Original Article

Fracture Resistance of Simulated Immature Teeth Obturated with Gutta-Percha or Resilon and Reinforced by Composite or Post

Behnam Bolhari[1], Elham Mojazi Amiri[2], Hamidreza Kermanshah[3], Sholeh Ghabraei[4]✉, Azad Jamei[5]

[1]Associate Professor, Dental Research Center Dentistry Research Institute, Department of Endodontics, Dental School, Tehran University of Medical Sciences,Tehran, Iran
[2]Associate Professor, Dental Research Center Dentistry Research Institute, Department of Restorative Dentistry, Dental School, Tehran University of Medical Sciences,Tehran, Iran
[3]Dentist
[4]Endodontist
[5]Assistant Professor, Dental Research Center Dentistry Research Institute, Department of Endodontics, Dental School, Tehran University of Medical Sciences, Tehran, Iran

✉ Corresponding author:
Sh. Ghabraei, Dental Research Center, Department of Endodontics, Dental School, Tehran University of Medical Sciences, Tehran, Iran

sholehghabraei@yahoo.com

Received: 2 August 2014
Accepted: 8 December 2014

Abstract
Objectives: The purpose of this ex- vivo study was to evaluate the fracture resistance of simulated immature teeth, obturated with Gutta-percha or Resilon and reinforced by either composite resin or fiber post.
Materials and Methods: Eighty-four human maxillary incisors were divided into seven groups (n=12). Teeth in all groups were prepared until Peeso #5 (1.5mm) could be passed through the apex. Root ends received 4mm of MTA plug as an apical barrier. Groups received the followings: 1.Gutta-percha, 2.Resilon, 3.Gutta-percha + composite resin, 4.Resilon + composite resin, 5.Gutta-percha + fiber post, 6.Resilon + fiber post and 7.No obturation (control group). Access openings were filled with composite resin. Specimens were then subjected to oblique load using Instron Testing Machine. The mean peak load at fracture was recorded and analyzed using ANOVA.
Results: Experimental groups had a significantly more fracture resistance than the control group ($P < 0.05$). No significant difference was seen between experimental groups. Teeth reinforced by fiber post showed favorable fracture resistance.
Conclusion: Treatment plans used in this study increase the fracture resistance of immature teeth. Use of fiber posts in immature teeth, may be the most favorable clinically applicable technique.
Key words: Fracture; Resistance; Gutta-percha; Immature; Teeth; Resilon
Journal of Dentistry, Tehran University of Medical Sciences, Tehran, Iran (2015; Vol. 12, No. 2)

INTRODUCTION

Traumatic accidents and sport activities may cause injuries to permanent teeth, which will possibly lead to necrosis of the pulp [1]. Literature shows that the majority of these traumas occur between 8 to 12 years of age, especially to the permanent maxillary incisors with immature root. Thin walls and wide apices of these roots make it difficult for the practitioners to perform the appropriate treatment [2, 3]. Therefore, suggested treatments should overcome these obstacles.

Frank et al, in 1966, showed that long-term use of calcium hydroxide (CH) in immature root apices, results in adequate apical healing, due to its antibacterial property and inducing the formation of an apical barrier, known as apexification [4].

However, this long procedure has some major drawbacks, such as requiring several patient visits. Therefore, patients may fail to attend some appointments, which increases the risk of temporary filling loss in between treatment sessions. The latter may lead to reinfection of the tooth and weakening of dentine structure due to the alkaline nature of CH [1, 5]. Use of MTA plug as a single step apical barrier placement technique was introduced as an alternative treatment for such cases [6]. MTA, in long term, induces the formation of a mineralized apical barrier (apexification). In short term, it creates a mechanical apical barrier (MTA plug). This method has the advantage of shorter treatment time and producing a hard apical barrier with a good seal [6, 7]. Howeverr, the remaining thin root walls, especially in the cervical region, are susceptible to fracture from secondary injuries. For this reason, use of reinforcement in such weak roots would be advantageous.

Gutta-percha remains the standard material of choice for root canal obturation. Recently, a new filling material named Resilon (Pentron Clinical Technologies, Wallingford, CT) was introduced. According to the literature, this material may create a solid “monoblock”, when used with its sealer, Epiphany SE, and reinforce the root structure [8, 9]. Studies by Teixeria et al, in 2004, and Mehrvarzfar et al, in 2012 on the compressive strength of endodontically treated teeth demonstrated that canals filled with Resilon had significantly higher compressive strength than those filled with gutta-percha. However, the ability of this new filling material in reinforcing the cervical area of immature teeth is still controversial. Application of composite resin as an obturating material has been suggested to maximize the fracture resistance of teeth [10-12]. But, it should be noted that composite resin removal in case of retreatment would be challenging for clinicians. Teixeria et al, and Glazer et al. showed that extending the composite resin apically beyond the access cavity to fill the coronal area of the root canal may increase the fracture resistance of the cervical area [13, 14].

Fiber post is another material recommended to reinforce the cervical area [15, 16]. It has approximately the same modulus of elasticity as dentin. Therefore, it evenly distributes forces (whether traumatic forces or occlusal forces) in the root [17, 18]. As mentioned earlier, thin dentinal walls are the biggest clinical challenge in treatment of immature necrotic teeth [21]. Currently, regenerative treatments are considered as a comprehensive and reliable treatment modality in endodontics. But, in case of failure of regeneration, other treatment plans should be applied. The purpose of this ex-vivo study was to fill the simulated immature teeth with gutta-percha or Resilon, and reinforce them with either composite resin or fiber post, to evaluate their fracture resistance in each technique.

MATERIALS AND METHODS

One hundred and ten freshly extracted maxillary incisors were selected for this study and observed under magnification for any microcracks or fractures. An X-ray was taken to ensure having a single canal each. The selected teeth were measured with a Boley gauge at 2 mm below the facial cementoenamel junction (CEJ) and the mean value was obtained. Teeth showing major deviations from the mean value (more than 20%) were excluded. Eighty-four teeth met the inclusion criteria. The teeth were divided into seven groups; six experimental and one control (n= 12). Standardization was made by measuring the root length from the apex to the facial CEJ, and cutting the apical portion of each root subsequently, using a carborundum disc (Dentorium, New York, NY, USA) with a straight handpiece (NSK, Tokyo, Japan), to obtain 12 mm of root length in all teeth. Coronal access cavity was

prepared using #4 bur (DIA-BURS, MANI, Japan) and a high-speed handpiece.
Canals were prepared with Mtwo rotary files (VDW, Munich, Germany) in a sequence of file # 15 up to file # 40 (all with 0.05 taper) and peeso reamers (LARGO, Dentsply, Swiss) accordingly until a #5 peeso could pass 1 mm beyond the apex. After instrumentation, in order to remove the smear layer, each root canal was irrigated with 3 mL of 6% NAOCL. After 2 minutes, the root canals were irrigated with 17% EDTA (Ariadent, Iran). One minute later, they were irrigated with 3 mL of sterile water. The irrigation procedures were done using 25 gauge syringes. Root canals were then dried using # 40 paper points (DIA DENT, Korea). MTA carrier was used to place a 4 mm apical plug of white ProRoot-MTA (Dentsply, USA) in each tooth. MTA plug was condensed using Schilder plugger (MAILLEFER, Dentsply, Switzerland). The apex was sealed using fingertip during this time to prevent MTA extrusion. The thickness and homogeneity of the MTA plugs were confirmed radiographically. The apices of these teeth were covered with a wet cotton pellet, and the coronal side of the plug (in the canal) was covered using a moist paper point. All teeth were then stored at 37°C and 100% humidity for 72 hours, allowing the MTA to set completely. The remaining portions of the teeth were treated in the following manner:
Group 1 (backfill with gutta-percha+ AH-26 sealer); AH-26 (Dentsply, DeTrey, Konstanz, Germany) was prepared according to the manufacturer's instruction. A layer was applied to the canal walls, using a #40 file. A sealer-coated #80 master cone (Produits Dentaires SA, Vevey, Switzerland) was inserted to the working length. Lateral condensation was commenced using a size 20 finger spreader (Dentsply Maillefer, Ballaigues, Switzerland). The void left by the spreader was filled with an auxiliary gutta-percha point of identical size. (Dentsply Maillefer, Ballaigues, Switzerland).
Root canal was filled up to the level of the CEJ. Excessive sealer was removed from the pulp chamber, using a dry cotton pellet.
Access openings were acid etched with 32% phosphoric acid (Morva Etch, Morvabon, Iran). Access cavity was then filled with A1 shade composite resin (Point 4, Kerr, Italy) in 1 mm increments, until the cavity was completely filled.
Group 2 (backfill with Resilon + Epiphany/SE): Epiphany sealer was mixed according to the manufacturer's instruction. A thin layer of the sealer was applied to the canal walls, using file #40. The root canals were then obturated as in group 1. After removing the excessive sealer from the chamber, light curing was performed for 40 seconds, to cure the coronal portion of the material. Access openings were filled as in group 1.
Group 3 (backfill with gutta-percha and AH-26 to 3mm below the CEJ+ composite resin): The obturation process was almost similar to group 1 except for the length of gutta-percha filling that was 3 mm apical to the facial CEJ. The remaining 3 mm and the access cavity were acid etched, rinsed and filled with composite resin similar to group 1.
Group 4 (backfill with Resilon and Epiphany to 3 mm below the CEJ + composite resin): The root canal was obturated as in group 2. But in this group, root canal was filled with Resilon up to 3 mm apical to the facial CEJ. The remaining 3 mm and the access cavity were filled as in group 3.
Group 5 (backfill with gutta-percha and AH-26 to 6 mm below the CEJ + fiber post): The root canal was obturated similar to group 1. But in this group, root canal was filled with gutta-percha up to 6 mm apical to the facial CEJ. Dual cure resin (Panavia F 2.0, Kuraray, Japan) was applied to the canal surfaces according to the manufacturer's instruction. Then, #3 fiber post (Reforpost, Angelus, Brazil) was dipped into the resin and inserted into the canal to the end of post space (6 mm) using finger pressure.

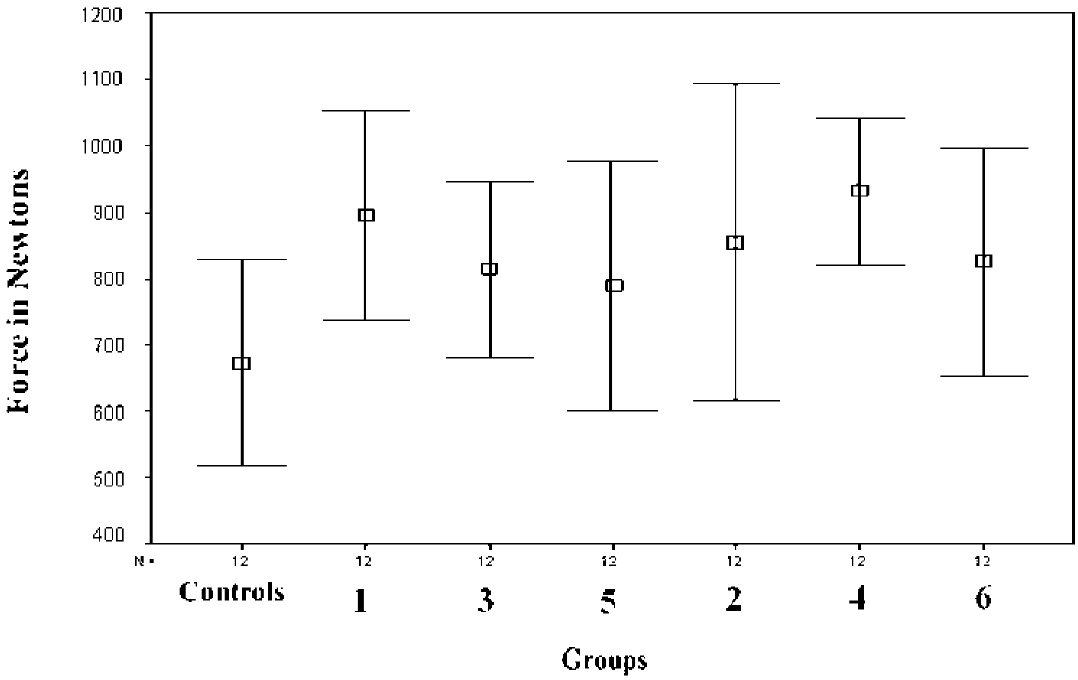

Fig 1. The mean load required to cause tooth fracture

Excess material was immediately removed. The light curing was performed for 10 seconds through the post.

The coronal portion of the fiber post was trimmed using a high-speed hand piece (NSK, Tokyo, Japan). The access openings were filled as in group 1.

Group 6 (backfill with Resilon and Epiphany to 6 mm below the CEJ + fiber post): The root canal was obturated similar to group 2. But in this group, root canal was filled with Resilon up to 6 mm apical to the facial CEJ. The remaining length of the canal and the access cavity were filled as explained for group 5.

Group 7 (control group): The remaining portions of the root canals were left unfilled. A cotton pellet was placed at a level just below the facial CEJ. The access cavity was filled as in group 1.

The apical 10 mm of all roots was covered with a layer of polyether (3M ESPE, Impregum Penta Soft, USA) to simulate the periodontal ligament.

The specimens were then embedded in self curing acrylic resin poured in cylinders, leaving a 2mm gap between acrylic surface and facial CEJ to simulate the physiologic relationship between the bone crest and tooth. The teeth were mounted using a surveyor to ensure a perpendicular relationship between the long axis of the tooth and the top surface of the acrylic block.

The specimens were stored at 37°C and 100% humidity until fracture testing.

An Instron Universal Testing Machine (Zwick-Roell Z050, Ulm, Germany) was used to apply load to each specimen at a crosshead speed of 5.0 mm/min (Figure 1). The specimens were fixed to the jig and the load was delivered at 135° relative to the long axis of the tooth in a lingual-labial direction at 3 mm coronal to the level of the lingual CEJ with a chisel-shaped tip.

The peak load at fracture was recorded and statistical analysis was performed using one-way and two-way ANOVA.

RESULTS

One-way and two-way ANOVA were used to compare the mean loads at fracture in seven groups.

Figure 1 and Table 1 show the mean fracture load of all groups. One-way ANOVA revealed significant differences between the groups (P<0.05). Based on Tukey's HSD test, there were only significant differences between the control group and others. By excluding the control group, two-way ANOVA indicated no significant effect of the obturation material (P>0.05) or the restorative method (P>0.05), and their interaction effect was not significant either. The modes of failure of the specimens are presented in Table 2.

DISCUSSION

The thin dentinal walls are responsible for most clinical problems related to immature necrotic teeth [19].

Root canal obturation and reinforcement following apexification are among the suggested treatments for such cases in endodontics. In this research, different treatment plans for these teeth were investigated.

In this study, maxillary central incisors were selected for various reasons such as high rate of fracture and less morphologic variations. To simulate immature teeth, roots were sectioned apically in such way that 12 mm of root length remained. Canal wall width was decreased using peeso #5 (1.5 mm diameter). However, this technique may not fully simulate the immature tooth structure. The cushioning effect of periodontal ligament in the clinical setting was simulated using a layer of polyether when mounting the teeth. Shalin Desai et al. [20] reported that PDL simulation had a significant effect on the results of ex-vivo studies on immature teeth. Other studies have also indicated that it disseminates the load applied to the tooth [21-23]. The angle of the load applied was 135°, to follow the average angle of contact between maxillary and mandibular incisors in a class I occlusion [22, 24-26]. To date, no study has reported an increase in structural strength of immature teeth after using MTA [7]. Therefore, in this study, 4mm of apical MTA plug was applied to the teeth, solely to simulate the apical closure of immature teeth performed in the clinical setting.

Table 1. The mean and std. deviation of compressive strength (Newton) of all groups.

Groups	N	Mean	Std. Deviation	Std. Error
1	12	895.3008	246.54943	71.17269
2	12	854.6358	374.79940	108.19527
3	12	814.4900	207.78601	59.98266
4	12	932.6117	174.66046	50.42013
5	12	789.6167	295.62076	85.33836
6	12	825.6867	269.26607	77.73042
Control	12	673.9067	242.89640	70.11815

Table 2. Fracture modes

Groups	Fracture modes
1 & 2	From 3 mm coronal to the lingual CEJ, extended obliquely through crown & root, up to facial CEJ
3 & 4	From 3 mm coronal to the lingual CEJ, extended obliquely through crown & root, up to approximately 2 mm apical to facial CEJ
5 & 6	From 3 mm coronal to the lingual CEJ, extended obliquely through crown & root, up to approximately 2 mm apical to facial CEJ without fracturing the post
Control	From 3 mm coronal to the lingual CEJ, extended obliquely through crown, up to facial CEJ

The results of this study showed that the control group with no backfilling had significantly lower fracture resistance than the experimental groups. In conclusion, MTA material does not have the potential to reinforce the weakened wall of immature teeth, and other additional obturation materials should be utilized to increase the structural strength of these teeth.

Reinforcing ability of composites has been approved by several studies [2, 5]. However, retreatment of canals obturated by composite resins is challenging due to difficulty in material removal. Thus, extending the composite only several millimeters beyond the access cavity may strengthen the tooth [2, 24, 27, 28]. In the current study, cervical area of the teeth in groups 3 and 4 was reinforced by 3 mm extension of composite resin from the access cavity. Katebzadeh et al. also evaluated the fracture resistance of simulated immature teeth, reinforced by composite resin in the coronal root area. Results of both studies showed a significant difference between these groups and the control group [29]. It should be mentioned that in our study, the groups filled with Resilon and reinforced with composite resin showed the highest fracture resistance compared to other groups; however, this difference was not statistically significant (mean load of fracture = 932.62 N, P= 0.4). Therefore, it may be concluded that filling the middle third of immature root canals with Resilon after sealing the apical third with MTA plug and reinforcing the coronal part with composite resin, has the potential of increasing the fracture resistance of the cervical area of immature teeth.

Some studies have investigated the fracture resistance of immature teeth filled with Resilon, the newly introduced filling material. But they showed different opinions on whether this material could provide additional strength or not [2, 27, 28, 30].

Gutta percha and Resilon have different physical properties, but their mechanical features such as modulus of elasticity and cohesive strength are the same.

The modulus of elasticity of gutta-percha, Resilon and dentine is 79, 87 and 17400 MPa, respectively [2, 24, 31]. Hence, these two materials act the same when used as root canal filling material [33]. Our study had a design similar to that of Stuart et al, [27]. They reported no difference between immature teeth filled with gutta-percha, Resilon, composite and the control group. Our findings however, showed a significant difference between teeth filled with either gutta-percha or Resilon up to the level of CEJ and the control group. Different types of teeth used in Stuart's study (maxillary canines and incisors and mandibular premolars) and the current study (maxillary incisors) may explain the different results. There was no difference between the groups reinforced by fiber post and other experimental groups in our study. Conversely, Schmoldt et al. [32] demonstrated that fiber posts used in immature teeth provided additional strength in teeth filled with either gutta-percha or composite. Such conflicting results may be justified by the results of a study by Hattori et al. [33] who indicated that the greater the space between the fiber post and root canal walls, the more cement used in this excessive space and subsequently, the more structural strength added to the immature teeth. Fiber post diameter used in Shmoldt's study was 1.37 mm with root canal diameter of 1.75 mm. Thus, there was 0.19 mm excessive space between the post and the root canal walls. He used composite resin as cement. But in the current study, post diameter and root canal diameter were the same (1.5 mm) and Panavia was used as cement. On the other hand, fracture pattern of teeth reinforced by fiber post was favorable and because of partial crown fracture at or above the CEJ, with no post fracture, these teeth can be restored after fracture. Therefore, the technique used in the current study may be clinically applicable. In the current study, cervical walls of the teeth were not weakened enough to fully simulate the immature teeth and also the crowns of the teeth did not have proportionately equal lengths. The mentioned two points may explain lack of a significant difference among experimental groups in the current study. On the other hand, to overcome this problem, Tanalp et al. (25) weakened the cervical area by using peeso reamer # 6 instead of # 5 and also sectioned the crowns in such way that all specimens had equal lengths from the CEJ. Their results were the same as ours except for the groups reinforced by fiber posts, which were significantly more fracture resistant than the other groups. Although, it should be noted that the fiber posts used in Tanalp's study were longer than the fiber posts used in the current study. After this comparison, it may be concluded that materials used for obturation and reinforcement in the current study have the potential for strengthening the teeth. But selection of the proper material for root canal filling and reinforcing the immature teeth may be challenging and requires further studies.

CONCLUSION

Our study demonstrated that the materials and methods used in this study for obturation and reinforcement of the immature teeth with intact crowns efficiently strengthened them. Use of fiber posts in immature teeth may have the advantage of enabling re-restoration of teeth after secondary fracture. More research is still needed on immature teeth with severely weakened cervical walls, different filling materials and different reinforcing techniques to achieve the gold standard treatment plan for necrotic immature teeth.

ACKNOWLEDGMENTS

We want to thank Dr. Mohammad Javad Kharrazifard, the statistical analyst of our study.

REFERENCES

1- Andreasen JO, Bakland LK, Flores MT, Andreasen FM, Andersson L. Traumatic dental injuries: a manual: John Wiley & Sons; 2013.

2- Lawley GR, Schindler WG, Walker WA 3rd, Kolodrubetz D. Evaluation of ultrasonically placed MTA and fracture resistance with intracanal composite resin in a model of apexification. J Endod. 2004 Mar;30(3):167-72.

3- O'Mullane DM. Injured permanent incisor teeth: an epidemiological study. J Ir Dent Assoc. 1972 Jul-Aug;18(4):160-73.

4- Frank AL. Therapy for the divergent pulpless tooth by continued apical formation. J Am Dent Assoc. 1966 Jan;72(1):87-93.

5- Trope M, Langer I, Maltz D, Tronstad L. Resistance to fracture of restored endodontically treated premolars. Endod Dent Traumatol. 1986 Feb;2(1):35-8.

6- Shabahang S, Torabinejad M. Treatment of teeth with open apices using mineral trioxide aggregate. Pract Periodontics Aesthet Dent. 2000 Apr;12(3):315-20; quiz 322.

7- Steinig TH, Regan JD, Gutmann JL. The use and predictable placement of Mineral Trioxide Aggregate in one-visit apexification cases. Aust Endod J. 2003 Apr;29(1):34-42.

8- Shipper G, Orstavik D, Teixeira FB, Trope M. An evaluation of microbial leakage in roots filled with a thermoplastic synthetic polymer-based root canal filling material (Resilon). J Endod. 2004 May;30(5):342-7.

9- Torabinejad M, Walton RE. Endodontics, Principles and Practice. 4th ed. ed2008.

10- Andreasen FM, Andreasen JO, Bayer T. Prognosis of root-fractured permanent incisors--prediction of healing modalities. Endod Dent Traumatol. 1989 Feb;5(1):11-22.

11- Cvek M. Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha. A retrospective clinical study. Endod Dent Traumatol. 1992 Apr;8(2):45-55.

12- Mohey el-Din el-Khodery A, el-Badhdady YM, Ibrahim RM. A comparative study of restorative techniques used to reinforce intact endodontically treated anterior teeth. Egypt Dent J. 1990 Jul;36(3):193-205.

13- Teixeira FB, Teixeira EC, Thompson JY, Trope M. Fracture resistance of roots endodontically treated with a new resin filling material. J Am Dent Assoc. 2004 May;135(5):646-52.

14- Glazer B. Restoration of endodontically treated teeth with carbon fibre posts--a prospective study. J Can Dent Assoc. 2000 Dec;66(11):613-8.

15- Sorensen J AS, Berge H, Edelhoff D. Selection criteria for post and core materials in the restoration of endodontically treated teeth. In: Proceedings of Conference on Scientific Criteria for Selecting Materials and Techniques in Clinical Dentistry. 2001;15:67-84.

16- Torbjorner A, Fransson B. A literature review on the prosthetic treatment of structurally compromised teeth. Int J Prosthodont. 2004 May-Jun;17(3):369-76.

17- Faria AC, Rodrigues RC, de Almeida Antunes RP, de Mattos Mda G, Ribeiro RF. Endodontically treated teeth: characteristics and considerations to restore them. J Prosthodont Res. 2011 Apr;55(2):69-74.

18- Nam SH, Chang HS, Min KS, Lee Y, Cho HW, Bae JM. Effect of the number of residual walls on fracture resistances, failure patterns, and photoelasticity of simulated premolars restored with or without fiber-reinforced composite posts. J Endod. 2010 Feb;36(2):297-301.

19- Hunter AJ, Feiglin B, Williams JF. Effects of post placement on endodontically treated teeth. J Prosthet Dent. 1989 Aug;62(2):166-72.

20- Desai S, Chandler N. The restoration of permanent immature anterior teeth, root filled using MTA: a review. J Dent. 2009 Sep;37(9):652-7.

21- Pini M, Wiskott HW, Scherrer SS, Botsis J, Belser UC. Mechanical characterization of bovine periodontal ligament. J Periodontal Res. 2002 Aug;37(4):237-44.

22- Soares CJ, Pizi EC, Fonseca RB, Martins LR. Influence of root embedment material and periodontal ligament simulation on fracture resistance tests. Braz Oral Res. 2005 Jan-Mar;19(1):11-6.

23- Rees JS. An investigation into the importance of the periodontal ligament and alveolar bone as supporting structures in finite element studies. J Oral Rehabil. 2001 May;28(5):425-32.

24- Bortoluzzi EA, Souza EM, Reis JM, Esberard RM, Tanomaru-Filho M. Fracture strength of bovine incisors after intra-radicular treatment with MTA in an experimental immature tooth model. Int Endod J. 2007 Sep;40(9):684-91.

25- 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 Dec;28(6):457-64.

26- Carvalho CA, Valera MC, Oliveira LD, Camargo CH. Structural resistance in immature teeth using root reinforcements in vitro. Dent Traumatol. 2005 Jun;21(3):155-9.

27- Stuart CH, Schwartz SA, Beeson TJ. Reinforcement of immature roots with a new resin filling material. J Endod. 2006 Apr;32(4):350-3.

28- Wilkinson KL, Beeson TJ, Kirkpatrick TC. Fracture resistance of simulated immature teeth filled with resilon, gutta-percha, or composite. J Endod. 2007 Apr;33(4):480-3. Epub 2007 Jan 22.

29- Katebzadeh N, Dalton BC, Trope M. Strengthening immature teeth during and after apexification. J Endod. 1998 Apr;24(4):256-9.

30- JO A. *Traumatic injuries of the teeth*. ed. 2 ed. Copenhagen: Munksgaard; 1981. p. 38-45, 97-116.

31- Williams C, Loushine RJ, Weller RN, Pashley DH, Tay FR. A comparison of cohesive strength and stiffness of Resilon and gutta-percha. J Endod. 2006 Jun;32(6):553-5. Epub 2006 Apr 4.

32- Schmoldt SJ, Kirkpatrick TC, Rutledge RE, Yaccino JM. Reinforcement of simulated immature roots restored with composite resin, mineral trioxide aggregate, gutta-percha, or a fiber post after thermocycling. J Endod. 2011 Oct;37(10):1390-3.
33- Hattori M, Takemoto S, Yoshinari M, Kawada E, Oda Y. Durability of fiber-post and resin core build-up systems. Dent Mater J. 2010 Mar;29(2):224-8.