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Effect of Intracanal Medicament and Gutta Percha on Fracture Resistance of Simulated Immature Teeth Reinforced with MTA and Fibre-Post: A Comparative in-Vitro Study

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Abstract

Background: Traumatized immature teeth pose a treatment dilemma for practitioners due to inadequate natural apical constriction and thin root walls that are prone to shatter hence it becomes necessary to reinforce it with suitable post and apical plug so as to provide adequate strength. Variable factors like intracanal medicament, obturating materials, reinforcement of canals etc. plays an imperative role in success of the treatment.

Aim: To evaluate and compare the effect of intracanal medicament and apical plug on fracture resistance of immature teeth restored with fiber post.

Methodology: 40 single rooted maxillary incisors were included in study. To achieve a final length of 15±1, teeth were sectioned 2 mm above and 13 mm beneath the CEJ for standardization. Access opening was done and Pro Taper rotary files up to#F3 were used to prepare canals. Peeso reamer #5 was used for simulation of immature apex to obtain a standard internal diameter of 1.5 mm. These teeth were then divided in two groups: Group A(n=20): with intracanal medicament $Ca(OH)_2$ and Group B(n=20) no intracanal medicament, which further were split into Group A_1(n=10): 5mm MTA Apical plug+ Rely X fiber post; Group A_2(n=10): 3mm MTA Apical plug +2mm GP + Rely X fiber post; Group B_1(n=10) and Group B_2(n= 10) same as Group A_1 and Group A_2 respectively but without intracanal medicament. Specimens were then subjected to fracture testing in Universal Testing Machine. The fracture resistance and fracture pattern were statistically analysed using ANOVA and post hoc Tukey test.

Results: The mean fracture resistance was more for specimens without intracanal medicament placement and those with placement of gutta-percha on MTA apical plug. Maximum fracture resistance was found in Group B_2 (2351.287±220.402). and minimum in Group A_1 1475.154±232.922

and was statistically significant ($p<0.001$). Most common fracture pattern observed was above CEJ. ($p> 0.05$)
Conclusion: Use of intracanal medicament $Ca(OH)_2$ diminishes fracture resistance of reinforced immature teeth over the period of time. Furthermore, use of gutta percha along with MTA in apical plug can act as shock absorber, thereby favours the prognosis.
Keywords: Immature teeth, Fracture resistance,Fiber post, $Ca(OH)_2$ intracanal medicament

I. INTRODUCTION

Dental injuries are most prevalent in teenagers aged 8 to 12 years old, when their teeth are still in developing stage. Maxillary incisors are the most commonly affected teeth. Such injuries frequently result in pulpal necrosis and cessation of root apex formation in developing teeth leading to immature teeth. Treatment of such teeth pose several challenges to clinicians due to inadequate natural apical constriction and slender /fragile dentinal root walls which are susceptible to fracture.[1]

To treat an immature permanent tooth with necrotic pulp, the best approach would be to regenerate functional pulpal tissue and then promote continued root development and apical closure.[2] Recently, revascularization, a regenerative endodontic procedure, has been attempted to treat immature permanent teeth. Although it has demonstrated a high potential for clinical success, it must be reviewed as it might not be successful in all cases.[3] Hence,apexification with various materials remains the treatment of choice for necrotic immature teeth.

The success of any endodontic therapy depends on various factors like chemo-mechanical debridement, root canal disinfection, and the type of material used for obturation and apical plug formation. The residual bacteria and their proliferation in the root canal system have adverse effects on the outcome of endodontic therapy for immature teeth.[4]

Several intracanal medicaments are utilized to effectively disinfect the root canal. Calcium hydroxide is the most commonly used intracanal medicament in endodontic therapy, as it is capable of encouraging hard tissue formation and has antibacterial action.The disinfecting action of calciumhydroxide (in addition to instrumentation and irrigation) is effective after at least one week of application.[5] Further treatment should be continued after 1 week and not be postponed for more than 1 month since the calcium hydroxide may be flushed away by tissue fluids through the open apex, leaving the canal susceptible to reinfection. Because calcium hydroxide washout is evaluated by its relative radiodensity in the canal, it is prudent to use a calcium hydroxide combination that includes a radiopaque material like barium sulphate which does not washout easily from the canals.

Gutta-percha, the traditional obturating material, does not adequately reinforce such teeth when used with an apical barrier; thus, novel materials are being investigated to reinforce immature teeth. Endodontically treated teeth are prone to fracture because of moisture loss, dentinal collagen degradation, decreased flexibility, and weakening of tooth structure during preparation.[6] Making the choice of material to fill the remaining canal space after an apical plug therefore becomes a crucial task in apexification procedures.

The use of Mineral Trioxide Aggregate (MTA) as an osteoconductive apical barrier material in single visit apexification procedure is becoming more common. Mineral trioxide aggregate provides scaffold for the formation of hard tissues and has the potential to create improved biological seal. It is a hydrophilic material with a setting time of 3 hours in the presence of moisture. The advantages of mineral trioxide aggregate include excellent sealing capability, good compressive strength, good biocompatibility.[7]

Complete obturation of root canals using these new calcium silicate-based materials, on the other hand, may diminish the fracture resistance over an extended period of time. This is due to the liberation of highly alkaline calcium hydroxide which triggers a caustic degradation of exposed collagen which is facilitated by the breakdown of intermolecular bonds in collagenfibrils, following increased water immersion and swelling. Also, obturating the root canals with calcium silicate-based materials (Mineral trioxide aggregate, Bio dentine, Bio aggregate) is not cost-effective.[8]

Several studies have found that fibre posts, which have a flexural strength comparable to dentin, can enhance the fracture resistance of immature roots and minimize the endanger of catastrophic fracture by providing a framework for the crown.[9] In addition, fibre posts are translucent and distribute loads quite uniformly on the root surface as their coefficient of elasticity is equivalent to that of dentin.[10] As a result of these mechanical and aesthetic properties, glass fibre posts are beneficial for use in anterior teeth.

Length of the post should be at least equal to the length of the clinical crown or at least two-thirds of the length of the root, but not less than half the root's length.[11]For the restoration of immature teeth with an intracanal post, the root length may be limited. Also, leaving the gutta-percha on the apical plug and or underneath the post might diminish the amount of space available for the post or require the clinician to reduce the plug thickness, compromising the seal. In these circumstances, it would be impossible to avoid direct placement of the post on the apical plug. As a result, question may arise pertaining to the fracture strength of tooth restored with post directly on the apical plug.

There is a dearth of literature on fracture resistance of tooth when fibre posts are placed directly on MTA apical plugs or when gutta-percha is used beneath the post. Therefore, this study aimed at evaluating the fracture resistance of immature teeth reinforced with fiber post placed directly above the MTA apical plug and with the placement of gutta-percha below the post and effect of intracanal medicament on same.

The null hypothesis proposed was use of $Ca(OH)_2$ intracanal medicament and placement of gutta percha beneath the fiber post does not affect the fracture resistance of immature teeth reinforced with MTA apical plug.

II. MATERIALS AND METHOD

The proposed study was conducted as in vitro study with prior permission and consent from the Ethical and Research committee of the Karnavati University. Fortysingle-rooted maxillary incisors, extracted owing to poor periodontal conditions were selected and the presence of single canals was confirmed with the radiographs.

Exclusion criteria were:

- Teeth with extensive caries
- Teeth with more than one root and root canal
- Teeth with internal or external root resorption
- Teeth having cervical abrasion, calcifications, cracks, deformations, anomalies
- Teeth with a previous root canal treatment/restoration.

Prior to the study, teeth were disinfected with 5.25 % NaOCl and kept in saline solution. Teeth were then cleaned with an ultrasonic scaler and placed in distilled water for storage until used for study.Standardization of teeth was done using a calliper at CEJ. The external dimensions of each tooth were measured labiolingually and mesiodistally and roots with similar dimensions were chosen.The crowns were sectioned approximately 2 mm coronal to the CEJ and the roots were sectioned 13 mm apical to the CEJ using a low-speed diamond disc to achieve a final length of 15+/- 1 mm for each tooth with straight root canal. A digital calliper was used to take the final measurements of the samples.

Endodontic access opening was made on the palatal surface using a No.4 round bur and endo Z bur in a highspeed handpiece. Barbed broaches were used to remove the pulp tissue.Working length estimation was done by inserting #15 hand K file (Mani,Japan) till the apical foramen and then subtracting 1 mm. Following instrumentation with hand files up to #20, root canal were prepared with ProTaper rotary files (Dentsply Maillefer, Ballaigues, Switzerland) up to #F3 till the estimated working length. Between consecutive file transitions, canals were irrigated with 2ml of 3% NaOCl and 5 ml 0.9 percent normal saline using 27-gauge needle and syringe followed by 2ml of saline for the final irrigation.

Following root canal preparation with rotary, peeso-reamers from #1 to #5 were used to standardize the root canal diameter of 1.5 mm. #5 peeso-reamer was used 1mm beyond the apex to stimulate the immature apex. Root canals were irrigated with 2 mL of 3% NaOCl followed by use of 5 mL of 17% EDTA to remove the smear layer and flushing with distilled water. Canals were dried with paper points. Throughout, the teeth were kept in moistened gauze.

The specimens were then randomly divided into two groups based on the placement of the intracanal medicament:

Group A (n= 20): With intracanal medicament $Ca(OH)_2$

Group B (n=20): No intracanal medicament

Each group was further sub-divided into:

Group A_1 (n=10) – 5mm MTA Apical plug+ glass fiber post

Group A_2(n=10) – 3mm MTA Apical plug +2mm GP + glass fiber post

Group B_1 (n=10) – 5mm MTA Apical plug + Glass fiber post

Group B_2 (n=10) – 3mm MTA Apical plug+ 2mm GP+ glass fiber post

In Group A, calcium hydroxide powder was mixed with sterile water with a metal spatula on a glass slab and was placed in the canals using lentulo spiral paste holder (Mani, Japan) and handpiece followed by placement of temporary filling material (3M ESPE Cavit G) and the samples were kept under 100% humidity at 37°Cfor 1 week. After 1 week, the temporary filling material and intracanal medicament were removed using 10 ml of 3 % NaOCl and 10 ml normal saline. Later, root canals were dried using paper points.

GroupA₁:

Mineral Trioxide Aggregate plus (PrevestDenpro ltd.) was mixed as per the manufacturer's instructions with a P: L ratio of 3:1 and placed into the canal space with the help of an amalgam carrier and compacted by an endodontic plugger (DentsplyMaillefer, Ballaigues,Switzerland) to achieve a 5 mm thick apical plug and it's apical end was closed with a moistened cotton pellet/ saline moistened Gelatamp (RoekoColtene / Whaldent) to simulate clinical condition and to prevent extrusion of material .Final length of MTA plug was verified radiographically. MTA was covered with a moist cotton pellet, and the access cavity was filled with temporary filling material (3M ESPE Cavit G). Then, the samples were kept at 37°C and 100% humidity for 24 hours to allow complete set of MTA. Later, samples were kept at 37°C for a week.

Group A_2:

MTA apical plugs with a thickness of 3 mm were created and its length was verified radiographically.To allow complete set of MTA, a wet cotton pellet was placed upon it and the samples were stored at 37°C and 100% humidity for 24 hours. After 24 hours, 2mm of gutta-percha was placed on it followed by temporary filling material (3M ESPE Cavit G) and samples were kept at 37°Cfor one week.

Subgroup $B_1$and B_2 were prepared in a same manner as group A_1 and A_2 respectively.

The post space was shaped using #2 Rely X post drills (3M ESPE) with 1.6 mm diameter for placement of post in the remaining empty area of the root canal. The surface of the post was cleaned with alcohol and dried. The root canals were cleaned with water using a syringe and gently dried with paper points. Rely X Unicem 2 self-adhesive resin cement (3M ESPE) was manipulated and introduced into the canal according to the manufacturer's instructions and #2, 10 mm Rely X fiber post (3M ESPE) was then seated in the root canal using finger pressure. The excess resin was immediately removed, and the assembly was light cured for 40s. The projecting coronal section of the fibre post was then cut using a high-speed handpiece before being filled with composite resin.

For fracture testing, the root surfaces were covered with a 0.2–0.3 mm thick layer of polyvinyl siloxane impression material before being embedded in self-curing acrylic resin with a 2 mm gap between the top of the acrylic and the CEJ to simulate periodontal membrane. This space represents the distance between the bone crest and the tooth.

Fracture test was carried outin Universal testing machine (Instron,Canton, MA, USA) by applying compressive load at the palatal surface 3 mm coronal to the CEJ at a point corresponding tothe middle of the mesiodistal width of the sectioned surface to simulate the usual angle of contact between maxillary and mandibular incisors in class I occlusion.A metallic rod with a round tip was attached to the upper movable compartment of testing machine travelling at cross-head speed of 1 mm/min was used until failure occurs and the load at fracture was recorded in Newtons.The fracture pattern was assessed with a modified classification system suggested by Santos-Filho et al[12]

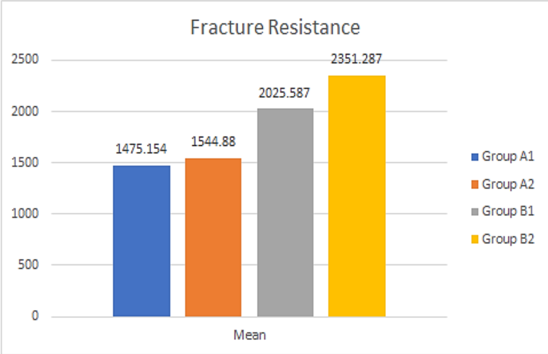
a. Fracture above CEJ
b. Fracture at CEJ level
c. Mid root fracture
d. Apical root fracture
e. Vertical root fracture

III. STATISTICAL ANALYSIS

Statistical analysis was done with Statistical Package for Social Sciences (IBM SPSSversion 21.0. Armonk, NY: IBM Corp.) at 95% CI and 80% power. Descriptive statistics was performed in terms of mean and standard deviation. Analysis of Variance(ANOVA) followed by Tukey's post hoc test was applied to check for statistically significant differences in fracture resistance between Group A_1, A_2, B_1 and B_2 and $p<0.05$ was considered to be statistically significant.

IV. RESULTS

The mean fracture resistance for Group A_1 was 1475.154±232.922; and for Group A_2 was 1544.88±133.589 respectively. The mean fracture resistance of Group B_1 and B_2 was found to be 2025.587±307.552 and 2351.287±220.402 respectively. **(Graph 1)**



Graph 1: *Comparison of mean fracture resistance of the simulated human immature teeth treated with MTA apical plug and fiber post with and without $Ca(OH)_2$ and gutta-percha*

Intragroup comparison:

There was no statistically significant difference observed in the fracture resistance between Group A_1 and A_2 ($p>0.05$) Whereas, in group B_2 where gutta percha was placed, statistically significant difference was seen in the fracture resistance when compared with group $B_1$where fiber post was placed directly over the MTA apical plug. (p value=0.017)

Intergroup comparison:

Tukey's post hoc test showed high statistically significant difference in the fracture resistance between Group A_1 and B_1 and between Group A_1 and B_2 respectively. ($p<0.001$) **(Table 1)**

The study showed less fracture resistance in groups where intracanal medicament were placed (Group A_1 and A_2) compared to groups where no intracanal medicament was placed. (Group B_1 and B_2) ($p<0.001$)

The fracture pattern observed in most of the specimens (27 out of 40) had fracture line above the CEJ **(Figure 1)**and rest of the samples had fracture at CEJ. ($p> 0.05$)

Figure 1: *Sample showing Fracture line above CEJ*

***Table 1** Intergroup comparison of the fracture resistance of the simulated human immature teeth treated with MTA apical plug and fiber post with and without $Ca(OH)_2$ and gutta-percha*

(I) Groups	(J) Groups	Mean Difference (I-J)	P value	95% Confidence Interval	
				Lower Bound	Upper Bound
Group A_1	Group A_2	-69.72600	.907	-349.1376	209.6856
	Group B_1	-550.43300*	**<0.001***	-829.8446	-271.0214
	Group B_2	-876.13300*	**<0.001***	-1155.5446	-596.7214
Group A_2	Group A_1	69.72600	.907	-209.6856	349.1376
	Group B_1	-480.70700*	**<0.001***	-760.1186	-201.2954
	Group B_2	-806.40700*	**<0.001***	-1085.8186	-526.9954
Group B_1	Group A_1	550.43300*	**<0.001***	271.0214	829.8446
	Group A_2	480.70700*	**<0.001***	201.2954	760.1186
	Group B_2	-325.70000*	**0.017***	-605.1116	-46.2884
Group B_2	Group A_1	876.13300*	**<0.001***	596.7214	1155.5446
	Group A_2	806.40700*	**<0.001***	526.9954	1085.8186
	Group B_1	325.70000*	**0.017***	46.2884	605.1116

*. The mean difference is significant at the 0.05 level.

V. DISCUSSION

Dentin formation is disrupted and root development is halted when teeth with incomplete root formation undergo pulp necrosis as a result of trauma, caries, or other pulpal pathosis.Treatment of immature teeth is difficult due to their thin walls and open apex. As a result, appropriate treatment is crucial. After endodontic and restorative procedures, fracture of young teeth with thin dentinal walls and incomplete root is a major concern. To strengthen the roots in such circumstances, an artificial apical barrier for sealing the apical foramen with calcified tissue followed by proper root canal filling material and post insertion is required.

In our study, human maxillary central incisors were included to evaluate fracture strength as they are most prone to trauma. Immature human teeth would have been ideal for our study, but they were unavailable.Several studies[13,14] have demonstrated that increasing the internal diameter of a mature root canal to 1.5 mm can imitate the anatomy of an immature root. As a result, in our study, a peeso reamer up to No.5 was employed to simulate the immature root apex.

Intracanal medications are frequently utilized to supplement root canal disinfection and induce apical closure. Intracanal drugs may potentially interfere with fracture resistance of dentinal walls since they remain in direct contact with dentin for extended periods of time. Calcium hydroxide is the most often used intracanal medicament and its antibacterial activity is attributed to its high pH and ability to induce periapical tissue remineralization. In our study, it was discovered that calcium hydroxide dressing for 7 days caused a significant reduction in fracture resistance and Group A_1 1475.154±232.922 had the lowest fracture resistance when compared to the other experimental Groups. The mechanism of CH-induced root weakening is related to changes in the organic matrix, including denaturation of proteins and proteoglycans that function as a connection between hydroxyapatite crystals and dentin organic matrix collagen fibrils. This would leave the dentin structure with less biological support, which might affect its mechanical properties.[15] This result was in accordance with study done by Valera et al. who stated that calcium hydroxide dressings used over extended periods of time resulted in 20% of root fractures [16]

Apexification is a nonsurgical procedure for creating a calcific barrier at the open apex of immature teeth which in turn keeps toxins and bacteria away from the peri radicular tissue and facilitates placement of filling material. The advantages of using MTA as apical barrier includes- shorter treatment time, suitable apical seal and stimulation of hard tissue formation, reduced chances of root fracture.[17]

In our study, 3 mm and 5 mm plug MTA plug were used. MTA has been used as an apical plug with various thicknesses in various trials. Martin et al.[18] conducted research that stated that a 3-5 mm thick orthograde MTA apical plug produced a sufficient seal. Although full orthograde MTA root filling created a better initial seal than a 3-5 mm-thick MTA plug, the fracture strength of the two experimental groups was comparable, and there was no advantage in increasing the thickness of the MTA apical plug for root strengthening in apexification.

Several studies have assessed the fracture resistance of teeth restored with direct placement of posts on apical plugs but there is scarce literature depicting the impact of gutta percha placement on apical plug on fracture resistance of tooth. Our study found a substantial difference between groups with varied MTA thicknesses when the post was placed directly on the plug without the use of gutta-percha (groups A_1 and B_1) and presence of gutta-percha on the plug (groups A_2 and B_2). More amount of force was required for fracture in the groups where gutta-percha with a thickness of 2 mm was put on the apical plug of 3 mm thickness.The possible reason behind it is that gutta-percha acts as shock absorber. It absorbs the fracture load and transmits less force to the root structure owing to its flexibility and along with root canal sealer it reinforces the root dentin.

Endodontically treated juvenile teeth can benefit from composite resin, glass ionomer reinforced cement, resin root canal filling materials (Resilon), and different post systems. Intracanal posts may be a viable alternative for extending the clinical life of an immature tooth.[19] Cast metal posts and cores, prefabricated metal posts with amalgam or composite cores and fibre posts with composite cores are the most often utilised types of posts. Regardless of their popularity, cast post and core systems have significant drawbacks, including uneven load distribution, biological side effects from microleakage and corrosion and colour reflection of the cast post and core on all-ceramic restorations which may influence the long-term success of restoration. Prefabricated post systems such as resin posts reinforced with fibres are presently the most extensively used for the restoration of severely injured teeth due to an elastic modulus close to that of dentin, biocompatibility, and great aesthetics for tooth-coloured restorations and hence they were preferred in our study to reinforce the tooth after apical plug formation.

The samples in our study were produced to mimic the circumstances seen in practice by magnifying the root canal and apex. Although covering the roots with silicon or wax before mounting in acrylic resin may not entirely mimic clinical circumstances and tooth location in bone, it was done to replicate periodontal ligament and root movements during load application which was similar to study done by Schmoldt et al. and Dikbas et al. [20,21].

The direction and impact of trauma determines the fracture line of tooth. Cvek found that endodontically treated immature teeth had a significantly higher rate of cervical root fracture in a retrospective investigation.[22] This was also supported by in vitro studies done by Schmoldt et al.[20]and Tuna et al[23] assessing the fracture resistance of immature teeth restored with various materials in which they revealed that the fractures were most prevalent in the cervical third. In our study most common fracture pattern observed was above the CEJ. Fiber posts used in immature teeth provides additional strength to thin root dentinal walls of immature teeth and stress concentration occurs at or above CEJ.[24] Moreover, fracture occurring above the CEJ, on the other hand, might be advantageous for restoration without extra therapeutic intervention (i.e., surgical intervention) of a fractured tooth.[3]

VI. LIMITATIONS

- Teeth utilised in our study may approximate the morphology of immature teeth,but they may not completely replicate tissue composition and physical properties.
- The type of forces applied by an Instron testing machine in a single cycle for failure, as well as the variations between the oral and laboratory settings cannot fully represent the clinical condition.

To get a definite conclusion on the restoration of immature teeth, more research on the fracture strength of teeth with varied apical plugs in the presence/absence of gutta-percha and the post and core system is necessary. Also, duration of $Ca(OH)_2$ application and its effect on root dentinal surface should be evaluated employing a scanning electron microscope.

VII. CONCLUSION

Within the limitation of our study, it can be concluded that root dentin properties of immature teeth can be affected by $Ca(OH)_2$ intracanal medicament placement. However, fracture resistance of immature teeth can be improved by placement of gutta percha over apical plug which helps to absorb the fracture stresses and fiber post helps to reinforce the endodontically treated tooth.

CONFLICT OF INTEREST DECLARATION:

We declare that there is no conflict of interest between the authors.

CONTRIBUTION DETAILS:

1. Patel Megha: Conception of idea and preparation of manuscript
2. Vadher Rupal: Conducted in vitro study
3. Patel Chhaya : Analysis of data
4. Bhatt Rohan: Review of manuscript adding scientific content
5. Joshi Kaushal: Compilation of data
6. Disha Makwani: Compilation of data

REFERENCES

1. Andreasen JO, Andreasen FM, Bakland LK, Flores MT. Traumatic dental injuries, a manual. 2nd ed. Oxford: Blackwell Munksgaard; 2003. 58–60.
2. K. M. Hargreaves, A. Diogenes, and F. B. Teixeira, “Treatment options: biological basis of regenerative endodontic procedures,” Journal of Endodontics, vol. 39, no. 3, pp. S30–S43, 2013.
3. Topçuoğlu HS, Kesim B, Düzgün S, et al. The effect of various back filling techniques on the fracture resistance of simulated immature teeth performed apical plug with Biodentine. Int J Paediate Dent 2015;25(4):248–254.
4. Al-kahtani A, Shostad S, Schifferle R, et al. In-vitro evaluation of microleakage of an orthograde apical plug of mineral trioxide aggregate in permanent teeth with simulated immature apices. J. Endod. 2005; 31:117–119.
5. Bystrom A, Claesson R, Sundqvist G. The antibacterial effect of camphorated paramonochlorophenol, camphorated phenol and calcium hydroxide in the treatment of infected root canals. Endod Dent Traumatol1985; 1:170.
6. Papa J, Cain C, Messer HH. Moisture content of vital vs endodontically treated teeth. Endod Dent Traumatol1994; 10:91-3.
7. Uppal AS, Bhullar MK, Bhushan J, Kochhar GK. Apexification. Dent J Adv Stud 2013; 1:55-57.
8. Sawyer AN, Nikonov SY, Pancio AK, et al. Effects of calcium silicate-based materials on the flexural properties of dentin. J Endod2012;38(5):680–683.
9. Qualtrough AJ, Mannocci F. Tooth-colored post systems: a review. Oper Dent 2003; 28:86-91.

10. Ferrari M, Scotti R. Fiber Posts: Characteristics and Clinical Applications. 1st Edition. Milan (Italy): Masson, 2002.
11. Braga NM, Paulino SM, Alfredo E, Sousa-Neto MD Vansan LP. Removal resistance of glass-fiber andmetallic cast posts with different lengths. J Oral Sci 2006; 48:15-20.
12. Santos-Filho PC, Castro CG, Silva GR, Campos RE, Soares CJ. Effects of post system and length on the strain and fracture resistance of root filled bovine teeth. Int Endod J 2008; 41: 493–501.
13. Çiçek E, Yılmaz N, Koçak MM, Sağlam BC, Koçak S, Bilgin B. Effect of Mineral Trioxide Aggregate Apical Plug Thickness on Fracture Resistance of Immature Teeth. J Endod. 2017;43 (10):1697-1700.
14. Hemalatha H, Sandeep M, Kulkarni S, et al. Evaluation of fracture resistance in simulated immature teeth using Resilon and Ribbond as root reinforcements – anin vitro study. Dent Traumatol2009; 25:433–8.
15. Andreasen JO, Farik B, Munksgaard EC. Long-termcalcium hydroxide as a root canal dressing may increase risk of root fracture. Dent Traumatol 2002;18: 134–137.
16. Valera MC, Oliveira LP, Carvalho CAT, Camargo CHR. Evaluation of the occurrence of fractures in teeth submitted to apexification treatment. Dent Traumatol 2015; 31(5):385-9.
17. Witherspoon DE, Small JC, Regan JD, Nunn M. Retrospective analysis of open apex teeth obturated with mineral trioxide aggregate. J Endod2008; 34:1171-6.
18. Martin RL, Monticelli F, Brackett WW, Loushine RJ, Rockman RA, Ferrari M, et al. Sealing properties of mineral trioxide aggregate orthograde apical plugs and root fillings in an in vitro apexification model. J Endod 2007; 33:272-5.
19. Dilmener FT, Sipahi C, Dalkiz M. Resistance of three new esthetic post-and-core systems to compressive loading. J Prosthet Dent 2006; 95:130-6.
20. Schmoldt SJ, Kirkpatrick TC, Rutledge RE, Yaccino JM. Reinforcement of simulated immature rootsrestored with composite resin, mineral trioxideaggregate, gutta-percha, or a fiber post afterthermocycling. J Endod 2011 37:1390-3.
21. Dikbas I, Tanalp J, Koksal T, Yalnız A, Güngör T. Investigation of the effect of different prefabricated intracanal posts on fracture resistance of simulated immature teeth. Dent Traumatol2014;30:49-54.
22. Cvek M. Prognosis of luxated non-vital maxillaryincisors treated with calcium hydroxide and filledwith gutta-percha. A retrospective clinical study.Endod Dent Traumatol 1992; 8: 45–55.
23. Tuna EB, Dincol ME, Gencay K, Aktoren O. Fracture resistance of immature teeth filled with BioAggregate,mineral trioxide aggregate and calciumhydroxide. Dent Traumatol 2011; 27: 174–178.
24. Tanalp J, Dikbas I, Malkondu O, Ersev H, Gungor T,Bayirli G. Comparison of the fracture resistance of simulated immature permanent teeth using various canal filling materials and fiber posts. Dent Traumatol 2012; 28: 457–464.