DOI: 10.24938/kutfd.1795839 Kırıkkale Üniversitesi Tıp Fakültesi Dergisi 2026;28(2):175-180
Original Article *Özgün Araştırma*

ASSESSING PERIAPICAL BONE HEALING VIA FRACTAL ANALYSIS: CALCIUM HYDROXIDE VS. TRICALCIUM SILICATE SEALERS IN SINGLE-VISIT ROOT CANAL TREATMENT

Fraktal Analiz ile Periapikal Kemik İyileşmesinin Değerlendirilmesi: Tek Seanslı Kök Kanal Tedavisinde Kalsiyum Hidroksit ve Trikalsiyum Silikat Patların Karşılaştırılması

Özgün GÜLDEREN[1] Esma SARIÇAM[2]

[1] *Clinic of Endodontics,, Bolu İzzet Baysal Oral and Dental Health Center, BOLU, TÜRKİYE*
[2] *Department of Endodontics, Faculty of Dentistry, Ankara Yıldırım Beyazıt University, ANKARA, TÜRKİYE*

ABSTRACT

Objective: This study aimed to compare the effectiveness of two root canal sealers, Sealapex (calcium hydroxide-based) and AH plus bioceramic (tricalcium silicate-based), in promoting periapical healing following single-visit endodontic treatment, utilizing fractal analysis as a quantitative assessment tool.

Material and Methods: A retrospective analysis was conducted on periapical radiographs of 14 mandibular molars with periapical lesions, equally divided into sealapex and AH plus bioceramic groups. In total, 28 roots from 14 mandibular molars were included in the analysis. Fractal analysis was performed on radiographs taken immediately after treatment and at the 3-6-month follow-up to evaluate changes in trabecular bone structure. The box-counting method in ImageJ was used to calculate fractal dimension (FD) values, with statistical analysis performed using dependent and independent t-tests. Statistical significance was set at $p<0.05$.

Results: Both sealers demonstrated significant reductions in FD values over time (dependent t-test; $p<0.05$), indicating improved periapical healing. However, no statistically significant difference was observed between the two sealers in initial or follow-up FD values (independent t-test; $p>0.05$). Radiographic regression of lesion size further supported these findings.

Conclusion: The study concludes that both sealapex and AH plus bioceramic sealers are equally effective in promoting periapical healing in single-visit endodontic procedures. Fractal analysis serves as a reliable method for quantifying healing outcomes, with no significant superiority of one sealer over the other.

Keywords: *Biocompatible materials, calcium hydroxide, endodontics, fractals*

ÖZ

Amaç: Bu çalışmanın amacı, tek seanslı endodontik tedavi sonrası periapikal iyileşmeyi desteklemede iki farklı kök kanal patının -*sealapex* (kalsiyum hidroksit bazlı) ve *AH plus bioceramic* (trikalsiyum silikat bazlı)- etkinliğini, nicel bir değerlendirme aracı olarak fraktal analiz kullanarak karşılaştırmaktır.

Gereç ve Yöntemler: Periapikal lezyonu bulunan 14 alt çene azı dişinin periapikal radyografları retrospektif olarak incelendi. Dişler eşit şekilde *Sealapex* ve AH *plus bioceramic* gruplarına ayrıldı. Toplamda 14 mandibular molar dişe ait 28 kök analiz kapsamına dâhil edildi. Trabeküler kemik yapısındaki değişiklikleri değerlendirmek amacıyla, tedavi sonrası hemen ve 3-6 aylık takiplerde alınan radyograflara fraktal analiz uygulandı. Fraktal boyut (FB) değerleri *ImageJ* programındaki kutu sayma yöntemiyle hesaplandı, istatistiksel analiz bağımlı ve bağımsız t-testleri ile yapıldı. İstatistiksel anlamlılık düzeyi $p<0,05$ olarak belirlendi.

Bulgular: Her iki pat grubunda da zamanla FB değerlerinde anlamlı azalma gözlendi (bağımlı t-testi; $p<0,05$) ve bu durum periapikal iyileşmeyi göstermektedir. Ancak başlangıç ve takip FB değerleri açısından iki pat arasında istatistiksel olarak anlamlı bir fark saptanmadı (bağımsız t-testi; $p>0,05$). Lezyon boyutunda gözlenen görsel gerileme de bu bulguları desteklemektedir.

Sonuç: Çalışma, tek seanslı endodontik tedavide hem *Sealapex* hem de AH *plus bioceramic* patlarının periapikal iyileşmede eşit derecede etkili olduğunu ortaya koydu. Fraktal analiz, iyileşme sonuçlarını nicel olarak değerlendirmede güvenilir bir yöntem olarak öne çıkmaktadır ve iki pat arasında anlamlı bir üstünlük bulunmamaktadır.

Anahtar Kelimeler: *Biyouyumlu materyaller, kalsiyum hidroksit, endodonti, fraktaller*

Correspondence/Yazışma Adresi: **Dr. Esma SARIÇAM**
Department of Endodontics, Faculty of Dentistry, Ankara Yıldırım Beyazıt University, ANKARA, TÜRKİYE
Phone/Tel: numarayok **E-mail**/E-posta: esmasaricam@aybu.edu.tr
Received/Geliş Tarihi: 07.10.2025 **Accepted**/Kabul Tarihi: 06.04.2026

KÜ Tıp Fak Derg 2026;28(2):175-180
Doi: 10.24938/kutfd.1795839

INTRODUCTION

Successful root canal therapy relies on several critical steps: Thorough mechanical preparation of the root canals, effective disinfection using irrigation solutions, complete removal of microorganisms from the root canal system, and a tight, three-dimensional seal during filling. To prevent re-infection caused by microleakage, whether apical or coronal, the root canal system must be properly sealed.[1] Various techniques and materials are employed for root canal filling.[2] Among these, the combination of a thermoplastic core material with a stable, insoluble root canal sealer is widely regarded as the optimal method for achieving both apical and coronal obturation.[3-5] Commonly used root canal sealers include zinc oxide eugenol, calcium hydroxide, epoxy resin, methacrylate resin, and bioceramic-based materials, each with distinct properties.[6]

Calcium hydroxide-based sealers are particularly notable for their antibacterial properties, which are attributed to their high pH (approximately 12.5).[7] These sealers are bactericidal, radiopaque, and resorbable over time. They are also biocompatible, non-damaging to permanent teeth, and easy to remove if necessary.[8] Sealapex (SybronEndo, Romulus, MI, USA), a calcium hydroxide-based sealer, is favored for its biocompatibility and ability to produce high-quality fillings.[9] It is particularly effective in promoting the healing of periapical tissues and contains a higher concentration of calcium ions compared to other calcium hydroxide-based sealers.[10] Studies have shown that sealapex has a similar capacity for periapical lesion healing as MTA Fillapex, a mineral trioxide aggregate (MTA)-based sealer.[11]

In recent years, bioceramic-based root canal sealers have gained significant attention due to their excellent biological compatibility, low toxicity, and ability to provide a superior three-dimensional seal. These materials remain dimensionally stable during setting and exhibit bioactivity by promoting hard tissue formation.[12] Bioceramics are non-inflammatory and non-toxic when in contact with living tissues. They also stimulate the formation of hydroxyapatite at the bone interface, contributing to osteoinductive effects during bone healing.[13] Examples of bioceramic-based sealers include EndoSequence BC Sealer, BioRoot RCS, and TotalFill BC.[14] AH Plus Bioceramic Sealer (Dentsply Sirona, Charlotte, USA) is a premixed tricalcium silicate cement-based sealer that, according to the manufacturer, offers advantages such as a faster setting time, lower solubility, reduced film thickness, and higher radiopacity compared to EndoSequence BC Sealer.[15] Radiographic assessment plays a crucial role in evaluating the healing of periapical lesions following endodontic treatment. Conventional radiographic interpretation is largely subjective and may not fully reflect subtle microstructural changes in trabecular bone. Therefore, quantitative image analysis techniques have been introduced to objectively evaluate bone architecture and healing processes. Fractal analysis is a quantitative, objective, and non-invasive method that enables the assessment of trabecular bone complexity and structural changes in radiographic images, making it a promising tool for evaluating tissue architecture and detecting abnormalities in standard radiographs.[16,17]

In dentistry, fractal analysis has been increasingly applied to assess periapical healing after endodontic treatment and bone regeneration following surgical procedures.[18] It has proven effective in evaluating bone quality using two-dimensional radiographs.[19] The ImageJ software is commonly used for fractal analysis, where a region of interest (ROI) is selected on the radiograph, and the program calculates the fractal dimension value.[20] In endodontics, fractal analysis has been utilized to evaluate post-treatment changes in periapical lesions, with studies suggesting that changes in fractal dimension values can serve as a clinical indicator of trabecular bone healing.[21,22]

A review of the literature revealed no studies comparing the periapical healing efficacy of AH plus bioceramic and sealapex sealers. This retrospective study aims to investigate the healing outcomes of teeth with periapical lesions treated with sealapex and AH plus bioceramic sealers using fractal analysis. The null hypothesis is that there will be no significant difference in the fractal dimension values of periapical bone tissue before and after endodontic treatment between these two sealers.

MATERIALS AND METHODS

The study material comprised periapical radiographs of mandibular molar teeth with periapical lesions, treated using a standardized protocol and single-visit endodontic procedures by the same clinician (O.G.) at the Ankara Yıldırım Beyazıt University Oral and Dental Health Education and Research Hospital between April 2022 and February 2024. Radiographs were taken immediately post-treatment and during follow-up visits.

Inclusion Criteria:

1. Patients aged 18 years or older.
2. High-quality periapical radiographs taken after endodontic treatment.
3. First or second mandibular molars with periapical lesions treated using the same protocol.
4. Root canal treatment completed using either sealapex or AH plus bioceramic sealers.
5. Availability of periapical radiographs taken immediately after treatment.
6. Availability of follow-up radiographs taken ‘3-6 months’ post-treatment.

KÜ Tıp Fak Derg 2026;28(2):175-180
Doi: 10.24938/kutfd.1795839

Exclusion Criteria:

1. Poor-quality periapical radiographs taken after treatment.
2. Teeth with inadequate root canal treatment.
3. Teeth exhibiting periodontal issues.
4. Teeth with cracks, fractures, or a history of trauma.

Based on these criteria, archival records identified 7 teeth for each group (sealapex and AH Plus Bioceramic), resulting in a total of 14 teeth. Fractal analysis was performed on the mesial and distal roots separately; therefore, the unit of analysis was the root rather than the tooth. In total, 28 roots from 14 mandibular molars were included in the analysis. The required sample size was also determined and corrected using a power analysis conducted with the G-Power program, based on findings from a prior study evaluating post-endodontic healing in teeth with periapical lesions (effect size=2.11, α=0.05, power=0.95).[21] The analysis indicated a minimum of 6 teeth per group, totaling 12 teeth.

The endodontic treatment protocol for the included teeth was as follows: Access cavities were prepared, and working lengths were determined using a #15 K-type stainless steel file, using a stable occlusal reference point and set 1 mm short of the apical foramen. Root canal preparation was performed using One Shape (#25/.06) rotary nickel-titanium files (Micro-Mega SA, Besançon, France) with an endodontic motor (AI motor, Guilin Woodpecker Medical Instrument, China) at 400 rpm and 2.5 N/cm torque. Irrigation was conducted with 2 mL of 2.5% sodium hypochlorite, followed by final irrigation with 2 mL of 17% EDTA, 2 mL of 2.5% sodium hypochlorite, and 2.5 mL of distilled water. After drying with 25/06 paper points, the canals were obturated using gutta-percha cones (Sure Dent Corporation, South Korea) with either AH plus bioceramic or sealapex sealer, applied via the lateral condensation technique. Access cavities were restored with composite resin, and all treatments were completed in a single visit.

The study analyzed two periapical radiographs per tooth: onetaken immediately after treatment and another during a 3-6-month follow-up. Fractal analysis was performed on the periapical bone tissue of the mesial and distal roots using the box counting method in ImageJ. Regions of interest (ROIs) measuring 30x30 pixels were selected in the periapical area of 28 roots (Figure 1). The White and Rudolph box counting method was employed for fractal dimension calculation (Figure 2).[20]

The ROIs were processed as follows: A 30x30 pixel ROI was duplicated and blurred using the Gaussian Blur function (sigma=35 pixels). The blurred image was subtracted from the original, and 128 gray tones were added per pixel. The image was converted to 8-bit format, thresholded to create a binary image, and noise was reduced using the "Erode" function. The "Dilate" function enhanced the trabecular structure, and the "Invert" option highlighted the trabecular outlines. Finally, the "Skeletonize" function prepared the image for fractal analysis, and the "Fractal box counting" tool calculated the fractal dimension.

Statistical analysis was performed using SPSS v.22. The Shapiro-Wilk test confirmed normal data distribution. Statistical analysis was performed using dependent and independent t-tests, and statistical significance was set at $p<0.05$. This study received ethical approval from the Ankara Yıldırım Beyazıt University Health Sciences Ethics Committee (Approval Number: 21.03.2024/03-619).

RESULTS

It was visually confirmed by two observers (O.G., E.S.) that the periapical lesion size in all teeth had regressed. The immediate post-treatment and follow-up fractal values of the two sealers used in the study, both individually and in total, are shown in Table 1. Fractal analysis values decreased significantly over time in both groups (dependent t-test, $p<0.05$). The initial and final fractal analysis values of the two groups did not differ statistically significantly (independent t-test, $p>0.05$).

Table 1: Fractal dimension values obtained immediately after treatment and follow-up of the periapical radiographs (n: number of roots)

Sealer	n	After treatment Mean±SD	Follow-up Mean±SD	p
Sealapex	14	1.3297±0.0600	1.2572±0.0790	0.046
AH Plus Bioceramic	14	1.2932±0.0487	1.1901±0.1063	0.007
Total	28	1.3114±0.0568	1.2236±0.0980	0.001

KÜ Tıp Fak Derg 2026;28(2):175-180
Doi: 10.24938/kutfd.1795839

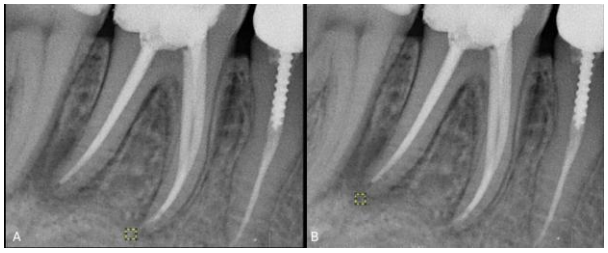


Figure 1: Regions of interest (ROIs) selected on (A) mesial and (B) distal periapical areas of the lower molars

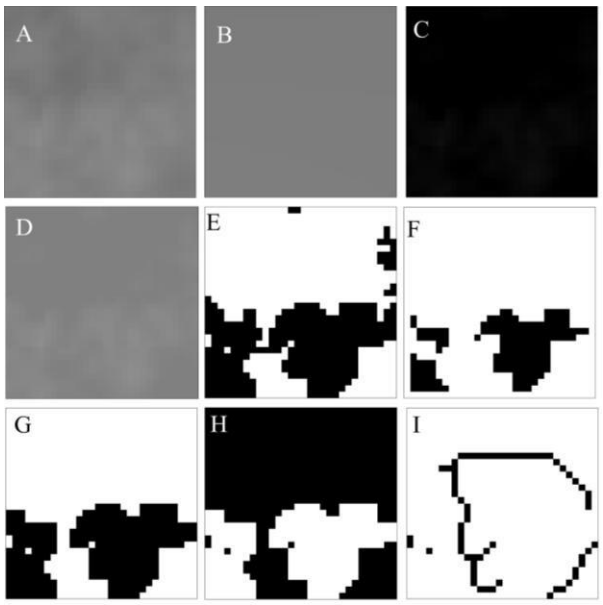


Figure 2: Series of fractal dimension analyses of the ROI determined on the Figure 1. (A) Region of interest. (B) Region of interest process with Gaussian Blur filters, (C) Subtracted blurred image from the original image, (D) Addition of a grey value of 128 to each pixel location, (E) Threshold, (F) Erosion, (G) Dilatation, (H) Inversion of the colors (I) Skeletonization

DISCUSSION

This study used fractal analysis to examine the impact of two root canal sealers, sealapex and AH Plus Bioceramic, on the healing of periapical lesions. The results demonstrated a significant reduction in fractal dimension (FD) values over time in both groups, indicating improved trabecular bone structure and periapical healing. However, no statistically significant difference was observed between the two sealers in terms of their initial and follow-up FD values in single-visit endodontic procedures. These results support the use of sealapex and AH plus bioceramic in endodontic treatments by indicating that they are both successful in promoting periapical healing.

Fractal analysis has emerged as a reliable, non-invasive, and quantitative method for detecting changes in trabecular bone architecture, particularly in periapical healing. Studies such as those by Aydin et al. and Tosun et al. have successfully employed fractal analysis to evaluate the effects of endodontic treatments on periapical bone quality.[22,23] Ugur Aydin et al. reported that fractal analysis could effectively detect changes in periapical bone structure following root-end surgery, while Tosun et al. demonstrated its utility in assessing healing after multivisit nonsurgical endodontic retreatment. [22,23] These studies underscore the validity of fractal analysis as a tool for quantifying bone healing, supporting its use in the current study.

According to earlier studies, FD values generally increase when lesions heal, which contrasts with the findings of the study.[21-26] Although the ability of fractal analysis to objectively measure trabecular bone architecture makes it a valuable addition to traditional radiographic evaluation methods, the technique has limitations, including its reliance on high-quality radiographs and the potential for variability in ROI selection. These contradictory findings may stem from differences in ROI sizes, tooth types, and methodological variations across studies.

The decrease in FD values observed in the present study may be related to the early healing phase (3-6 months). Bone healing is a complex and dynamic biological process that involves sequential stages of inflammation, bone resorption, and subsequent new bone formation. During this remodeling phase, temporary alterations in trabecular architecture may occur, which can influence the complexity of the trabecular pattern detected in radiographic images.[18,19] Therefore, transient changes in FD values during the early stages of healing may reflect ongoing bone remodeling rather than a lack of tissue repair. Furthermore, methodological factors, including differences in ROI size and image-processing protocols applied during fractal analysis, may also affect FD measurements.

The comparable performance of AH plus bioceramic and Sealapex in promoting periapical healing can be attributed to their respective properties. sealapex, a calcium hydroxide-based sealer, is known for its biocompatibility, antibacterial activity, and ability to release calcium ions, which contribute to tissue repair and hard tissue formation.[7,8,10] These properties make it a suitable material for inducing periapical healing, as evidenced by the significant reduction in FD values in this study. Similarly, AH plus bioceramic, a tricalcium silicate-based sealer, has been shown to exhibit excellent biocompatibility, bioactivity, and sealing ability.[12,13,15] Its ability to induce hydroxyapatite formation and osteoinductive effects likely contributed to the observed healing outcomes.

The lack of significant differences between the two sealers may be due to their shared ability to create a favorable environment for periapical healing. Both materials provide effective sealing of the root canal system, preventing microbial re-infection and promoting tissue repair. Additionally, their biocompatibility and bioactive properties likely play a role in reducing inflammation and stimulating bone

regeneration. These findings are consistent with previous studies that have reported similar healing outcomes for calcium hydroxide-based and bioceramic sealers.[9,11,14]

Single-visit endodontics has gained popularity in recent years due to its efficiency and convenience. Single-visit and multi-visit endodontic treatment approaches did not significantly differ in healing rates, according to a systematic study, indicating that both can be successful when the right case selection and procedures are followed.[27] Similarly, a randomized controlled trial by Yildiz et al. reported comparable periapical healing and postoperative pain levels between single-visit and multi-visit treatments, supporting the viability of single-visit treatment in selected cases.[24] In this study, all the cases received endodontic treatment in a single visit, and after therapy, the lesion's size decreased, and no symptoms persisted. The success of both sealers in promoting periapical healing in a single-visit setting highlights their clinical reliability and effectiveness. This finding is particularly relevant in modern endodontic practice, where efficiency and patient satisfaction are prioritized.

The present study has several limitations that should be considered when interpreting the findings. First, the retrospective study design may introduce inherent selection bias. Second, the relatively small sample size may limit the statistical power and generalizability of the results. Moreover, the follow-up period ranged from 3 to 6 months, which may have influenced the assessment of the healing process. Another limitation is the absence of an inter-observer reliability assessment during the radiographic evaluation. Finally, the use of two-dimensional periapical radiographs instead of three-dimensional imaging techniques may limit the ability to fully assess complex changes in trabecular bone structure. Future studies evaluating the magnitude of fractal dimension change (ΔFD) between baseline and follow-up may provide additional insight into the dynamics of periapical bone remodeling.

Within the limitations of this study, both sealapex and AH plus bioceramic sealers were effective in promoting periapical healing, as evidenced by the significant reduction in fractal dimension values over time. However, the relatively small sample size and retrospective design limit the generalizability of the results, and future studies with larger cohorts and longer follow-up periods are required.

Conflict of interest: The authors have no conflicts of interest to declare.

Researchers' Contribution Rate Statement: Concept/Design: ES; Analysis/Interpretation: ES; Data Collection: ES, OG; Writer:ES, OG; Critical Review: ES; Approver: ES, OG.

Support and Acknowledgement: No financial support was received from any institution or person.

Ethics approval and consent to participate This retrospective study received ethical approval from the Ankara Yıldırım Beyazıt University Health Sciences Ethics Committee (Approval Number: 21.03.2024/03-619).

REFERENCES

1. Muliyar S, Shameem KA, Thankachan RP, Francis PG, Jayapalan CS, Hafiz KA. Microleakage in endodontics. *J Int Oral Health.* 2014;6(6):99-104.
2. Capar ID, Ertas H, Ok E, Arslan H. Comparison of single cone obturation performance of different novel nickel-titanium rotary systems. *Acta Odontol Scand.* 2014;72(7):537-542.
3. Atmeh AR, AlShwaimi E. The effect of heating time and temperature on epoxy resin and calcium silicate-based endodontic sealers. *J Endod.* 2017;43(12):2112-2118.
4. Eymirli A, Sungur DD, Uyanik O, Purali N, Nagas E, Cehreli ZC. Dentinal tubule penetration and retreatability of a calcium silicate-based sealer tested in bulk or with different main core material. *J Endod*. 2019;45(8):1036-1040.
5. Neelakantan P, Grotra D, Sharma S. Retreatability of 2 mineral trioxide aggregate-based root canal sealers: A cone-beam computed tomography analysis. *J Endod.* 2013;39(7):893-896.
6. Zordan-Bronzel CL, Esteves Torres FF, Tanomaru-Filho M, Chavez-Andrade GM, Bosso-Martelo R, Guerreiro-Tanomaru JM. Evaluation of physicochemical properties of a new calcium silicate-based sealer, Bio-C Sealer. *J Endod.* 2019;45(10):1248-1252.
7. Kaur A, Shah N, Logani A, Mishra N. Biotoxicity of commonly used root canal sealers: A meta-analysis. *J Conserv Dent.* 2015;18(2):83-88.
8. Leonardo MR, Silva LA, Utrilla LS, Assed S, Ether SS. Calcium hydroxide root canal sealers-histopathologic evaluation of apical and periapical repair after endodontic treatment. *J Endod.* 1997;23(7):428-432.
9. Borges AH, Guedes OA, Pereira TM, Guapo-Pavarina R, da Rosa WLO, Piva E. Evaluation of selective physicochemical and biological properties of different root canal sealers. *Iran Endod J.* 2019;14(2):126-132.
10. da Silva LA, Leonardo MR, da Silva RS, Assed S, Guimaraes LF. Calcium hydroxide root canal sealers: Evaluation of pH, calcium ion concentration and conductivity. *Int Endod J.* 1997;30(3):205-209.
11. Gomes-Filho JE, Watanabe S, Cintra LT, et al. Effect of MTA-based sealer on the healing of periapical lesions. *J Appl Oral Sci.* 2013;21(3):235-242.
12. Al-Haddad A, Che Ab Aziz ZA. Bioceramic-based root canal sealers: A review. Int *J Biomater.* 2016;2016:9753210.
13. Uygun AD, Sen S, Celik S. Comparison of biocompatibility of epoxy resin and bioceramic-based root canal sealers. *Clin Oral Investig.* 2024;28(12):673.
14. La Rosa GRM, Canova FS, Leotta ML, Pedulla E. Effects of heating on bioceramic sealers: A scoping review of

chemo-physical properties and clinical implications. *Odontology*. 2025;113(1):1-14.
15. Sanz JL, Lopez-Garcia S, Rodriguez-Lozano FJ, et al. Cytocompatibility and bioactive potential of AH plus bioceramic sealer: An *in vitro* study. *Int Endod J.* 2022;55(10):1066-1080.
16. Kiyohara S, Sakurai T, Kashima I. Early detection of radiation-induced structural changes in rat trabecular bone. *Dentomaxillofac Radiol.* 2003;32(1):30-38.
17. Soltani P, Sami S, Yaghini J, Golkar E, Riccitiello F, Spagnuolo G. Application of fractal analysis in detecting trabecular bone changes in periapical radiograph of patients with periodontitis. *Int J Dent.* 2021;2021:3221448.
18. Gomes NR, Albergaria JDS, Henriques JAS, et al. Comparison between fractal analysis and radiopacity evaluation as a tool for studying repair of an osseous defect in an animal model using biomaterials. *Dentomaxillofac Radiol.* 2019;48(7):20180466.
19. Majumdar S, Lin J, Link T, Millard J, et al. Fractal analysis of radiographs: Assessment of trabecular bone structure and prediction of elastic modulus and strength. *Med Phys*. 1999;26(7):1330-1340.
20. 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(5):628-635.
21. Ince Yusufoglu S, Ugur Aydin Z, Tulumbaci F, Bayrak S. Evaluation of different Apexification treatments of teeth with immature apices and apical periodontitis on the fractal dimensions of trabecular bone. *Aust Endod J.* 2021;47(2):163-169.
22. Ugur Aydin Z, Toptas O, Goller Bulut D, Akay N, Kara T, Akbulut N. Effects of root-end filling on the fractal dimension of the periapical bone after periapical surgery: Retrospective study. *Clin Oral Investig.* 2019;23(9):3645-3651.
23. Tosun S, Karataslioglu E, Tulgar MM, Derindag G. Fractal analysis and periapical index evaluation of multivisit nonsurgical endodontic retreatment: A retrospective study. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2022;133(2):245-251.
24. Yildiz B, Dumani A, Isci AS, Sisli SN, Tumani Ustdal B, Yoldas O. Outcome of single-visit root canal treatment with or without MTAD: A randomized controlled clinical trial. *Int Endod J.* 2024;57(1):2-11.
25. Aricioglu B, Gunacar DN, Kosar T, Sanal Cikman A, Pertek Hatipoglu F, Maras E. Assessment of bone quality of apical periodontitis treated with MTA plug and regenerative endodontic techniques. *Aust Endod J.* 2022;48(3):444-450.
26. Kurt Ö, Koyuncu S, Güleç M, Şimşek E. Fractal dimensional analysis of follow-up data after endodontic treatment: A retrospective study. *Akd Dent J.* 2024;3(3):122-129.
27. Figini L, Lodi G, Gorni F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth. *Cochrane Database Syst Rev.* 2007(4):CD005296.