EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 68, 2805:2812, July, 2022

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 18-03-2022 • Accept Date : 19-05-2022 • Available online: 30-06-2022 • DOI : 10.21608/edj.2022.127781.2026

THE IMPACT OF DIFFERENT ROOT CANAL PREPARATION SIZES AND TAPERS ON FRACTURE STRENGTH OF ROOTS

Mohammed Turky [*] *and* Reem Gamal[**]

ABSTRACT

Introduction: The purpose of the study was to investigate the impact of root canal preparation with different sizes and tapers on fracture strength of roots.

Methods: A total of 42 freshly extracted intact human permanent mandibular premolars. Teeth were randomly divided into 7 groups I-VII (n =6): un-instrumented root canals (control), 25/0.04, 25/0.06, 30/0.04, 30/0.06, 35/0.04and 35/0.06 respectively. K3XF rotary files (Kerr Endodontics, Orange, CA) were used for canal instrumentation with distilled water irrigation. Fracture strength was tested using a universal test machine.

Results: Group I (control) had the highest statistically significant mean compared with the experimental groups II-VII. The means and standard deviation for groups I-VII were 1022.08±87.61, 819.29±97.11, 691.63±82.39, 719.14±102.58, 668.60±185.20, 669.32±130.63 and 669.32±130.63, respectively.

Conclusion: Under the conditions of the present study, we can conclude that increasing preparation size and taper up to 35/0.06 did not affect the fracture strength of roots. Instrumentation of mandibular premolars up to 35/0.06 did not affect their fracture strength.

KEYWORDS: Fracture strength, fracture resistance, apical preparation size, apical preparation diameter, taper.

INTRODUCTION

Root canal preparation is one of the most important steps in endodontic treatment[1, 2]. An old endodontist saying, “What is removed from the root canal may be more important than what is placed inside it”[3].

Although many advancements have been made in endodontics in the last years, the complicated root canal anatomy still adversely affects root canal preparation[4]. The apical third is the most difficult to be cleaned and shaped because of the ever-increasing complexity of the anatomy[5].

* Department of Endodontics, Faculty of Dentistry, Minia University, Egypt
** Department of Biomaterials, Faculty of Dentistry, Minia University, Egypt

Larger apical preparations increase the depth and the volume of irrigation solution which reaches the apical region as well as results in intracanal bacterial reduction[6]. While preparation of the root canal system should be performed enough to eradicate the microorganisms, pulp tissue and infected dentine, the amount of dentine removal should be restricted in order not to create a potential risk of fracture[7, 8].

With innovation of rotary file systems, root canal instrumentation becomes an easier and a better debridement could be accomplished because of their larger tapers[9]. On the other hand, larger taper to be considered due to additional removal of dentine might affect fracture strength of the root[10-13].

Some previous studies have evaluated the influence of the apical preparation size or taper separately on the fracture strength of the roots[14-16]. However, few studies investigated the effect of different tapers and apical preparation sizes on the fracture strength of roots [17, 18]. So, it seemed to be valuable to evaluate the impact of both on fracture strength of roots. Our null hypothesis is that different preparation sizes and tapers will not affect the fracture strength of prepared roots.

MATERIALS AND METHODS:

Sample size calculation:

Sample size was calculated using G*Power software (G*Power 3.1.9.7 for windows, Heinrich-Heine, Dusseldorf Germany). Yıldız EG et al(18) study was taken into consideration to calculate the effective size (f=0.5972). As a result, a minimum of 42 samples (n=6 for each group) was found to be sufficient, with an 80% power and a significance level of 0.05.

Samples selection:

A total of 42 freshly extracted intact human permanent mandibular premolars were collected from the outpatient clinic of the Faculty of Dentistry, Minia University. The teeth underwent scaling and root planning to remove residual organic and inorganic tissue. Then, they were washed under running water and immersed in 0.1% thymol solution at 4°C till their use to minimize the negative effects of extraction trauma, dryness and storage conditions on roots [14]. Periapical radiographs in mesiodistal and buccolingual directions were taken to select the teeth with nearly similar root canal morphology.

Eligibility

Inclusion criteria

- Single-rooted teeth with single root canals (type I Vertucci's classification[19].
- Mature teeth with completely formed apices.
- Teeth with angle of the root curvatures <10° as determined by Schneider's method[20].
- A ratio between the internal long diameter and the short diameter of < 2 at a level of 5mm from the apex

Exclusion criteria

- Teeth with root caries or cracks (examination was done under a magnification of 20X using a stereomicroscope (Leica, MZ6, Germany).
- Teeth with internal or external root resorption.
- Teeth with previous endodontic treatment.
- Teeth with multiple root curvatures or rapid apical curvatures.
- Teeth with calcified canals or anatomic abnormalities.

Samples preparation

The teeth were decoronated using a diamond disc (BesQual Diamond Disk, DIA #6, Korea) mounted on a low-speed handpiece under a copious watercooling to standardize the root length to 13 mm. Each root canal was scouted to the apex using a stainless-steel K-file ISO size 10 (Dentsply Sirona, Ballaigues, Switzerland) to check patency and those having an apical diameter larger than an ISO size 15 K-file (Dentsply Sirona, Ballaigues, Switzerland) or being non-negotiable were discarded and replaced.

Root canal preparation

The buccolingual and mesiodistal dimensions of the teeth were measured using an electronic caliper. Weights of the roots were calculated using a digital precision balance (Electronic balance ATY224, Shimadzu corporation, Kyoto, Japan) after the roots were dried using cotton pellets and paper points. Every 7 roots with similar dimensions were matched, and each of these was randomly distributed into a different group. Thus, 7groups were prepared, each group contained 6 roots:

- **Control group:** No instrumentation was performed.
- **25/0.04 group:** 15/0.04, 20/0.04 and 25/0.04 respectively.
- **25/0.06 group:** 15/0.04, 20/ 0.04, 25/0.04 and 25/0.06 respectively.
- **30/0.04 group:** 15/0.04, 20/0.04, 25/0.04 and 30/0.04 respectively.
- **30/0.06 group:** 15/0.04, 20/0.04, 25/0.04, 30/0.04 and 30/0.06 respectively.
- **35/0.04 group:** 15/0.04, 20/0.04, 25/0.04, 30/0.04 and 35/0.04 respectively.
- **35/0.06 group:** 15/0.04, 20/0.04, 25/0.04, 30/0.04, 35/0.04 and 35/0.06 respectively.

All instrumentation procedures were performed by a single experienced endodontist. Working length was determined visually by inserting a stainless-steel K-file ISO size 10 till it became visible at the apical foramen under a magnification of 20X. Then, a 0.5 mm was subtracted from this measurement. K3XF files mounted on an electrical endodontic motor (TriAuto mini; J. Morita MFG. CORP. Japan) were used with single length technique, the technique in which each instrument was introduced to working length after glide path preparation. The torque and the speed were adjusted according to the manufacturer's instructions. During instrumentation, root canal irrigation was accomplished using the conventional syringe irrigation technique with distilled water as the only root canal irrigant delivered via a 30gauge closed end side-vented needle placed 1mm short of working length. After instrumentation was completed, all samples were examined again under stereomicroscope to check appearance of cracks or any craze lines following instrumentation.

Fracture strength testing

The roots were wrapped with a stretch film and embedded vertically in a self-curing acrylic resin (Acrostone Dental Manufactuer. Egypt) up to 2 mm apical to the cementoenamel junction. A protractor was used to ensure the vertical alignment of the long axis of the roots. After the setting of the acrylic resin, the roots and stretch film were removed. A light-body silicone (Elite HD; Zhermack SpA, Badia Polesine, Italy) was placed into the roots cavity to simulate periodontal ligament, and the roots were reinserted. Any excess impression material was removed with a No. 12 scalpel blade. The mounted roots of each group were fixed into the lower jaw of the universal testing machine (Instron, 3345L8741, Assembled Canton, USA) figure (1). Then, a compressive load was applied to the center of the root by a stainless-steel ball (3.5mm in diameter) with a rate of loading 1mm/min parallel to the long axis of the root till fracture strikethrough. The maximum load value in (N) for each sample was recorded directly from the universal testing machine software.

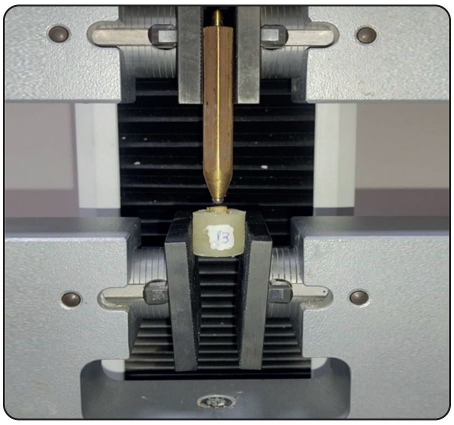

Fig. (1): Stainless-steel ball indenter (3.5mm in diameter) was fixed to the upper jaw of the universal testing machine and the mounted root was fixed to the lower jaw.

Statistical analysis

The obtained numerical values were statically analyzed by the statistical package for social sciences IBM® SPSS® (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 26 for Windows. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed parametric distribution. Two and one way-ANOVA were used to study the effect of the different apical sizes and tapers on mean fracture strength. Post Hoc LSD test was used to study the statistical significance between groups and the significance level was set at $P \leq 0.05$.

RESULTS

Regarding different tapers group I (control group) showed higher statistically significant mean of fracture strength compared to taper 0.04 and 0.06 which showed statistically insignificant mean to each other. Means and standard deviations (SD) of fracture strength (N) for the different tapers were presented in table (1) and figure (2)

Regarding different apical preparation sizes group I (control group) showed higher statistically significant mean of fracture strength compared to preparation sizes 25,30 and 35 which showed statistically insignificant mean to each other. Mean and SD of the fracture strength (N) for the different preparation sizes were presented in table (2) and figure (3).

Regarding different tapers and apical preparation sizes group I (control group) showed higher statistically significant mean of fracture strength compared to the experimental groups II-VII which showed statistically insignificant mean to each other.

Mean and SD of the fracture strength (N) for the different tapers and preparation sizes were presented in table (3) and figure (4).

TABLE (1): means and SD of fracture strength (N) for the different tapers

Taper	**Control**	**0.04**	**0.06**
Mean ±SD	1022.08±87.61	735.91±119.74 a	669.47±148.02 a

Means with the same letter were not statistically significantly different at P ≤0.05.

TABLE (2): means and SD of fracture strength (N) for the different preparation sizes.

Apical preparation sizes	**Control**	**25**	**30**	**35**
Mean ±SD	1022.08±87.61	755.46±107.73a	693.87±141.21a	658.75±154.02a

Means with the same letter were not statistically significantly different at P≤0.05.

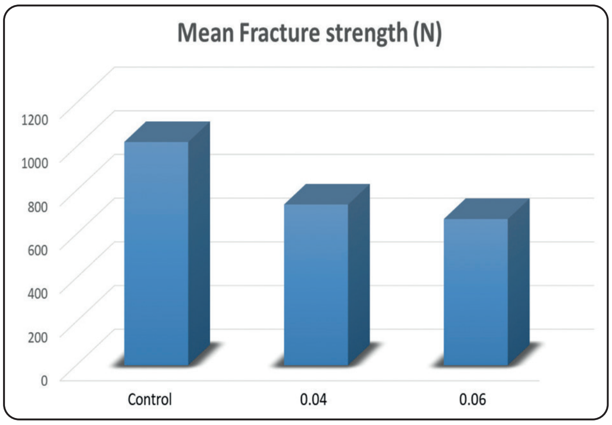

Fig. (2): column chart represents means of fracture strength (N) for the different tapers

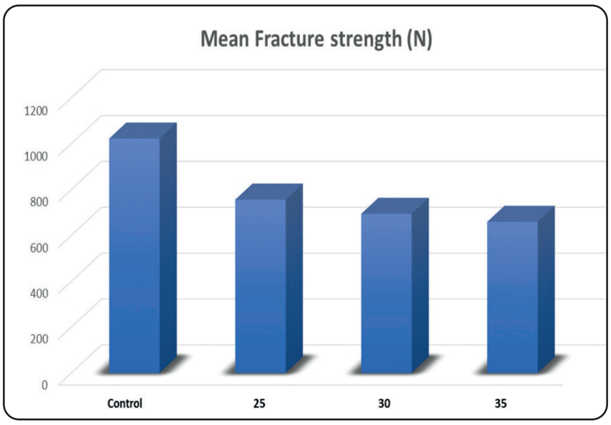

Fig. (3): means of fracture strength (N) for the different preparation sizes.

TABLE (3): Mean and SD of the fracture strength (N) for the different groups.

Groups	Mean±SD
I	1022.08±87.61
II	819.29±97.11a
III	691.63±82.39a
IV	719.14±102.58a
V	668.60±185.20a
VI	669.32±130.63a
VII	648.17±194.92a

Means with the same letter were not statistically significantly different at P≤0.05.

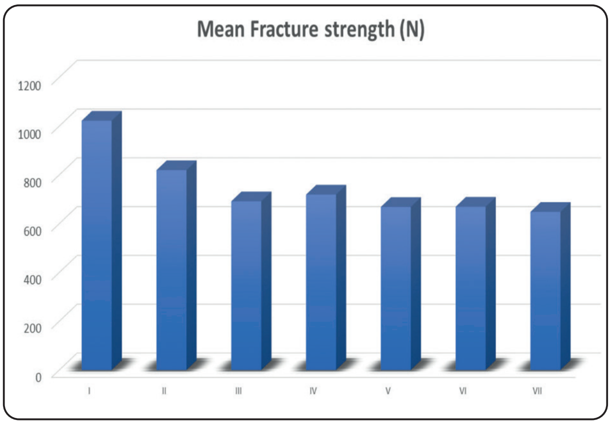

Fig. (4): Mean of the fracture strength (N) for the different groups.

DISCUSSION

To date, endodontic literature does not reach a final decision about a definite root canal preparation size and taper to obtain a completely debrided root canal system. Some studies[21] tried to prove that larger apical preparation could result in a well cleaned root canal. With the advent of minimally invasive concepts in endodontics, minimal preparation size was suggested to preserve as much tooth structure as possible especially in pericervical dentine areas[22]. However, other studies(23, 24) showed that minimal apical preparation might not be enough to thoroughly debride the complicated root canal system unless these types of preparation being associated with larger taper and irrigant agitation.

Although a thorough cleaning and shaping of the root canal system is of utmost importance for successful endodontic therapy[25]. The prognosis of root-filled teeth depends not only on the quality of the endodontic procedures but also on the amount of remaining dentine tissue (8). Any loss in tooth structure is considered the key reason for the increase in fracture predilection of endodontically treated teeth(26). To the best of our knowledge, there is little information about the effect of the different preparation sizes and tapers on fracture strength of the endodontically treated teeth. the present study aimed to assess the influence of root canal preparation with different sizes and tapers on fracture strength of the roots.

Although decoronation of the teeth does not simulate the clinical condition, it was done to standardize the roots length[18]. Our study used K3XF NiTi rotary files as they are available in different sizes and tapers[27]. They are manufactured using the R-phase technology which enhances the flexibility and resistance to cyclic fatigue with less chance of transportation(28).

Although K3XF files are recommended to be used with a crown-down technique, this technique would cause differences in the amount of the enlargement of the coronal and/or middle thirds of the roots(18), This would not serve the aim of our study. Therefore, in the present study, K3XF files were used with single length technique, similarly to a previous study by Prado et al.[29]. Distilled water was the only irrigant used to avoid the effects of NaOCl on the dentine properties[30].

There are two types of fracture strength tests, dynamic and static. Although dynamic loading was more likely to correlate with clinical situation, variations in its designs make it difficult to compare the results. In the present study, the compressive static loading using universal testing machine[31] was used as it is the frequently applied method due to its efficiency and comparable outcome parameters[32].

In the present study, the root canals were not filled as obturation of root canals can reinforce the fracture strength of the roots [29, 33]. So, it was not performed to avoid confounding of covariates[15] and the actual influence of the taper and the size of preparation on the fracture strength of roots could be assessed.

Our study showed that the control group had the highest fracture strength with a statistically significant difference compared with the experimental groups. This reflects that the removed tooth substance after root canal preparation could affect the fracture strength of the endodontically treated teeth and this is in accordance with many studies [16, 18, 31].

Our results revealed that the fracture strength was not affected when the root canal preparation taper was increased from 4% to 6%. This finding was agreed with many previous studies[14, 15, 18, 34]. This was also in contradictory to Zandbiglari et al[16] who found that larger tapers decreased the fracture strength. The difference might be attributed to the different file systems used in each group in the latter study, while our study used the same file system in all groups. Also, Zandbiglari et al[16] used a different instrumentation technique (crown down technique).

Our study showed that increasing the apical preparation sizes up to 35 did not affect the fracture strength and this was agreed with Lam et al[9] and Doğanay et al [18]. This was disagreed with Tian et al[17] who exhibited that the fracture load values of the mandibular premolars decreased as the apical diameter increased. The difference could be explained on the basis of different methodology. The latter study used larger apical sizes (from size 40 to 60) than those used in the present study. Our study tried to strict to the minimally invasive concept[22] and used smaller apical sizes (from size 25 to 35). In addition, Prado et al(29) observed that the fracture strength of premolars decreased by 43.7% after instrumentation to only 45/0.02.

The present study confirmed the null hypothesis. This was in contradictory to Kılıç et al [35] who found that increasing the apical preparation sizes and taper decreased the fracture strength. The difference might be attributed to the different samples (tooth type, root canal width). Kılıç et al assessed the influence of root canal preparation size and taper of middle mesial canals of the mandibular molar teeth. Although our results may differ from the clinical situation due to the oral environment variations, the objective of this in vitro study was to compare different variables in standard conditions.

However, absence of the coronal tooth structure, coronal restoration, occlusion or parafunctional habits which could affect the fracture resistance values are the most prominent limitations in the present study that should not be forgotten

Under the conditions of the present study, we can conclude that increasing preparation size and taper up to 35/0.06 did not affect the fracture strength of roots. Instrumentation of mandibular premolars up to 35/0.06 did not affect their fracture strength.

Further studies are needed to explain whether instrumentation of mandibular premolars up to 35/0.06 is sufficient to remove smear layer, debris and reduce the intracanal bacteria or not.

Conflicts of interest

The authors deny any conflicts of interest related to this study.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial or not- for -profit sectors.

REFERENCES

1. Schilder H. Cleaning and shaping the root canal. Dent Clin North Am. 1974;18:269-96.

2. Ruddle CJ. Cleaning and shaping the root canal system. Pathways of the Pulp. 8th ed. St Louis Mosby.2002. 231–92.

3. Baumgartner JC, Ingle JI, Bakland LK. Ingle's Endodontics 6 (Endodontics Six). BC Decker, Incorporated; 2008.

4. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. Journal of endodontics. 2004;30(8):559-67.

5. Yu D, Schilder H. Cleaning and shaping the apical third of a root canal system. General dentistry. 2001;49(3):266-70.

6. Shuping GB, Ørstavik D, Sigurdsson A, Trope M. Reduction of intracanal bacteria using nickel-titanium rotary instrumentation and various medications. Journal of endodontics. 2000;26(12):751-5.

7. Hülsmann M, Peters OA, Dummer PM. Mechanical preparation of root canals: shaping goals, techniques and means. Endodontic topics. 2005;10(1):30-76.

8. Kishen A. Mechanisms and risk factors for fracture predilection in endodontically treated teeth. Endodontic topics. 2006;13(1):57-83.

9. Lam PP, Palamara JE, Messer HH. Fracture strength of tooth roots following canal preparation by hand and rotary instrumentation. Journal of Endodontics. 2005;31(7):529-32.

10. Gher Jr ME, Dunlap RM, Anderson MH, Kuhl LV. Clinical survey of fractured teeth. Journal of the American Dental Association (1939). 1987;114(2):174-7.

11. Lagouvardos P, Sourai P, Douvitsas G. Coronal fractures in posterior teeth. Oper Dent. 1989;14(1):28-32.

12. Patel D, Burke F. Fractures of posterior teeth: a review and analysis of associated factors. Primary dental care: journal of the Faculty of General Dental Practitioners (UK). 1995;2(1):6-10.

13. Meister Jr F, Lommel TJ, Gerstein H. Diagnosis and possible causes of vertical root fractures. Oral Surgery, Oral Medicine, Oral Pathology. 1980;49(3):243-53.

14. Krikeli E, Mikrogeorgis G, Lyroudia K. In vitro comparative study of the influence of instrument taper on the fracture resistance of endodontically treated teeth: an integrative approach–based analysis. Journal of endodontics. 2018;44(9):1407-11.

15. Sabeti M, Kazem M, Dianat O, Bahrololumi N, Beglou A, Rahimipour K, et al. Impact of access cavity design and root canal taper on fracture resistance of endodontically treated teeth: an ex vivo investigation. Journal of endodontics. 2018;44(9):1402-6.

16. Zandbiglari T, Davids H, Schäfer E. Influence of instrument taper on the resistance to fracture of endodontically treated roots. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2006;101(1):126-31.

17. Tian SY, Bai W, Jiang WR, Liang YH. Fracture resistance of roots in mandibular premolars following root canal instrumentation of different sizes. Chin J Dent Res. 2019;22(3):197-202.

18. Doğanay Yıldız E, Fidan ME, Sakarya RE, Dinçer B. The effect of taper and apical preparation size on frac-

ture resistance of roots. Australian Endodontic Journal. 2021;47(1):67-72.

19. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral surgery, oral medicine, oral pathology. 1984;58(5):589-99.

20. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral surgery, Oral medicine, Oral pathology. 1971;32(2):271-5.

21. Lee O, Khan K, Li K, Shetty H, Abiad R, Cheung G, et al. Influence of apical preparation size and irrigation technique on root canal debridement: a histological analysis of round and oval root canals. International endodontic journal. 2019;52(9):1366-76.

22. Clark D, Khademi J. Modern molar endodontic access and directed dentin conservation. Dental Clinics. 2010;54(2):249-73.

23. Akhlaghi NM, Dadresanfar B, Darmiani S, Moshari A. Effect of master apical file size and taper on irrigation and cleaning of the apical third of curved canals. Journal of Dentistry (Tehran, Iran). 2014;11(2):188.

24. Albrecht LJ, Baumgartner JC, Marshall JG. Evaluation of apical debris removal using various sizes and tapers of ProFile GT files. Journal of endodontics. 2004;30(6):425-8.

25. Hales J, Jackson C, Everett A, Moore S. Treatment protocol for the management of a sodium hypochlorite accident during endodontic therapy. General dentistry. 2001;49(3):278-81.

26. Kishen A, Asundi AK. Photomechanical investigations on post-endodontically rehabilitated teeth. Journal of Biomedical Optics. 2002;7(2):262-70.

27. SybronEndo California, USA.: SybronEndo, California, USA; Cited 2022 january 22. [Available from]: https://www.usaopps.com/government_contractors/contractor-5970208-SYBRONENDO.htm.

28. Pérez-Higueras JJ, Arias A, José C. Cyclic fatigue resistance of K3, K3XF, and twisted file nickel-titanium files under continuous rotation or reciprocating motion. Journal of endodontics. 2013;39(12):1585-8.

29. Prado M, De Lima N, De Lima C, Gusman H, Simão R. Resistance to vertical root fracture of root filled teeth using different conceptual approaches to canal preparation. International endodontic journal. 2016;49(9):898-904.

30. Souza EM, Calixto AM, e Lima CN, Pappen FG, De-Deus G. Similar influence of stabilized alkaline and neutral sodium hypochlorite solutions on the fracture resistance of root canal–treated bovine teeth. Journal of endodontics. 2014;40(10):1600-3.

31. Turk T, Kaval M, Sarikanat M, Hülsmann M. Effect of final irrigation procedures on fracture resistance of root filled teeth: an ex vivo study. International endodontic journal. 2017;50(8):799-804.

32. Naumann M, Metzdorf G, Fokkinga W, Watzke R, Sterzenbach G, Bayne S, et al. Influence of test parameters on in vitro fracture resistance of post-endodontic restorations: a structured review. Journal of Oral Rehabilitation. 2009;36(4):299-312.

33. Çobankara FK, Üngör M, Belli S. The effect of two different root canal sealers and smear layer on resistance to root fracture. Journal of Endodontics. 2002;28(8):606-9.

34. Zogheib C, Sfeir G, Plotino G, De Deus G, Daou M, Khalil I. Impact of minimal root canal taper on the fracture resistance of endodontically treated bicuspids. Journal of International Society of Preventive & Community Dentistry. 2018;8(2):179-83.

35. Kılıç Y, Karataşlıoğlu E, Kaval ME. The effect of root canal preparation size and taper of middle mesial canals on fracture resistance of the mandibular molar teeth: An in vitro study. Journal of Endodontics. 2021;47(9):1467-71