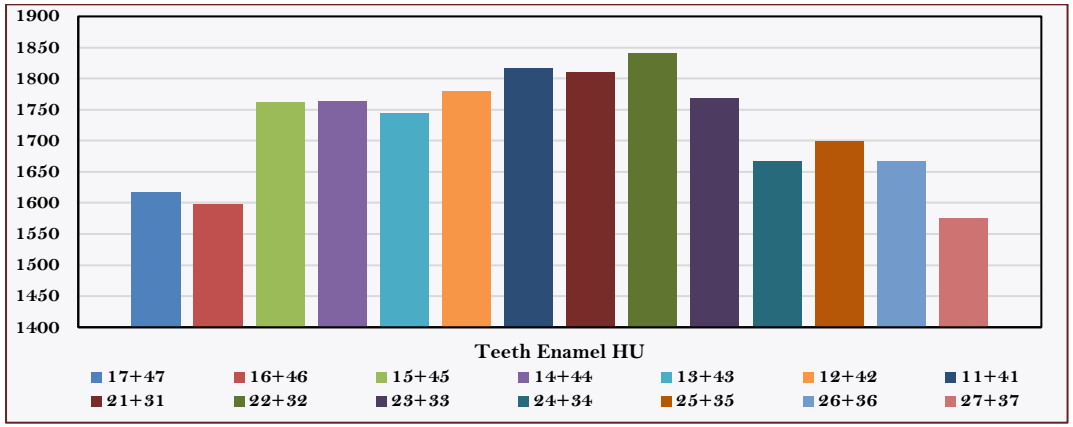


Figure 3. The mean values of enamel mineralization density obtained from upper, lower, right and left teeth.

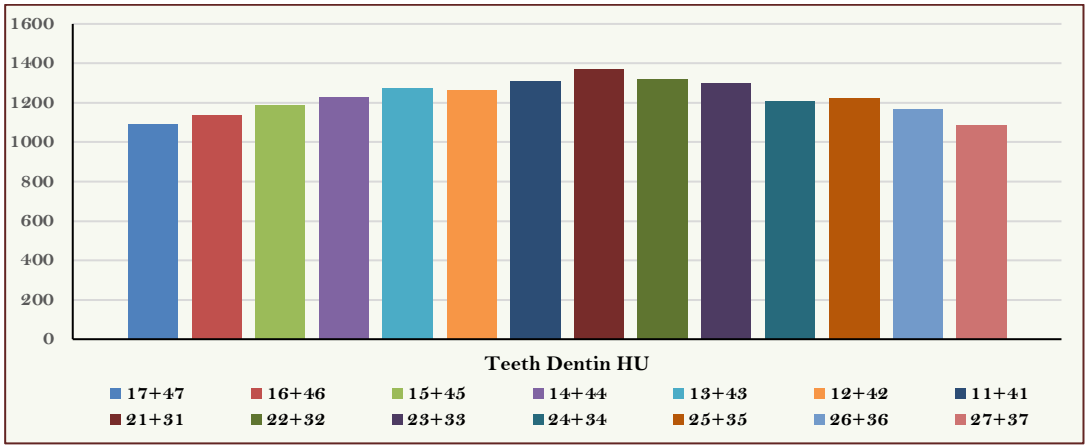


Figure 4. The mean values of dentin mineralization density obtained from upper, lower, right and left teeth.

Table 4. The mean values of enamel and dentin mineralization density obtained from upper and lower teeth.

Region	Enamel	Dentin
Maxilla	1728,55	1198,07
Mandible	1716,54	1253,59

Discussion

Despite comprehensive examinations of the morphology of teeth, the mineral density of teeth has not been clinically evaluated. However, with the development of current technological possibilities, mineral density measurements can now be taken from CBCT images obtained in-vivo from living subjects. Moreover, using micro-CT for experimental purposes, dental mineral density measurements can also be made in-vitro; this creates a great opportunity for researchers in planning studies.

The data on CBCT images can be examined on 3D isolated images of calcified dental structures and by calculating mineral density using image evaluation modelling and development software such as Mimics [18].

No study could be found in the literature specific to mineral density distribution from the crown to the apex of healthy teeth for each type of tooth in the dental array. Therefore, the current study can be considered of value as the first to have examined mineral density distribution in a series of teeth in the jaws through evaluation of the enamel and dentin mineral density from 3 regions of the teeth using the HU scale on CBCT image data. The data obtained showed that the enamel and dentin HU mineral density measurement values of all the teeth decreased from the incisor/occlusal edge towards the root tip ($p<0.05$) (Tables 1 and 2).

Moreover, according to the in-vivo results obtained in this study, the enamel density HU scale values in the CEJ were determined to be lower than the measurements taken in the other occlusal and buccal regions, which was seen to be consistent with the findings of an in-vitro micro-CT study [11]. This information offers a new and different perspective to researchers that the extent of the effect on dental enamel and dentin tissue of genetic disorders or a disease that affects growth and development can be measured with the HU scale. A further advantage of this method is that measurements can be taken in vivo without damaging the dental tissues.

The results obtained in this study demonstrate that mineral density analyses can be made in growth and development disorders, and the measurements are of high reliability since nutritional and developmental disorders affect bone development as well as tooth development.

There is no previous in-vivo study in the literature that has evaluated the differences in mineral density of teeth using 3D CBCT image data, and thus the current study is the first such study in this respect. The results of this study provide valuable information and contribute to the knowledge about mineral density evaluation.

The enamel and dentin mineral density values obtained from the teeth array showed decreasing HU values when examined from anterior teeth towards posterior teeth (Table 3 and Figures 1 and 2). As there is no such information in the literature, these findings can be seen to be important as new scientific data. When comparisons were made of the data obtained from the enamel and dentin tissues of teeth in the upper and lower jaw, there was seen to be no significant difference between the upper and lower jaws ($p>0.05$) (Table 4). These results show that the development of mandibular and maxillary teeth is parallel during growth and development.

This study can be considered to have opened new horizons for researchers and similar studies in the future to present different options for researchers in the early determination of decay, and the examination of the mechanisms related to enamel, dentin, and root mineralization, and to have provided useful results in respect of forming a quantitative numerical standard for comparisons of disease and age groups.

It is thought that the data of the current study will make a significant contribution to future, more detailed scientific studies related to mineral density measurement and that this is a useful method that can be easily applied.

However, it must not be forgotten that more radiation is applied to the patient with CBCT than with traditional imaging methods, and for CBCT to be used routinely in the clinic, there is a need for the radiation dose to be developed to be within acceptable limits.

Conclusion

In all the teeth, there were statistically significant decreases in the mineral density values of enamel and dentin tissue from occlusal towards the CEJ. Statistically significant decreases were observed in the mineral density values of enamel and dentin tissue from the anterior region towards the posterior region in the teeth in both the upper and lower jaws. No statistically significant difference was seen in the mineral density values of enamel and dentin tissue in the teeth of the upper and lower jaws.

The introduction of CBCT technology was an important development for dentistry research as the mineral density of teeth can be measured in HU scale units. An important opportunity presented to researchers is that mineral density differences in teeth in different regions can be measured with CBCT and the HU scale without damaging live tissue.

Authors' Contributions

YY	https://orcid.org/0000-0001-5961-4996	Conceptualization, Methodology, Formal Analysis, Investigation, Writing - Original Draft, Writing - Review and Editing and Visualization
EA	https://orcid.org/0000-0003-4302-6561	Data Curation, Writing - Review and Editing, Visualization and Supervision.

All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

Financial Support

None.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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