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Evaluation of the Fractal Dimension in the Apical Region of Primary Teeth with Unilateral and Bilateral Infraocclusion

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Research Article

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ABSTRACT

Objective: This study aims to employ fractal analysis (FA) to determine potential variations in the mandibular trabecular bone structure in the apical region among individuals with unilateral and bilateral infraocclusion of primary teeth compared to a control group.
Materials and Methods: Forty-three primary teeth identified from panoramic radiographs taken for diagnostic purposes between January 2018 and December 2023 in the Department of Oral, Dental, and Maxillofacial Radiology of our institution were included in this investigation. Categorical variables were analyzed using the chi-square test, while continuous variables were assessed through Student paired t-tests and ANOVA tests. The threshold for statistical significance was set at p<0.05.
Results: The analysis revealed that the mean fractal dimension (FD) did not significantly differ between unilateral and bilateral infraocclusion groups based on gender (p>0.05). Although the FDs in the apical regions of unilaterally infraoccluded teeth and their contralateral counterparts were observed to be lower, the disparity based on occlusion position did not reach statistical significance (p 0.11). Moreover, no significant distinctions were observed in the FD or resorption levels between teeth exhibiting bilateral infraocclusion on the right and left sides (p: 0.877, p:0.938). It was noted that the presence of an opposing tooth positively influenced the FD; however, this effect did not achieve statistical significance.
Conclusions: While infraocclusion is prevalent in mandibular primary molars, this study did not observe any discernible alterations in the mandibular trabecular bone structure attributable to infraocclusion. Unilateral infraocclusion, in particular, was found to be a common and relatively benign condition. Additionally, numerical anomalies such as hypodontia and supernumerary teeth might exhibit associations with infraocclusion.

Keywords: Fractals, Infraocclusion, Mandibula, Panoramic Radiography,

Unilateral ve Bilateral İnfraoklüzyona Sahip Süt Dişlerinin Apikal Bölgelerindeki Fraktal Boyutun Değerlendirilmesi

Süreç

Geliş: 17/05/2024
Kabul: 24/06/2024

ÖZ

Amaç: Bu çalışmada unilateral ve bilateral infraoklüzyondaki süt dişleri bulunan bireylerin, apikal bölgesindeki mandibular trabeküler kemik yapısının kontrol grubundan farklı olup olmadığının fraktal analiz yöntemi yöntemiyle belirlenmesi amaçlandı.
Gereç ve Yöntemler: Çalışmaya Ocak 2018-Aralık 2023 tarihleri arasında fakültemiz Ağız, Diş ve Çene Radyolojisi Anabilim Dalı'nda teşhis amaçlı çekilen panoramik radyografilerde tespit edilen 43 adet infraoklüze diş dahil edildi. Kategorik değişkenler ki-kare testi kullanılarak analiz edilirken, sürekli değişkenler Students t-testi ve ANOVA testleri kullanılarak değerlendirildi. İstatistiksel anlamlılık eşiği p<0,05 olarak belirlendi.
Bulgular: Ortalama fraktal boyut, cinsiyete göre unilateral ve bilateral etkilenme arasında istatistiksel olarak anlamlı bir fark bulunmadı (p>0,05). Unilateral infraoklüzyonlu dişlerin apikal bölgelerinde fraktal boyut, karşı taraflarına göre daha düşük olsa da, oklüzyon altındaki konumlarına göre istatistiksel olarak anlamlı bir farklılık bulunmadı (p:0,11). Sağ ve sol tarafta bilateral infraoklüzyonlu dişlerin rezorpsiyon seviyesi ile fraktal boyut arasında istatistiksel olarak anlamlı bir farklılık gözlenmedi (p:0,877, p:0,938). Karşıt arktaki dişin varlığı fraktal boyut üzerinde pozitif bir etki gösterdi, ancak bu etki istatistiksel olarak anlamlı değildi.
Sonuçlar: Bireylerin mandibular süt azı dişlerinde infraoklüzyon sıklıkla görülmektedir. Bireylerde infraoklüzyona bağlı mandibular bölgede trabeküler kemik yapısında değişiklik gözlenmemiştir. Unilateral infraoklüzyon, bireylerde sık görülen hafif bir infraoklüzyon türüdür. Hipodonti ve süpernümerer dişler gibi sayısal anomaliler infraoklüzyon ile ilişkili olabilir.

Anahtar Kelimeler: Fraktal Boyut, İnfraoklüzyon, Mandibula, Panoramik Film.

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Introduction

Infraocclusion, or submerged tooth, refers to a condition where a tooth is positioned below the occlusal plane. Although several terms are used interchangeably to describe this phenomenon[1], such as ankylosed tooth or impacted tooth, "infraocclusion" is the preferred term for its clinical designation. The etiology of infraocclusion remains uncertain, contributing to the ambiguity in its nomenclature.[1] It is commonly associated with dental ankylosis, where the tooth fuses with the surrounding bone.[2] Infraocclusion can usually be assessed clinically, although radiographic examination may be necessary for definitive diagnosis.[3] It typically occurs when the eruption mechanism fails, resulting in the tooth's inability to maintain its vertical position relative to adjacent teeth[4]. In clinical practice, infraocclusion is commonly categorized into three degrees[5]: mild, moderate, and severe. Mild infraocclusion involves a slight deviation, approximately 1 mm below the occlusal plane of the adjacent tooth. Moderate infraocclusion occurs when the affected tooth aligns at the same level as adjacent teeth' occlusal surface contact points. Severe infraocclusion is characterized by a significant submersion below the interproximal gingival tissue of the adjacent tooth. These classifications are based on the extent of submersion relative to the occlusal plane of neighboring teeth (Figure 1, Figure 2).

Infraocclusion is expected in the mixed dentition phase, especially in the mandibular primary molars[7], where the occlusal surface of these teeth tends to be 0.5-1 mm lower than adjacent teeth. In primary molars affected by infraocclusion, signs such as reduced mobility, metallic percussion sound, displacement of adjacent teeth, and narrowing of the dental arch may be evident.[8] The prevalence of these teeth ranges from 1.3% to 38.5%, varying according to age, gender, and ethnic origin, with the highest prevalence occurring in children aged 6-11 years.[9]

FD analysis is a widely used method for assessing the complexity and irregularity of structures, commonly applied in bone tissue quality evaluation.[10] FD values obtained through the box-counting method typically range from 1 to 2 in trabecular bone. Values nearing 2 indicate a more intricate bone microstructure, while those close to 1 highlight bone porosity, suggesting simpler microstructures.[11] In dentistry, FD analysis aids in detecting early periodontal changes in alveolar bone[12], determining trabecular structure in individuals with hypodontia[13], diagnosing osteoporosis-related pathologies[14], assessing bone tissue near implant sites[15], analyzing patients with temporomandibular joint dysfunction[16], and examining the relationship between disease severity and trabecular bone changes.[16] FA has been applied across various fields, facilitating investigations into complex relationships.[17]

However, the impact of the trabecular bone structure beneath primary teeth affected by infraocclusion has not yet been investigated in the existing literature. Hence, the primary objective of this investigation is to assess potential disparities in the mandibular trabecular bone structure between individuals presenting infraocclusion and a control cohort. This analysis will be conducted employing the FA methodology to discern any notable variations in bone

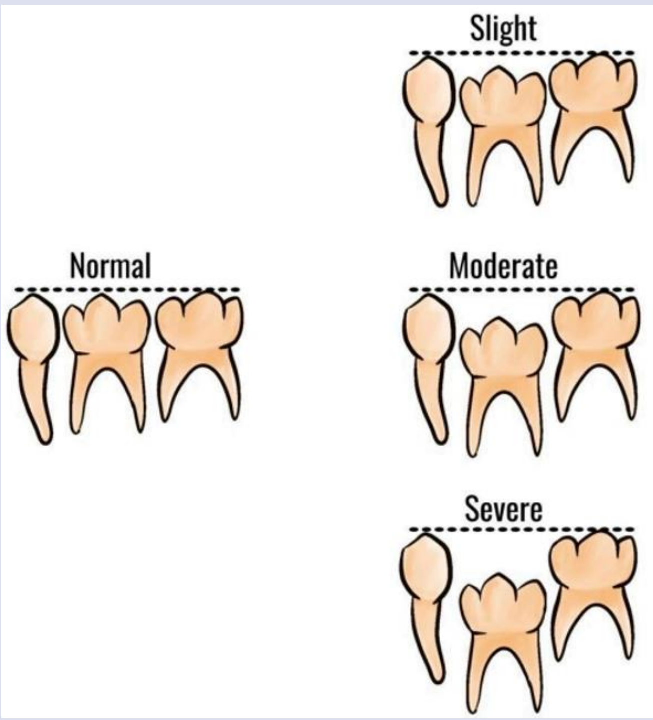

Figure 1: Schematic classification of infraocclusion of primary molars[6].

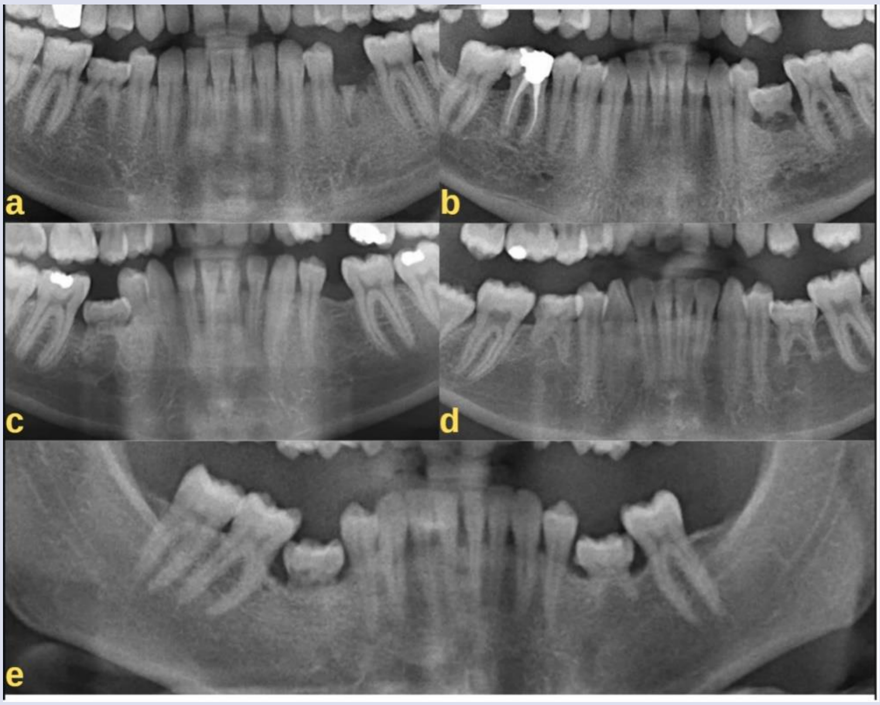

Figure 2: Panoramic radiograph of unilateral and bilateral infraoccluded primary teeth.

Materials and Methods

Samples Selection

This study received approval from the Non-Interventional Clinical Research Ethics Committee on March 21, 2024 (Decision No: 2024/03-21). This retrospective study aligned with the Declaration of Helsinki, ensuring all participants acquired informed consent. The study examined 43 primary infraoccluded teeth identified in panoramic radiographs taken for diagnostic purposes at our faculty's Department of Oral, Dental, and Maxillofacial Radiology between January 2018 and December 2023.

The study enrolled individuals aged 12-30 with permanent or mixed dentition per the inclusion criteria. Exclusion criteria included a history of orthodontic or orthognathic surgery, impacted teeth, root displacement from factors like cyst tumors, craniofacial anomalies, a prior history of trauma or fractures in the mandibular or maxillary regions, and poor-quality panoramic images containing metal or motion artifacts. Additionally, FA was conducted on 28 unilateral infraoccluded teeth and the bone at the apex of the contralateral teeth. The FD in the apical region of 15 bilateral infraoccluded teeth was also evaluated based on the level of resorption, classified as follows: 0: no resorption, 1: 1/3 root resorption, 2: 2/3 root resorption, and 3: complete root resorption. In this study, other dental anomalies seen in the mouth of individuals with infraocclusion will also be examined.

Region of Interest Determination

The panoramic radiographs utilized in this research were captured using the ORTHOPHOS XG device from Sirona, USA, with settings of 60 kV, 3 mA, and an exposure time of 14.1 seconds. Our faculty ensured the routine monitoring and maintenance of these parameters. An experienced oral and maxillofacial radiologist (at least five years) evaluated the images. For FA, two regions of interest (ROI's) were identified. Using the Square tool in ImageJ, a 30 × 30-pixel square was manually drawn around the apex of both the infraoccluded and the contralateral teeth. The radiologist conducted the measurements on a 23-inch computer in a dark room, where panoramic radiographs and tomographic data are typically analyzed, limiting the examination to three hours per day to prevent grayscale sensitivity loss due to prolonged exposure.

Fractal Dimension Examination

The FA procedures in ImageJ adhered to the protocol set forth by White and Rudolph.[18] Each ROI was duplicated post-cropping. A Gaussian filter (sigma, 35) was applied to the duplicated image to eliminate significant brightness variations. The resultant blurred image was then subtracted from the original to accentuate trabecular bone and bone marrow spaces, with an additional 128 gray values added. Subsequently, the image underwent binarization to produce a black-and-white format. Noise was removed via erosion, while dilation sharpened the external lines of the structures. Following image inversion, trabecular bone was represented by black areas and bone marrow spaces by white areas. Skeletonization was then executed. FA involved counting boxes ranging from 2 to 64 pixels on the skeletonized image using ImageJ's Fractal box count plugin (Figure 3). FD values for the apex of infraoccluded teeth and contralateral teeth ROIs were documented.

Statistical Analysis

The data were analyzed using IBM SPSS V23 (IBM Co., Armonk, NY)—statistics program. The chi-square test was used to compare categorical variables according to group. The effect of resorption level on fractal dimension in bilateral infraoccluded teeth was analyzed by one-way (ANOVA) test since the data were normally distributed according to the Shapiro-Wilk test. The fractal dimension in the apical regions of teeth with unilateral infraocclusion was analyzed using the Paired Student t-test. Analysis results were presented as mean ± standard deviation and median (minimum-maximum) for quantitative data and frequency (percentage) for categorical data. The significance level was taken as p<0.05.

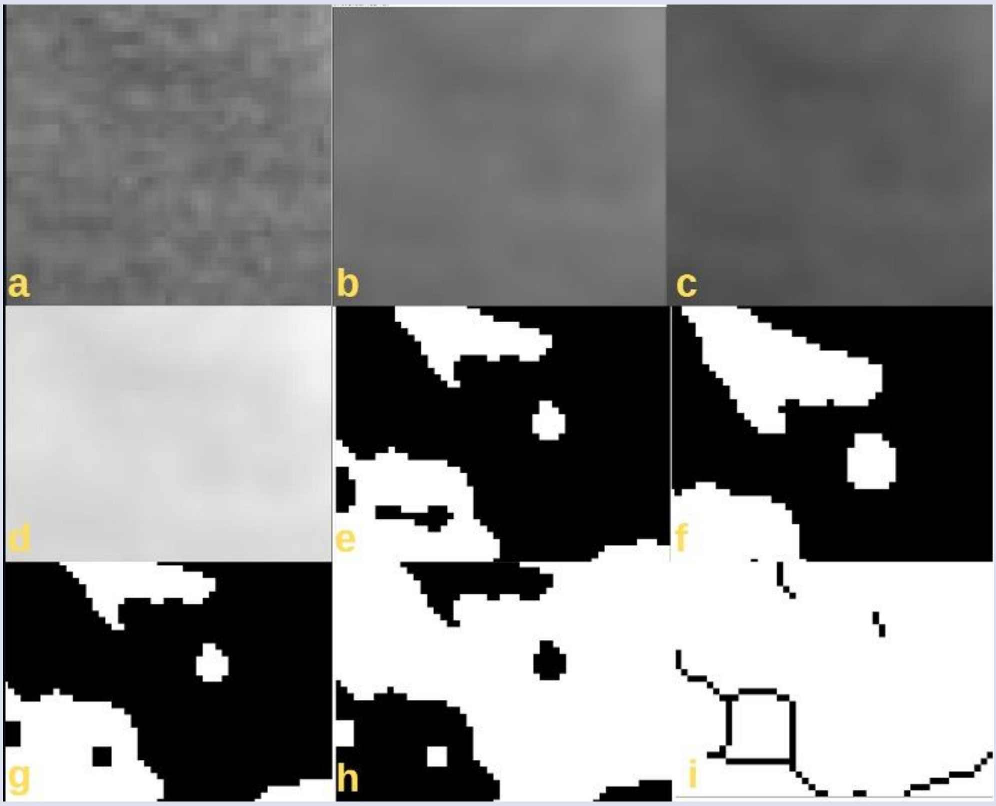

Figure 3: 3a: Duplicated, 3b: Blurred image, 3c: Gaussian filter 3d: Addition of a gray value of 128, 3e: Binarized, 3f: Erode, 3g: Dilate, 3h: Invert 3i: Skeletonize

Results

The study included 58 teeth with infraocclusion, of which 28 (65.1%) were unilateral and 15 (34.9%) were bilateral. Among them, 23 (53.5%) were female and 20 (46.5%) were male. The mean age of the patients was calculated as 21.51±5.39 years. The mean FD and the occurrence of bilateral involvement did not show any significant differences according to gender (p > .05) (Table 1). It was noted that the FD in the apical regions of unilateral infraoccluded teeth and their contralateral counterparts was lower. However, no statistically significant difference was based on the position beneath the occlusion (p: 0.11) (Table 2). No statistically significant difference was observed between the resorption and FD levels in bilateral infraoccluded teeth on the right and left sides (p: 0.877, p: 0.938) (Table 3). No statistically significant difference was observed in the FD between unilateral infraoccluded teeth and their contralateral counterparts based on gender (p: 0.86) (Table 4). Other dental anomalies were found in the cases (Figure 4), and the statistical table of distribution according to gender is in Table 5. Furthermore, the presence or absence of a tooth in the contralateral side of unilateral infraocclusion did not show statistically significant differences in the FD, both on the right and left sides, separately (p: 0.832). A contralateral tooth positively affected the FD, although this effect was not statistically significant.

Table 1. Statistical table of fractal dimension in the apices of infraoccluded teeth according to sex.

Gender	N	Mean	Std. Deviation	Std. Error Mean	p*
Female	30	1.0381	.09101	.01662	.184
Male	26	1.0497	.21670	.04250	

** Paired Student T test, FD: Fractal Dimension, Std: Standart, p<0.05.*

Table 2. Statistical table of FD value in the infraoccluded and contralateral tooth apex region.

Region of FD	Mean	N	Std. Deviation	Std. Error Mean	p*
Infraoccluded tooth apex	1.0339	28	.20547	.03883	.11
Contralateral tooth apex	1.0530	28	.10020	.01894	

**Paired Student T test, FD: Fractal Dimension, Std: Standart, p<0.05.*

Table 3. Statistical table of FD value at the apex of the infraoccluded tooth according to the level of root resorption.

	Root Resorption Level (Mean±SD)				
	No Resorption	**1/3 Root**	**2/3 Root**	**3/3 Root**	**p****
FD-right	1.06±0.1	1.05±0.11	1.08±0.6	1.04±0.4	.87
FD-left	1.0±0.25	.99±0.29	1.01±0.1	1.05±0.6	.94

**One-Way ANOVA test, FD: Fractal Dimension, p<0.05.

Table 4. Statistical distribution of systematic classification of ınfraocclusion in primary dentition by gender.

Infraocclusion classification	Gender		Total	p*
	Female	Male		
Slightly	8	9	17	.552
Moderate	8	4	12	
Severe	7	7	14	
Total	23	20	43	

* Chi-squared Test, p<.005.

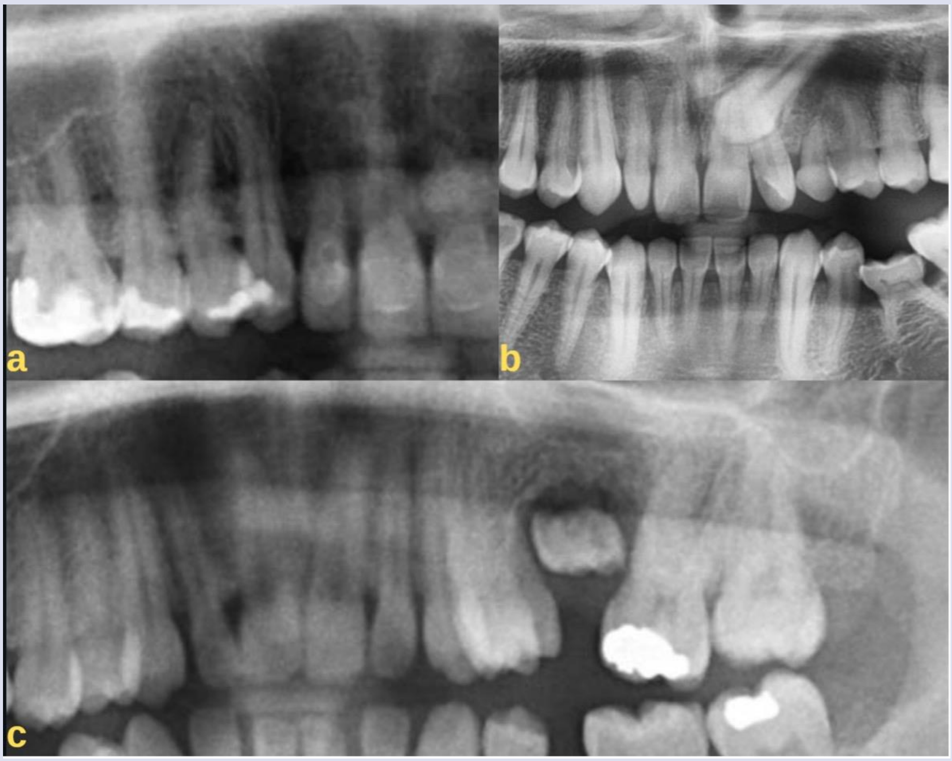

Figure 4: Dental anomalies observed in individuals with infraocclusion. (4a: Dens invaginatus 4b: Microdontia 4c: Tooth agenesis)

Table 5. Table of other dental anomalies found in the cases and statistical distribution table according to gender.

Dental Anomalies	Microdontia	Hypodontia	Dens Invaginatus	Dileseration	p*
Female	1	4	1	1	.692
Male	1	3	1	0	

* Chi-squared Test, p<0.05.

Discussion

While infraocclusion can be diagnosed clinically, evaluating its severity in children poses challenges. Therefore, dental radiographs play a crucial role in assessing such abnormalities. This retrospective analysis aimed to investigate trabecular patterns in the apical region of primary molars affected by unilateral and bilateral infraocclusion in Turkish individuals. The study utilized FA methodology and aimed to document any concurrent dental anomalies observed in panoramic radiographs.

Infraocclusion is strongly correlated with root resorption, a phenomenon often influenced by the eruption of premolar teeth and the shedding process of primary dentition, with possible variations depending on age. Peretz *et al.*[4] reported an increase in moderate infraocclusion rates between the ages of 8-10 and severe infraocclusion rates between the ages of 11-13. The study by Sidhu and Ali[19], noted that severe infraocclusion affected 2.5-8.3% of all infraoccluded primary molars. In our study, we observed a high prevalence of mild infraocclusion in primary second molars, which we attribute to the broad age range considered in our study.

In Kurol's study[20], based on clinical observations of 1059 children aged 3-12 years, it was found that infraocclusion was more prevalent in girls aged 3-6 years, while it was more common in boys aged 7-12 years. The incidence of infraocclusion of primary second molars was similar to the findings reported by previous studies; there was an insignificant difference in the prevalence of infraocclusion by gender.[21,22] However, Steigman *et al.*[23] discovered a higher incidence of ankylotic mandibular second primary molars among boys. Similarly, our study did not identify any statistically significant variation in infraocclusion occurrence based on gender.

According to Bjerklin and Bennett's classification, mild infraocclusion is the most frequently encountered category.[24] This observation is consistent with the findings reported by Brearley and McKibben[5], as well as Cardoso Silva *et al.*[22] In our study, employing the same classification method, primary molars were identified with mild (40%), severe (32%), and moderate (28%) degrees of infraocclusion, respectively.

Infraoccluded primary molars may lead to implications for the development and eruption of permanent teeth, potentially causing delays. Studies indicate that over half of the children with infraocclusion exhibit dental variations[25]. Dental anomalies accompanying this condition are often associated with hypodontia, dens invaginatus, and supernumerary teeth. Several studies have indicated a rise in dental anomalies linked to infraocclusion, including sub-occlusion of primary molars, palatally displaced canines, hypodontia, microdontia of maxillary lateral incisors, and distal angulation of mandibular second premolars.[26] Additional research has identified associated anomalies such as aplasia of permanent teeth, supernumerary teeth, radix entomolaris of permanent teeth, and a high prevalence of agenesis.[22,27] Several studies have noted increased infraocclusion in primary molars without successors.[28,29] In this study, hypodontia was the most prevalent accompanying anomaly, followed by microdontia and dens invaginatus in successor teeth (Figure 4, Table 5). In treatments such as dental implant placements and orthodontic interventions, it is valuable for clinicians to be aware of the bone quality in patients with infraocclusion.[30,31] It is noted that permanent tooth absence may lead to inadequate alveolar bone development.[32,33]

Infraocclusion treatment typically requires a multidisciplinary approach combining orthodontics, fixed and removable prosthetic treatments, and oral-maxillofacial surgery. This treatment involves varied approaches depending on the child's age and dentition stages.[34,35] Orthodontic treatment and dental implants are often considered to preserve bone structure in infraocclusion patients. However, it is generally advised to postpone these procedures until growth and development are complete, typically around ages 16-20.[36] Early placement of dental implants in children is primarily reserved for severe cases of tooth loss and is infrequently reported in the literature.[37,38] Additionally, in orthodontic treatment, it is emphasized that tooth movement may accelerate in cases of decreased bone density, and increased anchorage may be necessary in regions with low bone density.[39] In clinical practice, assessing the bone tissue condition in patients with infraocclusion is paramount. Fractal methods have been utilized to investigate the impact of systemic diseases on the jaw.[40,41] However, more studies need to conduct FD analysis specifically in individuals with infraocclusion.

This study examined individuals in the permanent and mixed dentition stages. Although it's usually recommended to wait until growth is complete before proceeding with dental implant procedures, analyzing the outcomes could offer valuable information about the trabecular bone structure in the mandible for patients receiving orthodontic treatment or dental implants. It has been noted that different methods should be used for analyzing the lower and upper jawbones. The box-counting method is the most commonly preferred method for calculations.[16] Therefore, this study only focused on deciduous teeth with infraocclusion in the mandible.

Panoramic or intraoral periapical radiographs and computed tomography (CT) are valuable tools for accurately measuring the distance between the surface of the infraoccluded tooth and adjacent teeth in cases of normal occlusion.[42] Most studies have evaluated FD in periapical, bitewing, and panoramic radiographs. For instance, Magat *et al.*[43], compared FA of trabecular bone between direct panoramic radiography and Cone Beam Computed Tomography (CBCT), stating that panoramic radiographs are more feasible and appropriate due to disadvantages such as higher radiation and lower image resolution associated with CBCT. Therefore, considering disadvantages like radiation dose, this study conducted analyses using direct panoramic radiographic images.

In FD analysis, the selection of ROI is influenced by parameters such as size, shape, and location of the region. It is noted that linear ROI usage is inadequate for evaluating trabecular structure, emphasizing the necessity of selecting planar ROIs.[44] In this study, planar ROIs were chosen. Since individuals were in mixed dentition and the study was conducted in a limited area, the size of selected ROIs varied according to the region.

Soltani *et al.*[45], conducted a cross-sectional study to examine trabecular bone alterations in periapical radiographs of individuals at various stages of periodontitis using FA. They found that FD values exhibited notable variations between moderate and severe periodontitis cases compared to individuals with healthy periodontal bone. However, it's worth noting that no significant difference in FD values was observed in the distal ROI for moderate and severe periodontitis cases. As it is known, periodontitis is a clinical condition with many influential factors. Bacterial and local etiological factors are very effective parameters in this regard. This study also showed that changes in the oral region, like these factors, impact the fractal distribution of the bone. Although our study had no statistical difference, the FD in infraoccluded teeth was lower than that of contralateral teeth. This shows that occlusal forces, although minor, have a positive effect on the FD.

A study examined the relationship between dental caries and mandibular trabecular bone using FD analysis during children's growth and development processes.[46] The results revealed no significant relationship between dental caries and trabecular bone in the jaw. This finding was similarly applicable to decayed infraoccluded teeth, reflecting a parallel situation to the results of our study.

A study on the impact of bruxism on the FD of mandibular trabecular bone using digital panoramic radiographs found lower FD values in the condyle regions of individuals with bruxism compared to those without.[47] Another study on 37 children with sleep bruxism reported significantly higher FD values in the angulus ($p = 0.03$) and condyle ($p = 0.03$) regions than controls.[48] It was also shown that ongoing occlusal forces in individuals with hyperactive masseter muscles alter the bone's fractal structure. Our study examined this effect on a single tooth but found no statistical difference, though infraocclusion may indicate a decrease in FD. Increased occlusal forces on all molar teeth, observed in studies on bruxism, contributed to the significant differences.

The limitations of this study are the small patient sample and the insufficient number of teeth examined. In future studies, the number of patients should be increased, and the condition of primary teeth in infraocclusion should be investigated. In addition, cases of primary teeth with infraocclusion can be categorized, and studies can be conducted covering both cortical and trabecular bone in the broader age range. A disadvantage of the study may be that it was retrospective and lacked quantitative measurements. There are also limitations in long-term follow-up or follow-up of patients with infraocclusion. Future research should focus on assessing changes in the severity of infraocclusion with age by including study groups spanning a broader age spectrum. To the best of the authors' knowledge, this study represents one of the most recent contributions and covers a limited number of topics covering all primary molars.

Conclusions

The research findings indicate that the quality of mandibular trabecular bone in the apical regions of individuals with infraocclusion did not significantly differ from that of the healthy group. However, patients presenting with such clinical characteristics require regular follow-up to monitor the severity of their condition, and treatment should be administered accordingly. Consequently, individuals with infraocclusion in primary teeth may necessitate additional procedures to facilitate further treatment in orthodontic and implant cases. Moreover, mandibular bone density plays a crucial role in procedures such as grafting and tooth movement, highlighting the importance of assessing and managing bone quality in such cases.

Acknowledgements

None.

Conflict of Interest

The Authors declare that there is no conflict of interest.

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