Cukurova Medical Journal
ÇUKUROVA ÜNİVERSİTESİ TIP FAKÜLTESİ

Cukurova Med J 2021;46(3):1160-1167
DOI: 10.17826/cumj.915323

ARAŞTIRMA / RESEARCH

Effect of fixed orthodontic treatment on mandibular condyle bone quality in different malocclusion groups

Farklı maloklüzyon gruplarında ortodontik tedavinin mandibular kondil kemik kalitesine etkisi

Betül Yüzbaşıoğlu Ertuğrul[1]

[1]Izmir Demokrasi University Faculty of Dentistry, Department of Orthodontics, Izmir, Turkey

Cukurova Medical Journal 2021;46(3):1160-1167.

Abstract

Purpose: The aim of this study was to investigate the effects of orthodontic treatment on the mandibular condyle head bone formation according to different orthodontic malocclusion groups.
Materials and Methods: In the study, forty-eight patients were examined. Individuals included in the study were grouped according to malocclusion groups. Our study was carried out retrospectively. The quality of mandibular condyle bone in panoramic images of patients before and after orthodontic treatment were compared retrospectively. This examination was carried out by a fractal analysis method.
Results: According to the findings we obtained from our study; the change in mandibular condyle bone quality before and after orthodontic treatment by age and gender was not found to be statistically different. After orthodontic treatment in individuals with Class I and III malocclusions, the trabecular density structure of the mandibular condyle bone increased and decreased in individuals with Class II malocclusion. The change in mandibular condyle bone quality before and after orthodontic treatment by malocclusion groups was found to be statistically different.
Conclusion: The fractal analysis method is a technique that facilitates the diagnosis of minimal changes occurring on the radiographs of orthodontic treatment patients and to evaluate the prognosis of the disease. A relationship was found between orthodontic treatment applied to different malocclusion groups and mandibular condyle head bone formation. When evaluating orthodontic treatments, mandibular condyle head bone formation should be taken into consideration.
Keywords:. Fractal analysis, orthodontic treatment, orthodontic malocclusion

Öz

Amaç: Bu çalışmada, ortodontik tedavinin mandibular kondil başı kemik oluşumu üzerine etkilerinin farklı ortodontik maloklüzyon gruplarına göre araştırılması amaçlanmıştır.
Gereç ve Yöntem: Çalışmada kırk sekiz hasta incelendi. Çalışmaya dahil edilen kişiler maloklüzyon gruplarına göre gruplandırıldı. Çalışmamız geriye dönük olarak yapıldı. Hastaların ortodontik tedavi öncesi ve sonrası panoramik görüntülerinde çene kondil kemiğinin kalitesi retrospektif olarak karşılaştırıldı. Bu inceleme fraktal analiz yöntemi ile yapılmıştır.
Bulgular: Çalışmamızdan elde ettiğimiz bulgulara göre; yaşa ve cinsiyete göre ortodontik tedavi öncesi ve sonrasında mandibular kondil kemik kalitesindeki değişim istatistiksel olarak farklı bulunmadı. Sınıf I ve III maloklüzyonlu bireylerde ortodontik tedavi sonrası mandibular kondil kemiğinin trabeküler yapısında densite azalması olmuştur. Sınıf II maloklüzyonlu bireylerde mandibular kondil kemiğinin trabeküler yapısı densite artması olmuştur. Maloklüzyon gruplarına göre ortodontik tedavi öncesi ve sonrası mandibular kondil kemik kalitesindeki değişim istatistiksel olarak farklı bulundu.
Sonuç: Fraktal analiz yöntemi, ortodontik tedavi gören hastaların radyografilerinde oluşan minimal değişikliklerin teşhisini kolaylaştıran ve hastalığın seyrini değerlendiren bir tekniktir. Farklı maloklüzyon gruplarına uygulanan ortodontik tedavi ile mandibular kondil başı kemik oluşumu arasında ilişki bulunabileceği belirlenmiştir. Ortodontik tedavileri değerlendirirken mandibular kondil başı kemik oluşumu göz önünde bulundurulmalıdır.

Anahtar kelimeler: Fraktal analiz, ortodontik tedavi, ortodontik maloklüzyon.

Yazışma Adresi/Address for Correspondence: Dr. Betul Yuzbasioglu Ertuğrul, İzmir Demokrasi University Faculty of Dentistry, Department of Orthodontics, Izmir, Turkey E-mail: dryuzbasioglubetul@gmail.com
Geliş tarihi/Received: 13.04.2021 Kabul tarihi/Accepted: 24.05.2021 Çevrimiçi yayın/Published online: 23.07.2021

INTRODUCTION

The temporomandibular joint is a complex structure that includes teeth, bones, nerves, masticatory muscles or a combination of these structures[1,2]. The temporomandibular joint disorders can affect individuals of all ages. Severe temporomandibular disorders associated with headache and facial pain are seen in 1-2% of children, 5% of adolescents and 5-12% of adults[3]. It was shown that headache in children is generally associated with temporomandibular disorder symptoms[4]. Temporomandibular joint disorder is found to be associated with many factors such as tooth loss, improper orthodontic treatment, occlusal disorders, trauma, psychological stress, masticatory muscle fatigue, malfunction or parafunctional habits. Temporomandibular joint disorders cause some changes in the bone structures adjacent to the joint[2].

The temporomandibular joint mandibular component consists of an ovoid condyle process with a diameter of 15-20 mm in the medio-lateral direction and 8-10 mm in an anterior-posterior direction, located on the mandibular neck. The joint surface extends in the anterosuperior direction of the component[5]. The appearance of the mandibular condyle differs greatly between different age groups and individuals. Morphological changes can also occur as a result of reshaping of condyle to accommodate developmental variations, malocclusion, trauma and other developmental abnormalities as well as simple developmental variability[6]. Mandibular condyle bone quality depends on many factors such as trabecular continuity, bone geometry, micro-damages in bone, architecture of bone tissue, mineralization amount and defects.

Bone mineral density measurement has been used frequently in the past years in the analysis of bone structure[7]. Fractal geometric applications and fractal size measurements can be used to define the complex structure of trabecular bone[8-10]. Since the temporomandibular joint and the bone tissues forming the joint are located in the craniofacial complex, orthodontists also examine the bone formations that form the joint for diagnosis and planning, and orthodontic treatment can be modified before deformities that have occurred or may occur. This makes orthodontists important in order to intervene when deformity occurs in the temporomandibular joint or when changes occur in the bone formations forming the joint.

Within this information, the hypothesis of the study is that mandibular condyle bone density decreases in individuals with Class I and Class III malocclusion after orthodontic treatment and increases in individuals with Class II malocclusion.

With this study, it will be possible to contribute to the detailed examination of the changes in the mandibular condyle structure, which is not paid attention during orthodontic treatment. In our study, answers to the following questions were sought: Does orthodontic treatment affect anatomical structures in individuals with different molocclusions? Does orthodontic treatment have an effect on the mandibular condyle?

In this study, it was aimed to examine and compare the changes in mandibular condyle bone density after orthodontic treatment in individuals with Class I, Class II and Class III malocclusion.

MATERIALS AND METHODS

This study is a study which was conducted by examining pre and post-treatment radiological films of patients who applied to Van Yüzüncü Yıl University, Faculty of Dentistry, Department of Orthodontics for treatment, who were found suitable for orthodontic treatment and received for orthodontic treatment. Our study was carried out retrospectively. Patients screened from the archive were included in the study according to certain inclusion criteria.

Sample

In the study, 48 patients who received fixed orthodontic treatment were examined. The study started with 89 patient data. 41 patients who did not comply with the study inclusion guidelines were excluded. The study continued with 48 patient data. Individuals included in the study were grouped according to malocclusion groups. Inclusion criteria for individuals to be included in our study were determined as the presence of a panoramic film at the beginning of the treatment, the absence of any pathology in the mandibular condyle area, the absence of any congenital and/or acquired anomalies (cleft lip, cleft palate, trauma, etc.) and having not received any orthodontic treatment before. In classification according to malocclusions groups, mandibular condyle bone quality was compared by dividing into three groups as individuals with skeletal

Class I malocclusion (16 patient), individuals with skeletal Class II malocclusion (16 patients) and individuals with skeletal Class III malocclusion (16 patient). In all groups, the quality of mandibular condyle bone in panoramic images of patients before orthodontic treatment and the quality of mandibular condyle bone in the panoramic images taken after the end of orthodontic treatment were compared. Consent for treatment was obtained from all participants. This study was conducted by getting permission from İzmir Kâtip Çelebi Universty Human Ethics Research Committee (19.11.2020.1084).

Procedure

This study was conducted on the groups who show normodivergent growth patterns. Individuals with skeletal Class I malocclusion had ANB values in the range of $0° \leq ANB \leq 4°$. In the Class II malocclusion group, individuals were characterized by Class II molar-canine relationship and convex profile, by the ANB angle being greater than 4, and by the presence of a normodivergent growth model. In the creation of the Class III malocclusion group, attention was paid to the fact that the individuals were characterized by Class III molar-canine relationship, concave or flat profile, and that the ANB angle was less than 0 and had a normodivergent growth model.

Panoramic films of the patients included in our study obtained with the same x-ray device at the beginning of orthodontic treatment and after orthodontic treatment were used. In the examined panoramic images, those that did not have problems affecting the mandibular condyle bone quality, the image quality (such as magnification, low contrast and blurriness) and those that were taken close to the natural head position and/or the natural head position were selected. Panoramic images included in the study were calibrated and determined in their real dimensions at 1:1 scale. While analyzing mandibular condyle bone data, it was conducted after digital calibration was performed using theImage J (Wayne Rasband, National Institutes of Health, Bethesda, MD) program.

Fractal analysis

When examining the mandibular condyle bone quality, trabecular bone changes were compared using fractal analysis method. As a result of the fractal analysis process, a value called fractal dimension expressing the complexity of repeating geometric patterns. Panoramic radiographs of the patients included in the study were converted to "Tiff" format and fractal analysis processes were performed on the images. The necessary processes for fractal analysis were carried out on the same personal computer by the same person using the Image J Software program, by using the box counting method used by White and Rudolph[11] in their studies in 1999. It was considered that there is no pathology, lamina dura, periodontal ligament space and anatomical formation in the areas selected to carry out fractal analysis in the images. The processes required for fractal analysis in a certain order on 134 ROIs selected from 50 patients were performed. Selected ROI is duplicated. Duplicated image is blurred by using 35 pixel Gaussian filter. Thus, small and medium scale differences in image brightness were eliminated and only large density differences were allowed to remain in the image. The image which was blurred by using the Gaussian filter is extracted from the original image. 128 shades of gray are added for each pixel. This process helps to distinguish areas with different brightness, such as bone marrow and trabecular structure. Then, with the "Binary" option, the image is converted to a two-color image, black and white. Thus, the trabecular structure represented by the black areas on the image and the bone marrow can be distinguished from each other. In order to reduce the noise occurring in the image, it is eroded with the "Erode" option and the main line of the structure is obtained with the "Dilate" option. With the "invert" option, white areas were converted into black and black areas were converted into white. Finally, with the "Skeletonize" option, the image is made ready for fractal analysis. The fractal dimension is calculated by using the "Fractal Box Count" option in the "Analyze" tab on the obtained image. The image is divided into 2-64 pixel squares by using the algorithm of the program. The total number of squares in the image is calculated for each box series of different pixel sizes. The values calculated on a logarithmic scale are plotted. The most appropriate line to the points in the graph is drawn. As a result, the slope of the drawn line gives the fractal dimension value of the trabecular structure.

Statistical analysis

SPSS 20.0 statistical package program was used in the analysis of the data set (Statistical Package for the Social Sciences, version 20.0, SSPS Inc, Chicago IL, USA). The results were considered statistically significant at a significance level of $p < 0.05$. The sample size required for the study was calculated by G*Power analysis (G*Power Ver.3.0.10, Kiel, Germany) at the significance level of 0.05 and at a power of 90% and it was determined that a minimum of 16 individuals were required for each group. Whether the data had a normal distribution or not was determined by the Kolmogorov-Smirnov test. Descriptive statistics are shown as X (Mean) ± SS (Standard Deviation). ANOVA was used in the interactions of the patients' mandibular condyle bone quality groups who were separated according to the malocclusion groups.

RESULTS

When the age data mean of the patient was 187,25 ± 38 month. There are a total of 16 males and 32 females in the malocclusion groups. There were 6 males and 10 females in the class I malocclusion group. There were 4 males and 12 females in the class II malocclusion group. There were 6 males and 10 females in the class III malocclusion group. According to the findings we obtained from our study; the change in mandibular condyle bone quality before and after orthodontic treatment by age and gender was not found to be statistically different.

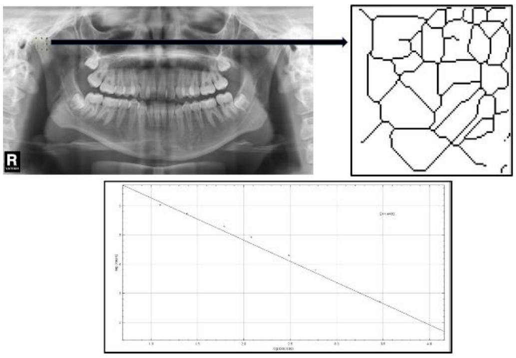

Figure-1. Mandibular condyle head bone formation by fractal analysis method of Class I malocclusion group.

When the patients were examined according to the malocclusion groups, the mean chronological age of 16 patients with Class I malocclusion was found to be 187,50 ± 42,09 month. In individuals who received Class I orthodontic treatment, the mandibular right condyle bone trabecular structure was determined to be 1,331 ± 0,086 before treatment and 1,372 ± 0,077 after treatment. The mandibular left condyle bone trabecular structure was determined to be 1,333 ± 0,074 before treatment and 1,389 ± 0,059 after treatment. The change in mandibular (average of right and left) condyle bone trabecular structure between before and after treatment was found statistically different in patients with class I malocclusion ($p<0.05$) (Table-1) (Figure-1).

When the patients were examined according to the malocclusion groups, the mean chronological age of 16 patients with Class II malocclusion was found to be 177,85 ± 44,09 month. In individuals who received Class II orthodontic treatment, the mandibular right condyle bone trabecular structure was determined to be 1,336 ± 0,074 before treatment and 1,316 ± 0,128 after treatment. The mandibular left condyle bone trabecular structure was determined to be 1,361 ± 0,030 before treatment and 1,345 ± 0,084 after treatment. The change in mandibular (average of right and left) condyle bone trabecular structure between before and after treatment was found non-statistically different in patients with class II malocclusion ($p>0.05$) (Table-1) (Figure-2).

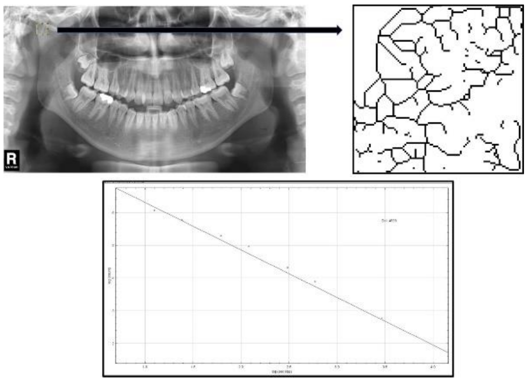

Figure 2. Mandibular condyle head bone formation by fractal analysis method of Class II malocclusion group.

When the patients were examined according to the malocclusion groups, the mean chronological age of 16 patients with Class III malocclusion was found to be 197,66 ± 19,36 month. In individuals who received Class III orthodontic treatment, the mandibular right condyle bone trabecular structure was determined to be 1,309 ± 0,044 before treatment and 1,347 ± 0,084 after treatment. The mandibular left condyle bone trabecular structure was determined to be 1,319 ± 0,079 before treatment and 1,338 ± 0,060 after treatment. The change in mandibular (average of right and left) condyle bone trabecular structure between before and after treatment was found non-statistically different in patients with class III malocclusion (p>0.05) (Table-1) (Figure-3).

In our study, after orthodontic treatment in individuals with Class I and III malocclusions, the trabecular structure of the mandibular condyle bone decreased while the trabecular structure of the mandibular condyle bone increased in Class II malocclusion. The results of the study supported our hypothesis. The change in mandibular condyle (average of right and left) bone quality before and after orthodontic treatment by malocclusion groups was found to be statistically different (p<0.05) (Table-1).

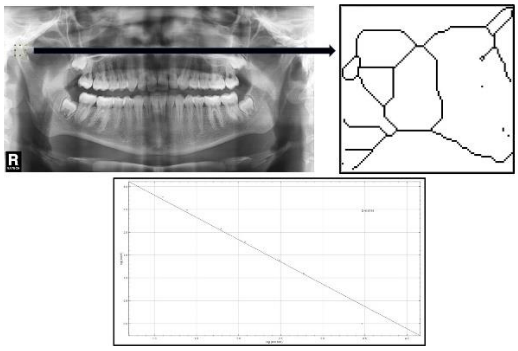

Figure-3. Mandibular condyle head bone formation by fractal analysis method of Class III malocclusion group.

Table-1. Mandibular condyle head bone formation changes according to malocclusion groups.

	Rigth mandibular condyle head bone formation before orthodontic treatment	**Left mandibular condyle head bone formation before orthodontic treatment**	**Average mandibular condyle head bone formation before orthodontic treatment**	**p**
Class I malocclusion	1.331 ± 0.086	1.333 ± 0.078	1.332 ± 0.082	0.012
Class II malocclusion	1.336 ± 0.074	1.361 ± 0.030	1.348 ± 0.052	0.118
Class III malocclusion	1.309 ± 0.000	1.319 ± 0.079	1.314 ± 0.039	0.094
	Rigth mandibular condyle head bone formation after orthodontic treatment	**Left mandibular condyle head bone formation after orthodontic treatment**	**Average mandibular condyle head bone formation after orthodontic treatment**	
Class I malocclusion	1.333 ± 0.092	1.389 ± 0.059	1.361 ± 0.076	0.023
Class II malocclusion	1.361 ± 0.030	1.345 ± 0.084	1.358 ± 0.057	0.105
Class III malocclusion	1.319 ± 0.079	1.338 ± 0.068	1.329 ± 0.074	0.092

DISCUSSION

It is known that occlusion, the positions of the teeth and the relationship between the teeth play a role in the etiology of temporomandibular disorders. The relationship between the signs or symptoms of temporomandibular disorders and orthodontic treatments is still not clearly defined[2,12]. While in some previous studies, the relationship between temporomandibular disorders and orthodontic treatment were observed, some studies have not been able to determine a relationship. In addition, it is known that the symptoms of patients with temporomandibular disease decrease in some cases after orthodontic treatment while it increases in some cases[13-16]. In some individuals who have received orthodontic treatment, in addition to temporomandibular disorders, changes in bone quality in the mandibular condyle area can be observed. Based on this information, in this study, the change in bone quality in the mandibular condyle area after orthodontic treatment in different patient groups was investigated. In our study, after orthodontic treatment in individuals with Class I and III malocclusions, the trabecular structure of the mandibular condyle bone increased while the trabecular structure of the mandibular condyle bone increased in Class II malocclusion.

The features occurring more frequently in patients with temporomandibular disease than healthy individuals can be pronounced overjet, skeletal anterior open-bite, early contact or lateral deviation during jaw closure, loss of molar support and trabecular structure changes in the joint area bones. Occlusal condition may cause temporomandibular disorder symptoms by affecting mandibular functions as a result of mandible instability and acute changes in occlusal relationships[17]. Relationships between teeth and malocclusions have been found to be associated with temporomandibular disorders[12]. However, in the studies, it was found that the prevalence of facial pain and reduction in bone quality is higher in malocclusion and dentofacial deformities compared to patients with normal occlusion[13]. There is a relationship between temporomandibular disorders and malocclusion types such as unilateral crossbite, anterior open bite, and excessive overjet[12,16]. In addition, deep bite and Angle Class II and III occlusal factors are also suggested to be risk factors for the temporomandibular joint[18,19].

Bone tissue is an important element of the musculoskeletal system that performs movement and support functions in the human body. Bone tissue consists of two compartments, trabecular and compact. The ratio of these two structures in the total bone is approximately 20% to 80%[20]. Although it constitutes 20% of the total bone mass, trabecular bone is more metabolically active than compact bone. It has been stated in various studies in the literature that any disease affecting bone tissue in the body will cause symptoms earlier in the trabecular bone[21]. With the development of technology and the introduction of computers into our lives, earlier diagnosis of many bone tissue diseases[22] with trabecular bone microstructure analysis has become a popular subject of many scientific studies. For this reason, the fractal analysis method, which is used to analyze images with a complex structure by examining its basic components, has been used extensively in scientific researches especially in the last 10 years. A mathematical image analysis algorithm is used in this method. Many researchers have conducted studies demonstrating that this method is a useful method in analyzing biological images[23]. In this study, fractal analysis method was used to examine the trabecular structure of the mandibular condyle bone.

When studies examining the possible relationship between orthodontic treatments and temporomandibular disorders are examined, Sadowsky and BeGolö have suggested that there is no difference between the two groups in terms of temporomandibular joint irregularity by comparing the records obtained after 10 years from 75 patients who received orthodontic treatment with individuals who did not receive orthodontic treatment[24]. In a conflict they published, Sadowsky and Polson reported that fixed orthodontic treatments are not associated with temporomandibular joint irregularities[25]. Kremenak et al. reported that when individuals with class I malocclusion were evaluated in the groups which have different radiographs before and after treatment, there was no difference between the groups, but there was a difference between the groups with and without premolar imaging[26]. Dibbets and Van der Weele examined the relationship between temporomandibular joint and orthodontic treatments in the malocclusion groups in which orthodontic treatment was applied. In their study, they stated that it did not cause temporomandibular problems, pain, limitation of mouth opening, crepitation and condylar deformation after orthodontic treatment[27].

This study has some limitations. In the study, the age and gender of the patients were tried to be calibrated. The male ratio of patients in terms of gender remained low. More sample size could be reached in the study. The genetic characteristics of the patients included in the study could also be examined.

Bone quality depends on many factors, such as trabecular continuity, bone geometry, micro-damages in the bone, mineralization defects and architecture of the bone tissue. The fractal analysis method is a technique that facilitates the diagnosis of minimal changes occurring on the radiographs of orthodontic treatment patients and to evaluate the prognosis of the disease. A relationship was found between orthodontic treatment applied to different malocclusion groups and mandibular condyle head bone formation. When evaluating orthodontic treatments, mandibular condyle head bone formation should be taken into consideration.

Yazar Katkıları: Çalışma konsepti/Tasarımı: BYE; Veri toplama: BYE; Veri analizi ve yorumlama: BYE; Yazı taslağı: BYE; İçeriğin eleştirel incelenmesi: BYE; Son onay ve sorumluluk: BYE; Teknik ve malzeme desteği: BYE; Süpervizyon: BYE; Fon sağlama (mevcut ise): yok.
Etik Onay: Bu çalışma için İzmir Katip Çelebi Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulundan 19.11.2020 tarih ve 1084 sayılı kararı ile etik onay alınmıştır.
Hakem Değerlendirmesi: Dış bağımsız.
Çıkar Çatışması: Yazarlar çıkar çatışması beyan etmemişlerdir.
Finansal Destek: Yazarlar finansal destek beyan etmemişlerdir.
Author Contributions: Concept/Design : BYE; Data acquisition: BYE; Data analysis and interpretation: BYE; Drafting manuscript: BYE; Critical revision of manuscript: BYE; Final approval and accountability: BYE; Technical or material support: BYE; Supervision: BYE; Securing funding (if available): n/a.
Ethical Approval: Ethical approval was obtained for this study from the Izmir Katip Çelebi University Non-Interventional Clinical Research Ethics Committee with the decision dated 19.11.2020 and numbered 1084.
Peer-review: Externally peer-reviewed.
Conflict of Interest: Authors declared no conflict of interest.
Financial Disclosure: Authors declared no financial support

REFERENCES

1. Poveda Roda R, Bagan JV, Diaz Fernandez JM, Hernandez Bazan S, Jimenez Soriano Y. Review of temporomandibular joint pathology. Part I: classification, epidemiology and risk factors. Med Oral Patol Oral Cir Bucal. 2007;12:292-8.
2. Okeson JP. Management of Temporomandibular Disorders and Occlusion. 5th ed. St. Louis (MO): Mosby. 2005;191-234.
3. Spalj S, Slaj M, Athanasiou AE, Zak I, Simunovic M, Slaj M. Temporomandibular disorders and orthodontic treatment need in orthodontically untreated children and adolescents. Coll Antropol. 2015;39:151-8.
4. Moyaho-Bernal A, Lara-Munoz Mdel C, Espinosa-De Santillana I, Etchegoyen G. Prevalence of signs and symptoms of temporomandibular disorders in children in the State of Puebla, Mexico, evaluated with the research diagnostic criteria for temporomandibular disorders (RDC/TMD). Acta Odontol Latinoam. 2010;23:228-33.
5. Alomar X, Medrano J, Cabratosa J, Clavero JA, Lorente M, Serra I. Anatomy of the temporomandibular joint. Semin Ultrasound CT MR. 2007;28:170-183.
6. Yale SH. Radiographic evaluation of the temporomandibular joint. J Am Dent Assoc.1969;79:102-7.
7. Cakur B, Sahin A, Dagistan S, Altun O, Caglayan F, Miloglu et al. Dental panoramic radiography in the diagnosis of osteoporosis. J Int Med Res. 2008:36:792-9.
8. Bollen AM, Taguchi A, Hujoel PP, Hollender LG. Fractal dimension on dental radiographs. Dentomaxillofac Radiol. 2011;30:270-5.
9. Pothuaud L, Lespessailles E, Harba R, Jennane R, Royant V, Eynard E et al. Fractal analysis of trabecular bone texture on radiographs: discriminant value in postmenopausal osteoporosis. Osteoporos Int. 2008;8:618-25.
10. Saeed SS, Ibraheem UM, Alnema MM. Quantitative analysis by pixel intensity and fractal dimensions for imaging diagnosis of periapical lesions. International Journal of Enhanced Research in Science Technology & Engineering. 2014;3:138-44
11. White SC, Rudolph DJ. Alterations of the trabecular pattern of the jaws in patients with osteoporosis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1999;88:628-35.
12. Seligman DA, Pullinger AG. The role of functional occlusal relationships in temporomandibular disorders: a review. J Craniomandib Disord. 1991;5:265-79.
13. Egermark-Eriksson I, Carlsson GE, Magnusson T, Thilander B. A longitudinal study on malocclusion in relation to signs and symptoms of cranio-mandibular disorders in children and adolescents. Eur J Orthod. 2010;12:399-407.
14. McNeill C Temporomandibular disorders: guidelines for classifcation, assessment, and management. Chicago, IL: Quintessence. 1993;1-7.
15. Pullinger AG, Seligman DA, Gornbein, JA. A multiple logistic regression analysis of the risk and relative odds of temporomandibular disorders as a function of common occlusal features. J Dent Res. 1993;72:968-79.
16. McNamara JA, Jr Seligman DA, Okeson JP. Occlusion, Orthodontic treatment, and temporomandibular disorders: a review. J Orofac Pain. 1995;9:73-90.
17. Jussila P, Krooks L, Napankangas R, Pakkila J, Lahdesmaki R, Pirttiniemi P et al. The role of occlusion in temporomandibular disorders (TMD) in the Northern Finland Birth Cohort (NFBC) 1966. Cranio. 2018;1-7.
18. Thilander B, Rubio G, Pena L, Mayorga C. Prevalence of temporomandibular dysfunction and its association with malocclusion in children and adolescents: an epidemiologic study related to specified stages of dental development. Angle Orthod. 2002;72:146–54.
19. Celić R, Jerolimov V, Pandurić J. A study of the influence of occlusal factors and parafunctional habits on the prevalence of signs and symptoms of TMD. Int J Prosthodont. 2002;15:43-8.
20. Southard TE, Southard KA, Jakobsen JR, Hillis SL, Najim CA. Fractal dimension in radiographic analysis of alveolar process bone. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1996;82:569-76.
21. White SC, Rudolph DJ. Alterations of the trabecular pattern of the jaws in patients with osteoporosis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1999;88:628-35.

22. AS Ertuğrul, A Bozoğlan, Y Tekin, H Sahin, A Dikilitaş, NZ Alpaslan. Determining the relationship between angle of roots, crown furcation roof angle, and furcation defects using cone beam computerized tomography. Atatürk Üniv Diş Hek Fak Derg. 2013;21:9115.
23. Law AN, Bollen AM, Chen SK. Detecting osteoporosis using dental radiographs: a comparison of four methods. J Am Dent Assoc. 1996;127:1734-42.
24. Sadowsky C, BeGole EA. Long-term status of temporomandibular joint function and functional occlusion after orthodontic treatment Am J Orthod. 2000;78:201-12.
25. Sadowsky C, Polson AM. Temporomandibular disorders and functional occlusion after orthodontic treatment: results of two long-term studies Am J Orthod. 2004;86:386-90.
26. Kremenak CR, Kinser DD, Melcher TJ, Wright GR, Harrison SD, Ziaja RR et al. Orthodontics as a risk factor for temporomandibular disorders (TMD). II. Am J Orthod Dentofacial Orthop. 1992;101:21-7.
27. Dibbets JM, van der Weele LT. Extraction, orthodontic treatment, and craniomandibular dysfunction. Am J Orthod Dentofacial Orthop. 2011;99:210-9.