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Root Length Changes in Orthodontically Displaced Teeth Treated with the Corticotomy Approach

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Abstract

The aim of the study: Corticotomy-facilitated orthodontics is a modern approach to resolve complicated orthodontic cases that may increase the pace of tooth movement. The study's goal was to assess the changes that occurred at the root level following orthodontic treatment when corticotomy was used. Material and methods: Based on Cone Beam Computer Tomography, measurements of the root length at T0 (before corticotomy) and T1 (after

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corticotomy) were taken after splitting the individuals into two groups (maxillary and mandibular corticotomy) (6 months after surgery). For statistical analysis of the data, many tests were utilized. Results: The root length values obtained at T1 showed minimal changes in length, with statistically insignificant values (for the maxillary arch, the values obtained were 13.36 ± 2.41 mm for women and 14.26 ± 2.06 mm for men; for the lower arch, the measured values were 12.38 ± 2.09 mm for women and 11.56 ± 2.29 mm for men). The canine on the left hemiarcade had the most significant change in root length following treatment, with a value assessed at T1 of 16.72 ± 1.78 mm, which was statistically significant, p 0.05. Conclusion: According to the data obtained in this study, when orthodontic therapy is associated with corticotomy, there is a decrease in root resorption that may occur in the case of conventional orthodontic treatments.

Keywords: Orthodontics, corticotomy, root resorption, dental displacement

Introduction

Because various changes in the supporting tissues of the tooth occur during orthodontic therapy, such as compression of the periodontal ligament, resorption and bone apposition, orthodontic movement of the teeth is considered a periodontal phenomenon (Patterson et al., 2016). Despite the fact that malocclusions are relatively common in the general population, people still refuse to see an orthodontic specialist to improve their situation, due to the prolonged treatment time (Bos et al., 2003). On the other hand, it is widely recognized that long-term therapy can lead to complications such as enamel demineralization, cavities, periodontal inflammation and even root resorption (Cantekin et al., 2011).

The duration of orthodontic treatment is determined by the amplitude of the tooth displacement, the technique used, the therapeutic objectives and the patient's compliance (Sayers et al., 2007). Different methods have been used to try to speed up tooth movement over time. According to Kale et al. (2014), the degree of tooth displacement may vary depending on the local or systemic administration of particular drugs, a result supported by Tyrovola et al. (2001) in their investigation. Root length and alveolar bone height are two factors that influence the degree of tooth displacement (Tyrovola et al., 2001). The ability of the teeth to move varies from patient to patient.

A procedure adjuvant to traditional orthodontic therapy called corticotomy has recently been introduced in order to achieve quicker tooth movement while avoiding potential harmful effects on dental and periodontal support (Patterson et al., 2016). Further research into this approach revealed that tooth movement is facilitated by an acceleration in local cellular metabolism, a phenomenon known as the Regionally Acceleratory

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Phenomenon (RAP). The rate of tooth displacement increases with various bone morphological changes, according to a series of experimental animal investigations (Le et al., 2018; Zuppardo et al., 2019).

A number of clinical studies have shown that the occurrence of radicular resorption is directly correlated with the prolonged duration of orthodontic treatment (Mann et al., 2022). On the other hand, one of the advantages of corticotomy would be that speeding up the pace of dental movement, thus reducing the duration of orthodontic treatment (Al-Naoum et al., 2019). Therefore, the aim of the current study is to observe the degree of root resorption in the teeth displaced by orthodontic forces in which the corticotomy surgery was performed.

Methods

This retrospective study included 60 patients (28 men and 32 women) with a moderate to severe degree of dental crowding, non-extraction treatment, no missing teeth or structural changes, and no periodontal problems such as gingival recession or bone loss. The patients with severe craniofacial abnormalities, missing teeth, those with anti-inflammatory medication, those clotting problems, with systemic disorders (diabetes) were excluded from the study. The sample was set up to use each patient as his own control, thereby increasing the power of small sample.

The case of each patient included in the study was documented with panoramic radiograph, profile teleradiography, study models and intraoral and extraoral photographs, as well as a Cone Beam Computer Tomography (CBCT) before the corticotomy intervention (after the alignment and leveling phase of the teeth - T0) and at the end of the orthodontic treatment (T1) in order to evaluate the root length before and after corticotomy.

The p atients were divided into 2 equal groups, the first group including patients with maxillary corticotomy, and the second group included patients with mandibular corticotomy. The study included all six frontal teeth (from canine to canine) from both arches, upper and lower.

A line was drowned at cemento enamel junction (CEJ) of the buccal surface in the sagital view. After which, the apical area was delimited for each tooth, subsequently being measured the root length from the CEJ to the apex of the tooth. All radiographic measurements were performed by an orthodontist and a periodontist. Written informed consent was procured from every patient after they were explained the study design and protocol.

Descriptive statistics (mean, median, standard deviation) and inferential statistics were used in the statistical study. The significance level for p was set at 0.05.

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Results

This study comprised sixty patients, including 32 females (with an average age of 39.50 7.87 years) and 28 men (with an average age of 30.73 6.21 years).

The highest root length value at T0 in the maxillary arch was measured in female patients at 12.40 ± 2.07 mm, while in male patients the measured value was 11.57 ± 2.29 mm. In contrast, at the lower arch, the root length for men (14.28 ± 2.03 mm) was greater than the measured value for women (13.38 ± 2.43 mm). The values of the root length measured at T1, showed minimal changes in their length, with statistically insignificant values (for the maxillary arch, the values obtained were 13.36 ± 2.41 mm for women and 14.26 ± 2.06 for men; in the lower arch the measured values were 12.38 ± 2.09 mm for women and 11.56 ± 2.29 mm for men) (Table 1).

Root length	Sex	T0 Median±SD (mm)	T1 Median±SD (mm)	P value
Lower arch	Females	12.40±2.07	12.38±2.09	0.21
	Males	11.57±2.29	11.56±2.29	0.18
Upper arch	Females	13.38±2.43	13.36±2.41	0.26
	Males	14.28±2.03	14.26±2.06	0.11

Table 1: Root length at T0 and T1 for maxillary and mandibular teeth in female and male patients

At the individual measurements of the root length made on dental groups at the upper arch, the tooth with the longest root length at T0 was the canine on the right side (17.04 ± 1.42 mm) being followed by the canine on the left side (16.77 mm ± 1.76 mm). The lowest values of root length were measured at the level of the lateral incisor in quadrant 1 (11.89 ± 1.32 mm) as well as at the level of the left lateral incisor (12.17 ± 1.18 mm). The most significant change in the root length after treatment was recorded in the canine on the left hemiarcade, the value measured at T1 being 16.72 ± 1.78 mm, the value is statistically significant, $p \leq 0.05$. For the right central incisor, the value measured at T1 remained unchanged from the value measured at T0 (12.90 ± 1.53 mm), the same situation for the lateral incisor on the left side, where the value measured at T1 was 12.17 ± 1.18 mm (Table 2).

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Root length	T0 Median±SD (mm)	T1 Median±SD (mm)	P value
13	17.04±1.42	17.02±1.47	0.36
12	11.89±1.32	11.86±1.33	0.32
11	12.90±1.53	12.90±1.53	0.94
21	13.07±1.52	13.04±1.60	0.50
22	12.17±1.18	12.17±1.18	0.83
23	16.77±1.76	16.72±1.78	0.02

Table 2: Root length at T0 and T1 for maxillary teeth

For the lower arch, the longest root length measured at T0 was obtained at the level of the canine on the left side (14.20 ± 1.66 mm), followed by the canine on the right side (14.16 ± 1.48 mm). The smallest root length was recorded at the level of the central incisor as 10.05 ± 1.32 mm. Unlike the maxillary arch, at the lower arch, statistically significant values were obtained at T1, in the case of 2 teeth. The highest degree of resorption was measured at tooth 43 (14.10 ± 1.49 mm), followed by tooth 33 (14.15 ± 1.69 mm), both values being statistically significant. In the case of teeth 31 and 32, the values at T0 and T1 were unchanged (10.10 ± 1.48 mm, respectively 10.32 ± 1.56 mm) (Table 3).

Root length	T0 Median±SD (mm)	T1 Median±SD (mm)	P value
43	14.16±1.48	14.10±1.49	0.02
42	10.49±1.59	10.48±1.59	0.21
41	10.05±1.32	10.04±1.31	0.30
31	10.10±1.48	10.10±1.48	0.18
32	10.32±1.55	10.32±1.55	0.43
33	14.20±1.66	14.15±1.69	0.01

Table 3: Root length at T0 and T1 for mandibular teeth

Discussion

The resorption and bone apposition cause dental displacement during orthodontic therapy (Chackartchi, 2017). However, it is well known that after corticotomy, the movements of the dento-alveolar structures appear to be related to the acceleration of the local metabolism at the level of the intervention (Hassan, 2015). However, it is hypothesized that this accelerated healing leads to much faster healing than physiological repair. The procedure increases the activity of osteoblasts and osteoclasts, which results in beneficial tooth displacement (Bell, 1972). The intervention consists of selective bone decortication, which results in a faster rate of change of the trabecular bone and the emergence of demineralization zones (Abbas, 2016).

The canines had the largest root length in both the maxillary and mandibular arches, according to measurements taken before corticotomy surgery in the current study. In one of his research on the root length of front

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teeth, Pilalas et al. (2016) came to a similar conclusion. When it comes to incisor root length, Arriola-Guillén (2020) discovered that the root teeth of the central incisors are longer than the root teeth of the lateral incisors. A similar finding was made in the current investigation, where the longest root length was recorded at the level of the left central incisor, with the values measured at the level of the lateral incisors being less than their own. When it comes to the mandibular arch, opinions are divided regarding the root length at the level of the incisor group. Wu et al. (2020) in a study in this direction concluded that the root of the four incisors is of equal length. In the present study, the root length measured at the level of the central incisors was shorter than that measured at the level of the lateral incisors. The same observation was made by Wu (2022) in a comparative study to determine the degree of root resorption by conventional radiological means and CBCT. On the other hand, some studies have shown that these observations may vary depending on the ethnic characteristics of the subjects involved, even observing in some cases a longer length of the lower central incisors than the lateral ones (Al-Okshi, 2019).

The root resorption is a typical adverse effect that can develop following conventional orthodontic treatment. According to the literature, most orthodontically treated individuals have varying degrees of root resorption. The prevalence of root resorption following orthodontic therapy varies greatly amongst researchers (Silva, 2017). According to Taithongchai et al., (1996) one-third of fixed appliance patients had more than 3 mm of root resorption, and at least 2% of orthodontic patients had more than 5 mm of root resorption. A series of studies in this area revealed that it can start a few weeks after the beginning of orthodontic treatment but can only be seen radiologically after 3 to 4 months (Sameshima, 2021). This was one of the reasons why the first measurements in this study were taken after the teeth had been aligned and leveled. When the pressures developed and exerted at the apical level surpass the tooth's resistance and flexibility, this complex biological process occurs (Weltman, 2010).

The precise process of orthodontically induced root resorption is unknown. This phenomenon, however, has a multifaceted origin. For root resorption during orthodontic treatment, several biological, mechanical and clinical aspects were evaluated (Yi, 2016). The technique or appliance utilized for orthodontic treatment can be a significant deciding factor in the degree of root resorption. In general, mild orthodontic pressures result in less resorption (Sameshima, 2010). A number of studies have found a link between the degree of root resorption and the length of orthodontic treatment (Yassir, 2021). On the other hand, other investigations have found a direct correlation between corticotomy and tooth displacement, implying that the length of treatment is reduced (Iglesias-Linares, 2017).

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Most prior investigations on the resorption of various dental groups concentrated on the maxillary arch incisors since it is considered that they are the most sensitive to the occurrence of resorption (Bellini-Pereira, 2021). Previous research has indicated that severe resorption occurs in around 1% of studied teeth, whereas other dental groups may have different degrees of resorption (Jyotrimay, 2021). When orthodontic therapy was combined with corticotomy in the current investigation, some changes in root length were found at the canines level in both arches. Alikhani et al. made the same observation in related research (Currell, 2019).

Many of the studies in which root length was assessed used panoramic radiographs or periapical radiographs, which were obtained by parallelizing the long cone. However, there are several flaws in measuring the degree of root resorption using panoramic radiography. Some researchers believe that the results were overestimated by approximately 20% (Meirinhos, 2021). On the other hand, during orthodontic treatment, tooth angulation may vary, resulting in changes in root length detectable on radiography (Rahmel, 2019). The measurements in this investigation were performed using CBCT images since the reconstitution is 1:1 and amplification errors are absent. As a result, investigations in which the degree of root resorption was evaluated using CBCT yielded more accurate findings than 2D pictures (Durack, 2011). Wang reached the same finding in one research, underlining the significance of 3D technology in assessing root resorption (Wang et al., 2013).

Although the current study emphasizes the benefits of corticotomy-assisted orthodontics, there are certain drawbacks, including the small number of participants included in the study and the short length of time during which the evaluation was completed. A higher number of participants, as well as the type of malocclusion treated, might result in different findings. As a result, further research is required to corroborate the findings of our study.

Conclusion

Although root resorption after orthodontic treatment seems to be an inevitable process, the observations in this study support the idea that corticotomy, when combined with conventional orthodontic treatment, by facilitating a faster movement of teeth, greatly reduces the risk of occurrence of this process. However, further research is needed to support this observation

Human Studies

The study was carried out in compliance with the Helsinki Declaration and was approved by the George Emil Palade University of Medicine and Pharmacy's Ethics Committee (1583/January 2022). After the research design and methods were described to each patient, written informed consent was obtained.

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Authors contribution

All the authors contributed equally at this research.

Conflicts of Interests

The authors declare no conflict of interest.

References:

1. Patterson, B. M., Dalci, O., Darendeliler, M. A., & Papadopoulou, A. K. (2016). Corticotomies and Orthodontic Tooth Movement: A Systematic Review. *Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons*, *74*(3), 453–473. https://doi.org/10.1016/j.joms.2015.10.011.
2. Bos, A., Hoogstraten, J., & Prahl-Andersen, B. (2003). Expectations of treatment and satisfaction with dentofacial appearance in orthodontic patients. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*, *123*(2), 127–132. https://doi.org/10.1067/mod.2003.84.
3. Maret, D., Marchal-Sixou, C., Vergnes, J. N., Hamel, O., Georgelin-Gurgel, M., Van Der Sluis, L., & Sixou, M. (2014). Effect of fixed orthodontic appliances on salivary microbial parameters at 6 months: a controlled observational study. *Journal of applied oral science : revista FOB*, *22*(1), 38–43. https://doi.org/10.1590/1678-775720130318.
4. Sayers, M. S., & Newton, J. T. (2007). Patients' expectations of orthodontic treatment: part 2--findings from a questionnaire survey. *Journal of orthodontics*, *34*(1), 25–35. https://doi.org/10.1179/146531207225021888
5. Kale, S., Kocadereli, I., Atilla, P., & Aşan, E. (2004). Comparison of the effects of 1,25 dihydroxycholecalciferol and prostaglandin E2 on orthodontic tooth movement. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*, *125*(5), 607–614. https://doi.org/10.1016/j.ajodo.2003.06.002
6. Le, M., Lau, S. F., Ibrahim, N., Noor Hayaty, A. K., & Radzi, Z. B. (2018). Adjunctive buccal and palatal corticotomy for adult maxillary expansion in an animal model. *Korean journal of orthodontics*, *48*(2), 98–106. https://doi.org/10.4041/kjod.2018.48.2.98.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

7. Zuppardo, M. L., Ferreira, C. L., de Moura, N. B., Longo, M., Santamaria, M., Jr, Lopes, S., Santamaria, M. P., & Jardini, M. (2019). Macroscopic and radiographic aspects of orthodontic movement associated with corticotomy: animal study. *Oral and maxillofacial surgery*, *23*(1), 77–82. https://doi.org/10.1007/s10006-019-00744-7.
8. Mann, C., Cheng, L. L., Çolak, C., Elekdag-Turk, S. T., Turk, T., & Darendeliler, M. A. (2022). Physical properties of root cementum: Part 28. Effects of high and low water fluoridation on orthodontic root resorption: A microcomputed tomography study. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*, S0889-5406(22)00134-2. Advance online publication. https://doi.org/10.1016/j.ajodo.2021.03.023.
9. Al-Naoum, F., Hajeer, M. Y., & Al-Jundi, A. (2014). Does alveolar corticotomy accelerate orthodontic tooth movement when retracting upper canines? A split-mouth design randomized controlled trial. *Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons*, *72*(10), 1880–1889. https://doi.org/10.1016/j.joms.2014.05.003.
10. Chackartchi, T., Barkana, I., & Klinger, A. (2017). Alveolar Bone Morphology Following Periodontally Accelerated Osteogenic Orthodontics: A Clinical and Radiographic Analysis. *The International journal of periodontics & restorative dentistry*, *37*(2), 203–208. https://doi.org/10.11607/prd.2723.
11. Hassan, A. H., Al-Saeed, S. H., Al-Maghlouth, B. A., Bahammam, M. A., Linjawi, A. I., & El-Bialy, T. H. (2015). Corticotomy-assisted orthodontic treatment. A systematic review of the biological basis and clinical effectiveness. *Saudi medical journal*, *36*(7), 794–801. https://doi.org/10.15537/smj.2015.7.12437.
12. Bell, W. H., & Levy, B. M. (1972). Revascularization and bone healing after maxillary corticotomies. *Journal of oral surgery (American Dental Association : 1965)*, *30*(9), 640–648.
13. Abbas NH, Sabet NE, Hassan IT. Evaluation of corticotomy-facilitated orthodontics and piezocision in rapid canine retraction. Am J Orthod Dentofacial Orthop. 2016 Apr;149(4):473-80. doi: 10.1016/j.ajodo.2015.09.029. PMID: 27021451.
14. Pilalas, I., Tsalikis, L., & Tatakis, D. N. (2016). Pre-restorative crown lengthening surgery outcomes: a systematic review. *Journal of clinical periodontology*, *43*(12), 1094–1108. https://doi.org/10.1111/jcpe.12617.

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

15. Arriola-Guillén, L. E., Valera-Montoya, I. S., Rodríguez-Cárdenas, Y. A., Ruíz-Mora, G. A., Castillo, A. A., & Janson, G. (2020). Incisor root length in individuals with and without anterior open bite: a comparative CBCT study. *Dental press journal of orthodontics*, *25*(4), 23e1–23e7. https://doi.org/10.1590/2177-6709.25.4.23.e1-7.onl.
16. Wu, C., Tang, H., & Chen, J. (2020). Cone-beam computed tomography for evaluating root length of maxillary and mandibular anterior teeth in open bite patients. 锥形束CT评估前牙开 患者上下颌前牙根长. *Zhong nan da xue xue bao. Yi xue ban = Journal of Central South University. Medical sciences*, *45*(12), 1444–1449. https://doi.org/10.11817/j.issn.1672-7347.2020.190578.
17. Wu, G., He, S., Chi, J., Sun, H., Ye, H., Bhikoo, C., Du, W., Pan, W., Voliere, G., & Hu, R. (2022). The differences of root morphology and root length between different types of impacted maxillary central incisors: A retrospective cone-beam computed tomography study. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*, *161*(4), 548–556. https://doi.org/10.1016/j.ajodo.2020.09.037.
18. Al-Okshi, A., Paulsson, L., Rohlin, M., Ebrahim, E., & Lindh, C. (2019). Measurability and reliability of assessments of root length and marginal bone level in cone beam CT and intraoral radiography: a study of adolescents. *Dento maxillo facial radiology*, *48*(5), 20180368. https://doi.org/10.1259/dmfr.20180368.
19. Silva, A. C., Capistrano, A., Almeida-Pedrin, R. R., Cardoso, M. A., Conti, A. C., & Capelozza, L., Filho (2017). Root length and alveolar bone level of impacted canines and adjacent teeth after orthodontic traction: a long-term evaluation. *Journal of applied oral science : revista FOB*, *25*(1), 75–81. https://doi.org/10.1590/1678-77572016-0133.
20. Taithongchai, R., Sookkorn, K., & Killiany, D. M. (1996). Facial and dentoalveolar structure and the prediction of apical root shortening. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*, *110*(3), 296–302. https://doi.org/10.1016/s0889-5406(96)80014-x.
21. Sameshima, G. T., & Iglesias-Linares, A. (2021). Orthodontic root resorption. *Journal of the World federation of orthodontists*, *10*(4), 135–143. https://doi.org/10.1016/j.ejwf.2021.09.003.
22. Weltman, B., Vig, K. W., Fields, H. W., Shanker, S., & Kaizar, E. E. (2010). Root resorption associated with orthodontic tooth movement:

a systematic review. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*, *137*(4), 462–12A. https://doi.org/10.1016/j.ajodo.2009.06.021.

23. Yi, J., Li, M., Li, Y., Li, X., & Zhao, Z. (2016). Root resorption during orthodontic treatment with self-ligating or conventional brackets: a systematic review and meta-analysis. *BMC oral health*, *16*(1), 125. https://doi.org/10.1186/s12903-016-0320-y.
24. Yassir, Y. A., McIntyre, G. T., & Bearn, D. R. (2021). Orthodontic treatment and root resorption: an overview of systematic reviews. *European journal of orthodontics*, *43*(4), 442–456. https://doi.org/10.1093/ejo/cjaa058.
25. Iglesias-Linares, A., & Hartsfield, J. K., Jr (2017). Cellular and Molecular Pathways Leading to External Root Resorption. *Journal of dental research*, *96*(2), 145–152. https://doi.org/10.1177/0022034516677539.
26. Bellini-Pereira, S. A., Almeida, J., Aliaga-Del Castillo, A., Dos Santos, C., Henriques, J., & Janson, G. (2021). Evaluation of root resorption following orthodontic intrusion: a systematic review and meta-analysis. *European journal of orthodontics*, *43*(4), 432–441. https://doi.org/10.1093/ejo/cjaa054.
27. Jyotirmay, Singh, S. K., Adarsh, K., Kumar, A., Gupta, A. R., & Sinha, A. (2021). Comparison of Apical Root Resorption in Patients Treated with Fixed Orthodontic Appliance and Clear Aligners: A Cone-beam Computed Tomography Study. *The journal of contemporary dental practice*, *22*(7), 763–768.
28. Currell, S. D., Liaw, A., Blackmore Grant, P. D., Esterman, A., & Nimmo, A. (2019). Orthodontic mechanotherapies and their influence on external root resorption: A systematic review. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*, *155*(3), 313–329. https://doi.org/10.1016/j.ajodo.2018.10.015.
29. Meirinhos, J., Martins, J., Pereira, B., Baruwa, A., & Ginjeira, A. (2021). Prevalence of Lateral Radiolucency, Apical Root Resorption and Periapical Lesions in Portuguese Patients: A CBCT Cross-Sectional Study with a Worldwide Overview. *European endodontic journal*, *6*(1), 56–71. https://doi.org/10.14744/eej.2021.29981.
30. Rahmel, S., & Schulze, R. (2019). Accuracy in Detecting Artificial Root Resorption in Panoramic Radiography versus Tomosynthetic

 ISSN: 1857-7881 (Print) e - ISSN 1857-7431

Panoramic Radiographs. *Journal of endodontics*, *45*(5), 634–639.e2. https://doi.org/10.1016/j.joen.2019.01.009.
31. Durack, C., Patel, S., Davies, J., Wilson, R., & Mannocci, F. (2011). Diagnostic accuracy of small volume cone beam computed tomography and intraoral periapical radiography for the detection of simulated external inflammatory root resorption. *International endodontic journal*, *44*(2), 136–147. https://doi.org/10.1111/j.1365-2591.2010.01819.x.
32. Wang, Y., He, S., Guo, Y., Wang, S., & Chen, S. (2013). Accuracy of volumetric measurement of simulated root resorption lacunas based on cone beam computed tomography. *Orthodontics & craniofacial research*, *16*(3), 169–176. https://doi.org/10.1111/ocr.12016.