Evaluation of Alveolar Bone Density at Furcation Sites Using Computer Tomography in Patients with Horizontal Bone Loss

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Abstract: *Objectives*: The aim of the current study was to evaluate quantitatively bone density in the maxillary and mandibular interradicular sites and to establish his determinants as assessed on computer tomography images.

Methods: Sections of 0.5 mm thickness horizontal CT sections were selected to measure bone density of the interradicular and interdentally septum in CTs from 29 individuals (17 females, mean age 40.44 years).

Results: There were statistically significant differences of mean value and of bone density at specific bone depth levels in the furcation area according to age, gender, tooth type and between the maxilla and mandible ($P < 0.05$). The multiple linear regression analyses showed, for both mean furcation alveolar bone density value as well as particular values at different bone level as dependent variable, a strong association with gender, distance from the furcation roof to the alveolar bone septum, presence of restorative treatment of caries, presence of endodontic treatment and mean alveolar bone density of the mesial and distal alveolar septum ($P < 0.0001$).

Conclusions: Using the CT in periodontology has demonstrated to be a valid support to diagnose the changes in the alveolar bone, to monitor the treatment results with a higher precision and to point out possible error sources.

Keywords: Computed tomography, periodontology, furcation, alveolar bone, periodontal disease.

INTRODUCTION

Periodontitis, a chronic inflammation of the supportive apparatus of the tooth, can result in loss of bone mass and microarchitectural deterioration. Trabecular structure (trabecular thickness, connectivity of the trabeculae, distribution of mineral content, and trabecular pattern) is important in studying the effect of periodontal disease on its supporting bone [1]. The presence of furcation involvement is one clinical finding that can lead to a diagnosis of advanced periodontitis and potentially to a less favourable prognosis for the affected tooth or teeth. Furcation involvement therefore presents both diagnostic and therapeutic dilemma [2].When describing treatment modalities for the furcation-involved tooth, the extension of periodontal destruction in the furcation area, i.e., the degree of furcation involvement, has traditionally been used as the major criterion for selecting specific treatment procedures [3]. Thus, assessment of bone density in the interradicular site can provide information that is essential for treatment plan selection and success prediction (Figure **1**).

Radiographs are used to confirm and extend the findings of the clinical examination and are essential in planning implant placement to determine the amount

Figure 1: Furcation areas.

and character of alveolar bone as well as the position of anatomical structures such as the maxillary sinus and inferior alveolar canal. The presence of gingivitis, periodontal pockets and gingival inflammation cannot be determined using radiographs, but radiographs are essential for determining the extent and severity of bone periodontal support and for detecting osseous lesions [4]. Conventional radiographic approaches assessing alveolar bone structure are limited by the fact that microarchitecture in 3-D cannot be inferred from isolated 2-D sections [5]. However, micro-CT can produce 3-D images of bone, allowing for detailed analysis of 3-D bone architecture and anisotropy [6,7]. Previous studies have shown that CT can provide valuable bone density data in implant placement regions, an indication that computed tomography (CT)

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images are clinically useful and that CT can provide accurate bone density measurements [8-12]. It was also revealed that computed tomography scanning permits a high identification rate and classification of molars with involved furcations [13] and may provide detailed information of furcation involvement and a reliable basis for treatment decision [14]. However, there are no studies that have assessed interradicular bone density related to periodontal status.

The aim of the current study was to use CBCT to investigate the determinants of alveolar bone density in interradicular areas of teeth with horizontal bone loss. Horizontal bone defect was defined according to Gomes-Filho *et al.* [15]: " bone loss perpendicular to the long axis of the tooth, along the whole length of the alveolar bone crest, with occurrence of resorption of the vestibular and lingual cortical laminae, and of the interdental bone". The hypothesis to be rejected was that there is no relation between interradicular bone quality and the alveolar bone level.

MATERIALS AND METHODS

The CT investigations of twelve males and seventeen females (mean age 40.44 years, range for male 25-60 years and for female 20-57 years) were selected for this study. Patients with general diseases, pathological lesions in the bones and jaw, those who took medication affecting bone metabolism or those with vertical alveolar bone loss were excluded. The CT investigations were recommended by their dentists for implant placement or orthodontic treatment planning. Prior to participation, subjects gave their informed consent that their CTs are used for analysis in the present study. The study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2000 [16].

Computer scans were performed on a SOMATOM Emotion (Siemens), in Explora Center -RX in Iasi, Romania. Syngo Program (eFilm software, al Merge eMed) was used to measure bone density on a given surface point and chosen, and the distance in mm. After the CT images were stored in the computer, 0.5 mm horizontal CT sections were selected to measure bone density, from the tip up to 3 mm, of the deep interradicular and interdentally septum. The program allows direct measurement of Hounsfield units (HU) average density of the central area of the interdentally septum. The presence or absence of carious lesions, fixed orthodontic treatment, endodontic treatments, periapicale lesions, and prosthetic crowns were noted.

To evaluate intra-examiner reproducibility, the same examiner re-measured five randomly selected subjects for all points following a 2 week interval.

Statistical Analysis

Descriptive statistics and statistical analyses were performed with computerized statistical package (SPSS 17.0, Inc., Chicago, USA) software. Differences between groups were identified with Student's *t*-test and ANOVA. Correlations among the alveolar bone density in the furcation and interdental areas at different bone depth levels were measured by Pearson's Correlation coefficient. Multiple linear regression analyses were performed utilizing age, gender, tooth type, distance from the fornix of the furcation to the bone crest of the defect, root trunk length, orthodontic treatment, untreated caries, decays restorative treatment, prosthetic treatment, endodontic treatment, presence of periapical lesions, mean alveolar bone loss on the mesial and distal sites and mean alveolar bone density of the mesial and distal interdental septum as independent variables in the study group.

RESULTS

Measurement Error

There was no statistically significant difference between the two sets of measurements using a paired *t*-test.

Bone Density

Prior to assessing interradicular differences, gender, age and side-based differences in bone density were assessed. There were statistically significant differences of mean value and of bone density at specific bone depth levels in the furcation between male and female (560.95 ± 45.67 *vs*. 394.59 ± 29.59; $P = 0.002$) subjects (Figure **2**), between different age groups (under 30 yrs: 435.67 ± 35.28, 31-40 yrs: 527.44 ± 45.85; 41-50 yrs: 660.80 ± 63.69, over 51 yrs: 297.00 ± 36.62; $P < 0.0001$) (Figure **3**), and between the maxilla and mandible (435.25 ± 29.25 *vs*. 610.26 ± 63.81; $P < 0.05$) (Figure **4**). No differences were noted between the left and right sides of the jaws (500.87 ± 41.93 *vs*. 444.16 ± 37.46; $P > 0.05$).

Statistically significant higher values of alveolar bone density (mean and specific bone depth levels) in the furcation are of mandibular second molar (700.67 ± 76.57) were revealed when compared with the maxilary first (448.91 ± 42.51; $P = 0.006$) and second molar

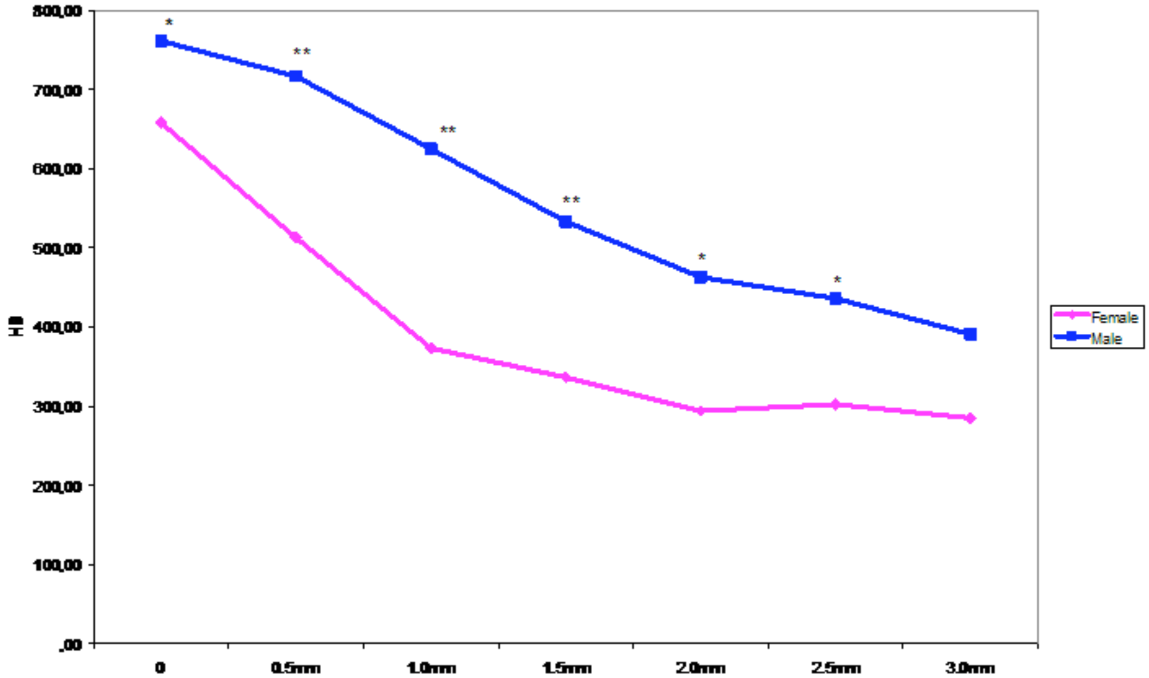

Figure 2: Mean interradicular bone density at 0, 0.5, 1, 1.5, 2, 2.0, and 3 mm apical to the alveolar bone crest of furcation area in the males and females (HU = Hounsfield units).

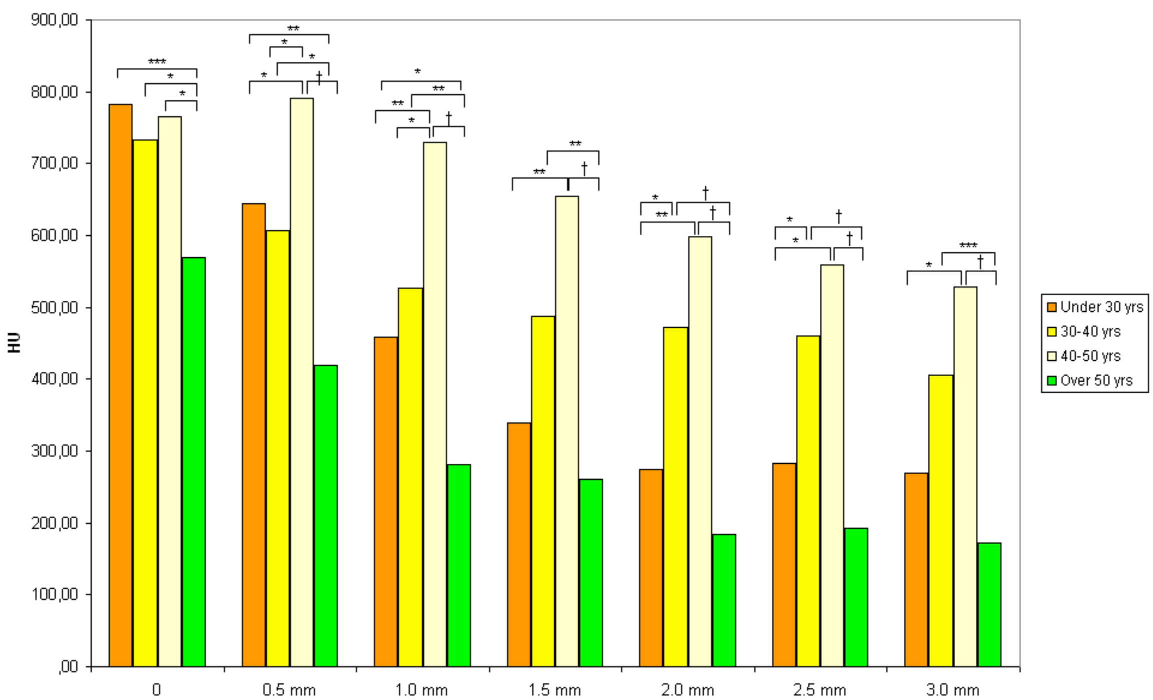

Figure 3: Mean interradicular bone density at 0, 0.5, 1, 1.5, 2, 2.0, and 3 mm apical to the alveolar bone crest of furcation area in different age groups (HU = Hounsfield units).

(425.01 ± 43.21; *P* = 0.005) as well as compared with mandibular first molar (429.42 ± 32.86; *P* < 0.05) (Figure **5**).

Alveolar bone density in the furcation area significantly correlated with alveolar bone density values of the interdental alveolar bone septum (r = 0.676, *P* < 0.0001) (Table **1**). The root trunk length was

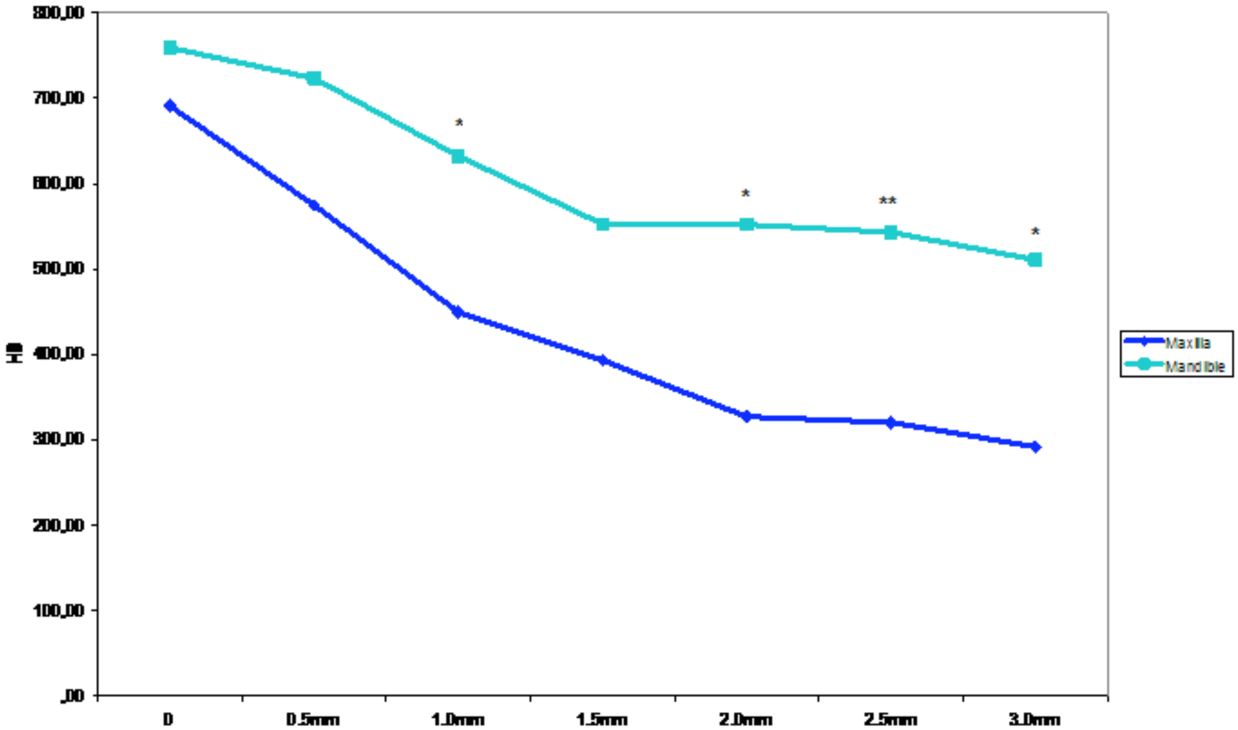

Figure 4: Mean interradicular bone density at 0, 0.5, 1, 1.5, 2, 2.0, and 3 mm apical to the alveolar bone crest of furcation area in the maxilla and mandible (HU = Hounsfield units).

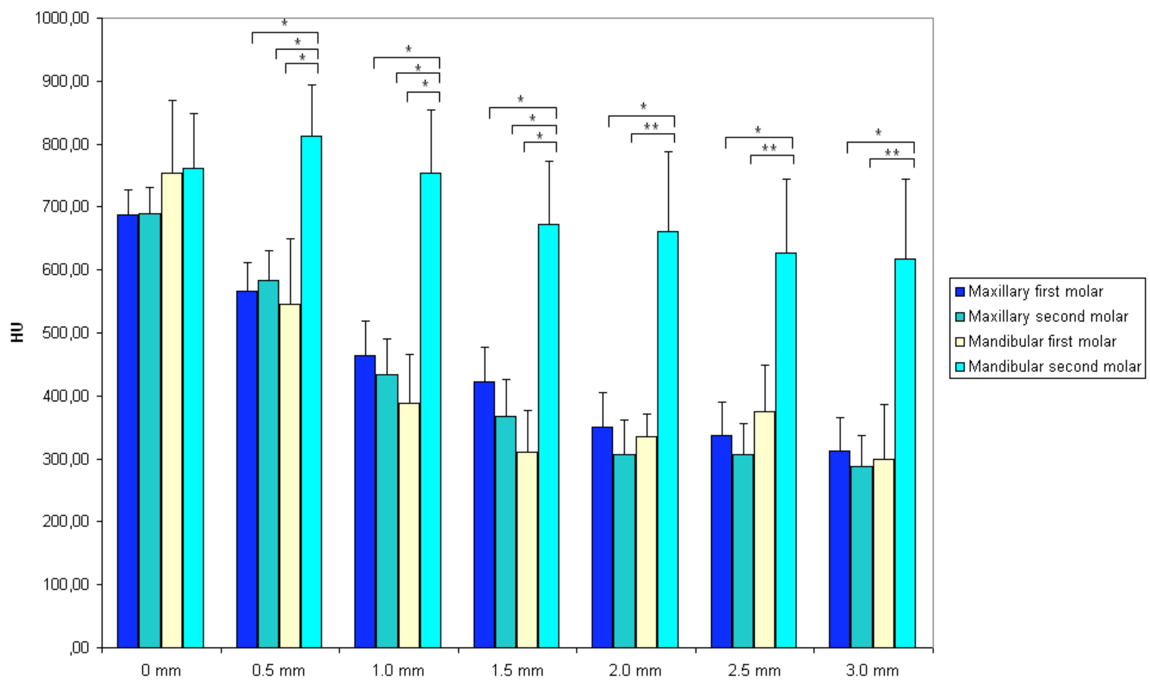

Figure 5: Interradicular bone density at 0, 0.5, 1, 1.5, 2, 2.0, and 3 mm apical to the alveolar bone crest of furcation area and comparison between different tooth types (HU = Hounsfield units).

also significantly correlated with the distance from the fornix of the furcation to the bone crest of the defect (r = -252, $P < 0.05$), but not with the alveolar bone density in the furcation area ($P > 0.05$).

Table 1: Correlations among the Alveolar Bone Density in the Furcation and Interdental Areas at Different Bone Depth Levels

	F 0 mm	F 0.5 mm	F 1.0 mm	F 1.5 mm	F 2.0 mm	F 2.5 mm	F 3.0 mm	Id 0 mm	Id 0.5 mm	Id 1.0 mm	Id 1.5 mm	Id 2.0 mm	Id 2.5 mm	Id 3.0 mm	Id 3.5 mm	Id 4.0 mm	Id 4.5 mm	Id 5.0 mm
Furcation level 0 mm	1																	
Furcation level 0.5 mm	0.496**	1																
Furcation level 1.0 mm	0.371**	0.879**	1															
Furcation level 1.5 mm	0.261*	0.759**	0.915**	1														
Furcation level 2.0 mm	0.213	0.592**	0.775**	0.910**	1													
Furcation level 2.5 mm	0.140	0.483**	0.657**	0.807**	0.932**	1												
Furcation level 3.0 mm	0.097	0.442**	0.615**	0.740**	0.875**	0.947**	1											
Interdental level 0 mm	0.088	0.094	-0.002	-0.031	0.000	-0.015	-0.018	1										
Interdental level 0.5 mm	0.092	0.076	0.065	0.041	0.020	-0.016	-0.073	0.722**	1									
Interdental level 1.5 mm	0.186	0.236	0.261*	0.274*	0.214	0.138	0.047	0.418**	0.737**	1								
Interdental level 1.5 mm	0.290*	0.495**	0.485**	0.434**	0.363**	0.272*	0.240	0.164	0.395**	0.739**	1							
Interdental level 2.0 mm	0.213	0.527**	0.573**	0.568**	0.570**	0.543**	0.509**	-0.043	0.133	0.500**	0.807**	1						
Interdental level 2.5 mm	0.248*	0.496**	0.628**	0.605**	0.620**	0.619**	0.628**	-0.110	0.039	0.382**	0.696**	0.806**	1					
Interdental level 3.0 mm	0.159	0.472**	0.600**	0.589**	0.629**	0.599**	0.664**	-0.127	-0.087	0.194	0.545**	0.668**	0.876**	1				
Interdental level 3.5 mm	0.105	0.402**	0.542**	0.539**	0.569**	0.574**	0.648**	-0.131	-0.087	0.172	0.446**	0.582**	0.784**	0.899**	1			
Interdental level 4.0 mm	0.111	0.349**	0.482**	0.501**	0.561**	0.593**	0.656**	-0.207	-0.184	0.009	0.299*	0.482**	0.707**	0.836**	0.907**	1		
Interdental level 4.5 mm	0.073	0.311*	0.434**	0.452**	0.507**	0.535**	0.616**	-0.146	-0.125	0.061	0.282*	0.416**	0.611**	0.724**	0.824**	0.912**	1	
Interdental level 5.0 mm	0.012	0.292*	0.437**	0.502**	0.568**	0.586**	0.658**	-0.210	-0.149	0.037	0.234	0.417**	0.572**	0.751**	0.811**	0.884**	0.901**	1

*: $P<0.05$; **: $P<0.01$; F 0 mm: Furcation level 0 mm; Id 0 mm: Interdental level 0 med mer.

The multiple linear regression analyses showed, for both mean furcation alveolar bone density value as well as particular values at different bone level as dependent variable, a strong association with gender, distance from the furcation roof to the alveolar bone septum, presence of decays restorative treatment, presence of endodontic treatment and mean alveolar bone density of the mesial and distal alveolar septum (Table **2**). The models were well fitted to the data (*P* < 0.0001).

DISCUSSION

In this study it was revealead a strong correlation between mean alveolar bone density value as well as particular values at different bone level in furcation area as dependent variable with gender, distance from the furcation roof to the alveolar bone septum, presence of restorative treatment of caries, presence of endodontic treatment and mean alveolar bone density of the

Table 2: Multiple Linear Regression Models with Alveolar Bone Density in the Furcation Areas (Mean Values and at Different Bone Depth Levels) as Dependent Variables

	Mean value of alveolar bone density in the furcation areas	Alveolar bone density in the furcation areas at 0 mm bone depth	Alveolar bone density in the furcation areas at 0.5 mm bone depth	Alveolar bone density in the furcation areas at 1 mm bone depth	Alveolar bone density in the furcation areas at 1.5 mm bone depth	Alveolar bone density in the furcation areas at 2 mm bone depth	Alveolar bone density in the furcation areas at 2.5 mm bone depth	Alveolar bone density in the furcation areas at 3 mm bone depth
Age	-0.059	**-0.491*** **	-0.199	-0.024	0.102	0.082	0.014	0.031
Gender	**0.244** **	**0.351** **	**0.378*** **	**0.308*** **	0.177	0.115	0.072	0.042
Tooth type	0.006	-0.034	0.050	-0.010	-0.061	0.006	0.037	0.058
Distance from the fornix of the furcation to the bone crest of the defect	**-0.217***	**-0.330** **	**-0.284***	-0.086	-0.075	0.000	**-0.357*** **	**-0.376*** **
Root trunk length	0.140	**-0.293***	0.100	0.137	0.183	**0.220***	0.191	0.140
Orthodontic treatment	-0.058	-0.042	-0.116	-0.091	-0.097	-0.049	-0.020	0.077
Untreated caries	0.029	**0.265***	0.042	-0.047	-0.031	-0.008	0.020	0.020
Restorative treatment	**-0.216***	-0.193	**-0.258***	**-0.300** **	**-0.256***	-0.107	-0.085	-0.073
Prosthetic treatment	0.035	**-0.295***	0.036	0.071	0.059	0.080	0.103	0.132
Presence of endodontic treatment	**0.220***	0.263	0.178	0.147	0.198	0.148	0.196	**0.233***
Presence of periapical lesion	-0.047	-0.201	-0.066	-0.105	-0.065	-0.053	0.047	0.038
Mean alveolar bone loss on the mesial and distal sites	0.067	0.027	-0.051	0.033	0.059	0.071	0.106	0.118
Mean alveolar bone density of the mesial and distal interdental septum	**0.672*** **	-0.083	**0.331** **	**0.634*** **	**0.703*** **	**0.740*** **	**0.675*** **	**0.652*** **
R^2	0.698	0.512	0.517	0.659	0.640	0.654	0.663	0.650
F	9.590	4.278	4.454	8.026	7.394	7.836	8.178	7.705
P	***0.0001***	***0.0001***	***0.0001***	***0.0001***	***0.0001***	***0.0001***	***0.0001***	***0.0001***

*: *P*<0.05; **: *P*<0.01; ***: *P*<0.001.

mesial and distal alveolar septum. Such data can help to explain differential failure rates of periodontal treatment of the furcation sites.

Bone densities in from different subjects, as well as from different sites within the same subject, exhibited variations, regardless of age and sex. These results are in line with a series of previous reports, who reported significant differences in mean bone mineral densities between male and female cadavers, older that 50 years old (age range 64-99 years) [17], while no differences in bone densities between Korean male and female up to 35 years of age were found [10]. These results suggest that the sex-based discrepancy between the two studies is age related [10].

Significant differences were noted between maxilla and mandible and between different tooth types. This is consistent with previous studies [8, 10]. Also, bone densities in the furcation areas progressively increased from the first to second mandibular molar, which agrees with another previous study who showed a gradual increase of cortical bone thickness in the mandible from anterior to posterior areas [18]. The results suggest that the mandibular posterior area may contain denser and thicker cortical bone.

There was no difference in bone density between left and right sides of the mandible in this study. This agrees with observations of bilateral symmetry in bone density in the same anatomic sites reported for rhesus monkey [19] and in humans [8], as well as with previous reports regarding alveolar bone loss in periodontal disease [20-24].

The distance from the cemento-enamel junction to the entrance of the furcation can vary extensively, from very short root trunks, to roots that may be fused to a point near the apex. Root trunk length is a key factor in both the development and the treatment of furcation involvement. Regarding the teeth with short root trunks, less attachment needs to be lost before the furcation is involved, but once the furcation is exposed, it may be more smooth for the progress of some surgical procedures and to be more accessible to maintenance procedures. In contrast, teeth with unusually long root trunk or fused roots may not be appropriate candidates for treatment once the furcation has been affected [2]. In the present study, the root trunk length was significantly correlated with the distance from the fornix of the furcation to the bone crest of the defect, but not with the alveolar bone density in the furcation area.

The multiple linear regression analyses showed, for both mean furcation alveolar bone density value as well as particular values at different bone level as dependent variable, a strong association with gender, distance from the furcation roof to the alveolar bone septum, presence of restorative treatment of caries, presence of endodontic treatment and mean alveolar bone density of the mesial and distal alveolar septum. It has been suggested that crestal bone density loss occurs before crestal bone height loss; therefore, radiographic analysis procedures that measure changes in bone density serve as sensitive methods for predicting future loss of crestal bone height [23]. It has been showed that alveolar process radiographic fractal dimension was significantly related to the alveolar process density [24], while fractal analysis evidenced significant differences between patients affected and not affected by periodontitis [1].

In conclusion, CT has been demonstarted to be important for evaluating the alveolar bone density at furcation sites, as defined by the AAP as ”the anatomic area of a multi rooted tooth where the roots diverge”[25]. The present study, derived from 29 adult subjects, showed that age, gender, the distance from the furcation roof to the alveolar bone septum, presence of decays restorative treatment and endodontic treatment as well as mean alveolar bone density of the mesial and distal alveolar septum were significant determinants of mean alveolar bone density at the furcation area. Although the precision of computer tomography in dentistry has been documented in several studies, the accuracy of the cross-sectional images in periodontal disease has not been shown. Using the CT in periodontology has demonstrated to be a valid support to diagnose the changes in the alveolar bone, to monitor the treatment results with a higher precision than the various previous radiographic techniques and to point out possible error sources. Further studies evaluating determinants of success rates of periodontal treatment related to bone densities at furcation areas as well as to other factors, such as smoking and root proximity, may elucidate the relative importance of these different causes of tooth loss related to furcation involvement.

Conflict of Interest and Source of Funding Statement

The study was self-financed by the authors. The authors report no conflicts of interest related to this study.

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