

Analysis of Bone Density in a Group of Patients with Dental Inclusion

SUMMARY

Background/Aim: Genetic and environmental etiologic factors have been described for maxillary canine impaction, except for the trabecular bone characteristics in the impacted area. The aim of this study was to evaluate the surface area and bone density using cone-beam computed tomography (CBCT) images of patients with maxillary impacted canines. **Material and Methods:** The sample comprised preorthodontic treatment, CBCT images of 24 participants with unilateral maxillary impacted canines, using the impacted side as study group and the non-impacted side as control group. CBCT images were acquired in portrait mode (17 x 23 cm high field of view) at 120 kV, 5 mA, 8.9 seconds exposure time, and 0.3 mm voxel size. Each root was divided into three levels (cervical, intermediate, and apical) to determine whether the bone density change varied with the tooth level. Moreover, each level was divided into four regions (palatal, distal, mesial, and buccal sides). Bone density was measured using Hounsfield Units. Comparisons were made using paired *t* tests and linear regression. Repeated measurements were obtained randomly from about 20% of the sample. **Results:** In subjects with unilateral impactions, the maxillary bone density was higher in the impacted side, with a mean difference of 350 HU. Bone density increases in the corono-apical direction of about 100 HU in the impaction site and about 50 HU in the site of the erupted canine. The repeated measurements showed similar results. **Conclusions:** The maxillary alveolar bone area and bone density are increased in the impacted side compared with the nonimpacted side.

Key words: Impacted Element, Erupted Element, Bone Density, Hounsfield Index

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Introduction

Nowadays the clinical-radiographic finding of impacted or misplaced dental elements within the bone is more and more frequent. One of the causes must also be attributed to the phylogenetic modifications of the jaws¹. Dental inclusion is defined as the absence in the arch of a tooth after the complete development of its root, or at least six months after the eruption of the contralateral with the fully formed root².

The lower third molars are statically the dental elements that appear most frequently towards the inclusion to which the maxillary canines follow. About 2% of the patients undergoing orthodontic treatment are affected by inclusion of permanent canines³.

Significant differences found in the sex most frequently affected by the anomaly; in fact, female sex has a higher incidence of inclusion, with a ratio ranging from 2:1 to 3:1 compared to the male sex^{4,5}. These data confirm the presence of a genetic component in the etiology of dental malposition with a possible involvement of sex chromosomes.

The delay of eruption or the inclusion of the canine may be described as a complex of factors that can come into play individually or in combination between them. The discrepancy between the perimeter of the arch and the size of the dental elements, the prolonged retention or early loss of the deciduous canine, the agenesis of the lateral incisor and the variation in the length or timing of the formation of its root all have an important etiological role on guide

function performed by the root of the lateral incisor during the path of intraosseous migration and eruption of the permanent canine. Also the anomalous position of the dental gem, the ankylosis of the corresponding deciduous, the presence of cysts or neoplastic formations, the dilaceration of the root are factors that can determine an inclusion representing an obstacle to the physiological eruptive itinerary of the considered element⁶.

The development and increasing use of CBCT in dental imaging has facilitated the study and classification of canines included. The CBCT has obvious advantages compared to traditional 2D images producing three-dimensional images visible in the three planes of the space. Other advantages include a lower radiation dose, lower costs and lower image distortion than other CT modalities^{7,8}. CBCT is used to assess the intraosseous position of the canine, as well as the predictors of inclusion, related to the inclination of the element following the axis of the lateral incisor, the distance from the occlusal plane and the reference sector⁹.

This dental imaging method gives an information about the quantity and quality of alveolar bone through the Hounsfield index which is based on the gray scale values into account. HUs are defined as linear transformations of X-ray attenuation coefficients measured in a material with reference to water (HU= 0). Nevertheless studies have been conducted to investigate the micro-structure of the bone through the analysis of fractals obtained from bone trabeculae¹⁰, the analysis of HU remains the traditional method for assessing the quality of the supporting bone of the tooth included¹¹.

After a careful review of the literature, the studies examined did not consider the bone density of the alveolar process as an etiological factor of canine inclusion. However, understanding the relationship between density and canine inclusion could be relevant at the time of diagnosis and treatment plan. Therefore, the null hypothesis of this study predicts the absence of a correlation between the bone density of the impacted element and the bone density of the contralateral erupted canine by evaluating the Hounsfield index.

Material and Methods

The sample of this study includes a group of 31 patients was analyzed, who attended the University Our Lady of Good Counsel's orthodontic clinic. They had to meet inclusive criteria such as:

- unilateral impaction of the maxillary canine;
- the spontaneous eruption of the contralateral canine as a tooth of the control group;
- growing patients;
- presence of all the dental elements in the arch, or if not yet completely erupted, in the correct position at the level of the apical region;
- no previous history of facial trauma or systemic diseases;
- no medical treatment that could alter facial growth patterns or bone quality;
- absence of periapical or periradicular pathologies or radiolucency of periodontal or endodontic origin;
- no severe facial or dental asymmetry;
- absence of loss of vertical or horizontal alveolar bone.

Seven patients were excluded who did not meet the required criteria because they were adults or with early loss of dental elements or longer meeting the requirements. The final sample consisted of 24 patients, 9 males and 15 females, with an age between 14 and 18 years, average age 15.3 years, of which 11 positioned palatally and 13 vestibularly.

The CBCTs of these patients obtained before any orthodontic treatment were analyzed using the Sirona scanner. To ensure that the voltage, current, resolution, field of view (FOV) and patient position did not affect the alveolar bone density measurements obtained from the CBCT images, CBCT parameters and patient position were identical in all CBCT scans. Before the CBCT scan, the patient was placed in a sitting position with the head in a vertical position and positioned so that the intersection lines were straight horizontally and vertically through the center of the region of interest. CBCT images were taken with the following parameters; Voxel resolution from 120 kVp, 47 mA, 250- μ m and 16 cm FOV.

The CBCT images of each patient were imported into Sirona's GALILEOS Viewer 1.9 medical imaging software. The software has 5 display windows (Figure 1.):

1. Overview;
2. 3D;
3. Tangential;
4. Cross;
5. Axial.



Figure 1. The software has 5 display windows

We used panoramic and 3D visualization for canine localization, while for the bone density determination, we used axial views in cases of canines with a very horizontal position, cross view. Bone density was measured using the Hounsfield index (HU) in the impacted and non impacted side, directly associated with the tissue attenuation coefficient. Bone density around each tooth was evaluated on three levels: cervical, intermediate and apical; where the cervical and intermediate levels were located respectively 3 and 8 mm apically at the amelocemental junction, and the apical level was located 1 mm coronal to the root apex. Furthermore, three adjacent slices were used, obtained at the cervical and intermediate level and two adjacent slices obtained at the apical level to acquire secure more complete information. At each level the measurements were carried out in four regions: at the palatal (P), vestibular (V), mesial (M) and distal (D) levels to measure the alveolar bone density on the four sides of the tooth (Figure 2)^{11,12}.

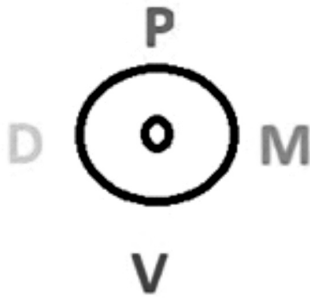


Figure 2. Measurements of the bone density: palatal (P), vestibular (V), mesial (M) and distal (D) levels of the tooth

Statistical Analysis

Data analysis was performed using the version 20 of IBM® SPSS® statistics. The database was created based on the numerical coding that fits its use of the statistical package. There are two different types of analysis, which are: a) descriptive analysis by calculating the mean, median, fashion, variance, standard deviation and for continuous data and proportion with a 95% confidence interval for nominal data; b) inferential analyzes referring mainly to bivariable methods. The tests applied considered the two-tailed analysis with the probability accepted for the type I error of 5%. These tests are Student T Test, for continuous analysis with nominal variable, linear regression analysis and F tests calculated by the association between two continuous variables and calculation of the determination coefficient for correlation analysis on two continuous variables. Both the linear regression and the correlation determine the contribution of various and numerous independent variables in the dependent variable that represents the objective of this study.

Results

Our sample consisted of 24 patients, divided into 15 females and 9 males, aged between 13 and 18 years, with an average of 15.3 years. The most frequently affected canine is 2.3, with a predominantly palatal position in 55% of subjects. In Table 1. the mean bone density was calculated at each radicular level of the study both in the impacted side and non impacted side. The impacted element is 1324 at the cervical level, 1423 at the middle level and 1494 at the apical level. The erupted element is 1105 at the cervical level, 1159 at the middle level and 1208 at the apical level. The total average is 1414 for the included canine and 1157 for the erupted canine. It is observed that the density increases in the corono-apical direction and is greater at the level of the impacted side by a quantity equal to about 100 units, while in the non impacted side, the increment is halved with a quantity.

In the Table 1. the result statistically significant is observing correlation between the bone density of the included element and the bone density of the erupted element in the arch. The statistical is 0.000, showing how the density is increased at the level of the included.

Table 1. Correlation between the bone density of the included element and the bone density of the erupted element in the arch

Unilateral Impaction	Mean	Std. Deviation	Mean diff. (SD) [95% CI]	P value	
Cervical Level	impacted	1323,92	156,44	219 (76.05)	0
	erupted	1104,92	101,69	[186.89, 251.11]	
Medium Level	impacted	1422,96	140,15	264.08 (78.09)	0
	erupted	1158,88	99,62	[231.11, 297.06]	
Apical Level	impacted	1494,21	126,61	285.96 (63.49)	0
	erupted	1208,25	96,69	[259.15, 312.77]	
Total	impacted	1413,65	137,85	256.29 (65.75)	0
	erupted	1157,36	97,48	[228.52, 284.05]	

In Table 2. the correlation between age and bone density is described, increasing in the apical direction both in the impacted side and in the non impacted side. Bone density at 13 years is 1296 HU in the included element and 1084 HU in the erupted element; at 14 years 1297 HU in the included element and 1075 HU in the erupted element; at 15 years 1428 HU in the included element and 1210 HU in the erupted element; at 16 years 1458 HU in the included element and 1136 HU in the erupted element; at 17 years 1477 HU in the included element and 1196 HU in the erupted element; at 18 years 1563 HU in the included element and 1247 HU in the erupted element. Also, shows how the increase in bone density in the impacted canine is statistically significant both at the cervical, middle and apical level; it does not appear to be on any level of the erupted canine.

Table 2. Correlation between age and bone density

	Age	Cervical Level Impacted	Medium Level Impacted	Apical Level Impacted	Cervical Level Erupted	Medium Level Erupted	Apical Level Erupted	Total Impacted	Total Erupted
years 13	Mean	1177	1310,5	1403	1016,5	1078,75	1158,75	1296,84	1084,6
	Nr	4	4	4	4	4	4	4	4
	St. deviation	153,3	132,88	117,7	103,18	105,88	101,07	127,29	102,26
years 14	Mean	1192,75	1288,75	1382,25	1026,5	1088,5	1112,25	1287,82	1075,73
	Nr	4	4	4	4	4	4	4	4
	St. deviation	85,74	59,85	89,86	61,88	88,25	95,16	66,23	81,15
years 15	Mean	1365,33	1473,83	1535,83	1159,33	1217,17	1253,5	1458,28	1210,1
	Nr	6	6	6	6	6	6	6	6
	St. deviation	102,87	96,98	99,23	66,84	62,66	40,33	94,28	53,96
years 16	Mean	1343,75	1439,25	1503,5	1094,5	1127,5	1187	1428,81	1136,27
	Nr	4	4	4	4	4	4	4	4
	St. deviation	182,15	194,17	171,66	117,08	102,88	111,3	182,21	108,03
years 17	Mean	1398,33	1492,33	1543,33	1138,67	1200	1250	1477,92	1196,19
	Nr	3	3	3	3	3	3	3	3
	St. deviation	104,32	88,9	79,66	49,66	51,45	74,71	90,49	58,48
years 18	Mean	1511	1559	1620,33	1198,67	1243,67	1298,33	1563,42	1247
	Nr	3	3	3	3	3	3	3	3
	St. deviation	61,26	38,22	41,48	105,36	95,18	72,28	46,95	89,8
	ANOVA	0,02	0,03	0,07	0,05	0,06	0,06	0,03	0,05

Finally, the correlation between bone density and sex of the patient with inclusion was evaluated. Table 3. shows an average of 1360 HU at the apical level in male subjects, 1453 HU at the medium level, 1518 at the apical level of the included element; in the erupted element an average of 1126 HU at apical level, 1174 HU at medium level, 1227 at apical level. In the female

subjects there is an average of 1302 HU at the apical level, 1404 HU at the medium level, 1479 at the apical level in the included element; in the erupted element an average of 1091 HU at the apical level, 1149 HU at the medium level, 1196 at the apical level. The differences were not statistically significant, despite a small increase in males.

Table 3. Correlation between bone density and sex

	Sex	Cervical Level Impacted	Medium Level Impacted	Apical Level Impacted	Cervical Level Erupted	Medium Level Erupted	Apical Level Erupted	Total Impacted	Total Erupted
Male	Mean	1360,22	1453,78	1518,67	1126,67	1174,78	1227,56	1444,16	1176,28
	Nr	9	9	9	9	9	9	9	9
	St. deviation	176,26	155,62	140,58	113,88	107,6	106,39	156,55	107,74
Female	Mean	1302,13	1404,47	1479,53	1091,87	1149,33	1196,67	1395,34	1146,01
	Nr	15	15	15	15	15	15	15	15
	St. deviation	145,26	132,11	120,1	95,37	97,09	92,25	127,5	92,8
	ANOVA	0,39	0,42	0,48	0,43	0,57	0,46	0,41	0,47

Discussion

The maxillary canines are statistically the second dental elements that most frequently undergo inclusion, after the lower third molars. The statistics reported in the literature are not uniform and this percentage varies according to the sample taken and the type of study carried out. However, we can say that about 2% of patients undergoing orthodontic treatment are affected by inclusion of permanent canines².

The analysis of our sample showed a prevalence of female patients affected by unilateral inclusion of the canine with a 2:1 ratio, in agreement with what Power and Short stated³. These data confirm the presence of a genetic component in the etiology of dental malposition with a possible involvement of sex chromosomes. The most frequently included canine was 2.3 compared to 1.3, with a ratio of about 2:1. In addition, 55% of patients showed an inclusion in the palatal area in accordance with what Ericson and Kurol said².

After analyzing the sample, we began to evaluate the pre-treatment CBCT of our patients. CBCT provides a 3D image of the craniofacial complex and enables dynamic images to be obtained differentiating from conventional radiography which can only generate a planar static image. In this study, CBCT images were used to assess cortical bone density due to image availability. HU-based density measurements help assess bone quality. This unit of measurement is directly associated with the fabric attenuation coefficient and is standardized based on the water attenuation coefficient: water, 0 HU; air, -1.000 HU; and enamel, 13000 HU. The possibility of consistent errors in the use of quantitative gray values from CBCT is a concern. A study measuring the bone density at the included and erupted canine showed that the correlation between CBCT and HU values is very high.

From a single scan the images can be reformatted to reproduce images obtained with the classic conventional radiography. Through the reconstruction of the images with a Visualization Software (Galileo Viewers) it was possible to evaluate the bone density, detected through the Hounsfield index, using the gray scale.

We calculated the average bone density at each level of the study (cervical-medium-apical) and the total mean, both for the element included and for the erupted element^{11,12}. It was possible to evaluate a statistically significant increase in density proceeding apically, exponentially greater in the element included, passing from a bone of type D2 at the cervical level to a bone of type D1 at the apical level according to the last classification of Misch¹⁴. D1 corresponds to values greater than 1250 HU, D2 includes values between 850 and 1250 HU. D1 is found mainly in the anterior mandible, in the buccal shelf and in the midpalatal region. D2 is found mainly in the anterior maxilla and in the mid-

palatal region. Furthermore, the difference between the average total bone density at the level of the included was significantly increased (SoP = 0.000) compared to that of the erupted element.

In addition, bone density has been correlated to the age of our patients, it has been noted that bone density increases with age, with statistically significant results in the element included. Kim, Park et al were the first that conducted a study about the correlation between the increase in bone density and the increase in age, with results similar to ours¹⁵. However, in the correlation between bone density and the sex of our patients, no statistically significant results were shown, despite a slight increase in male sex, again in accordance with the aforementioned article¹⁵.

Therefore, the method that uses the Hounsfield index to measure bone quality characteristics with CBCT has shown a statistical correlation between the measurements made. The objective of the use of the analysis was to determine whether bone density was a potential etiological factor of canine inclusion. Previous studies have cited genetics or the presence and morphology of the lateral incisor as potential etiologies for canine inclusion.

Palatally impacted canines have been associated with an increased space of the dental arch, while the vestibularly impacted canines have been associated with an inadequate space for eruption¹⁶. However, the density of the maxillary bone around the affected teeth has not been evaluated. The difference between the impacted and non-impacted sites supports the presumption that the increase in bone density on the affected side contributes to the inclusion of the developing canine⁸. These results, in fact, were obtained by measuring the density in two maxillary regions of the same subject, given the same genetic and environmental factors that could influence the growth of the bone bases and the development of the dental elements. To confirm this there is a study conducted by analyzing fractals derived from bone trabeculae, in which a monolithic bony structure is associated with the monolateral included canine, characterized by trabeculae of a smaller size than the contralateral erect, therefore a denser bone¹⁰.

Although more studies need to be performed regarding the correlation between bone microarchitecture and bone resistance using CBCT. Its application in patients with affected canines provides an additional alternative for the analysis of the characteristics of the surrounding alveolar bone. Therefore, this new validated method seems promising for further research and for clinical evaluation and prediction of canine inclusion based on bone density. This research is very useful to understand how bone density affects the anchoring of the dental element, which is especially useful at the time of the treatment plan.

Conclusions

Our CBCT analysis shows how the density of the maxillary alveolar bone is increased by the side of the included canine, rather than in the erupted. There is a statistically significant correlation of the increase in density with the increasing age of our patients. There is a non-statistically significant relationship between bone density and patient sex.

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