Reinforcement of Immature Roots with a New Resin Filling Material

Charles H. Stuart, DDS, Scott A. Schwartz, DDS,[†] and Thomas J. Beeson, DDS**

Abstract

The purpose of this study was to compare the reinforcement and strengthening ability of Resilon, gutta-percha, and a self-curing composite resin (Bisfil 2B) in endodontically treated roots of immature teeth. Sixty single rooted teeth were divided into five groups of 12 teeth each. Teeth in all groups except the negative controls were prepared with a #5 Peeso (1.5 mm) through the apex (simulating immature roots) and root ends were filled with a 4 mm barrier of MTA. After smear layer removal, canals in the three experimental groups were backfilled with gutta-percha, Resilon, or Bisfil 2B. The remaining canal space in the positive control group was left unfilled. Negative controls received no treatment. A horizontal fracture was created in the root of each specimen using an Instron and the mean peak loads to fracture were recorded. ANOVA revealed no significant difference between any of the treatment groups. Based on the results of this study, canal wall reinforcement of teeth with a canal diameter of 1.5 mm or less may not be necessary. *(J Endod 2006; 32:350–353)*

*From the Department of Endodontics, Wilford Hall Medical Center, Lackland AFB, Texas; [†]Department of Endodontics, University of Texas Health Science Center at San Antonio, San Antonio, Texas.

Address requests for reprint to Dr. Charles H. Stuart, Capt, USAF, DC, Wilford Hall Medical Center, Department of Endodontics, 2450 Pepperrell Street, Lackland AFB, TX 78236-5346. E-mail address: charles.stuart@lackland.af.mil.

0099-2399/$0 - see front matter

Published by Elsevier Company on behalf of the American Association of Endodontists.

doi:10.1016/j.joen.2005.08.001

Common injuries to permanent teeth result from falls, traffic accidents, violent acts, and participation in various sports (1). Many sports related injuries are common in younger children, ages 9 and 10, where teeth are still in the process of maturing (1). Pulpal necrosis of an immature tooth will necessitate endodontic treatment that can pose both endodontic and restorative challenges because of incomplete closure of the apex and thin dentinal walls (1–13).

Apexification, discussed by Frank (2) in 1966, addresses the problem of incomplete apical closure. This method utilizes long-term calcium hydroxide treatment to induce calcific bridge formation at the apex of the nonvital, immature root. Studies indicate that, although it may take up to 18 months, a successful hard tissue barrier will form 79 to 96% of the time (3, 4). In rare instances, the apexification procedure may result in a morphologically normal root-end rather than just a calcific bridge or cap (5). Calcific bridge formation is, in most cases, dependent upon the placement of an intracanal medicament such as calcium hydroxide, although a recent report described an unusual case in which apical closure occurred in the absence of intracanal medication (6).

A recent study by Andreasen et al. (7) suggests that long-term calcium hydroxide therapy may weaken immature roots. As a result, an alternative has been proposed (1). This new technique includes minimal instrumentation, disinfection with sodium hypochlorite, and short-term use of calcium hydroxide for 2 to 4 wk as an intracanal medicament. At the obturation visit, the apical portion of the canal is filled with a 4 mm plug of MTA and the remaining canal space is subsequently backfilled with gutta-percha. Finally, a bonded composite resin is used to fill the access opening (1). Advantages of this technique include shorter treatment time, development of a good apical seal, and MTA-induced hard tissue deposition periradicularly (8, 9).

Studies vary with regard to which material would best reinforce and seal the remainder of the root after an apical barrier of MTA or an apexification procedure with calcium hydroxide (10–15). Immature teeth could benefit from strengthening to protect against possible fracture from trauma and normal occlusal forces. In addition to root strengthening, other important considerations for an ideal material would include ease of placement, ease of removal for additional restorative procedures, the ability to bond to dentin, and protection from coronal microleakage. Studies investigating the use of a bonded composite resin within the weakened root have demonstrated that it possesses the greatest potential to strengthen and reinforce the thin dentinal walls of immature teeth (10–12).

Resilon (Pentron, Wallingford, CT) is a new resin material used for obturating root canals that handles similar to gutta-percha. It can be laterally condensed, as well as heat softened and injected into the root canal system. It is used in conjunction with a dual cure, resin based sealer, Epiphany (Pentron), which forms a bond to the dentin walls and Resilon core (16). Resilon can be removed from the root canal system with heat, solvent, or rotary instrumentation in cases where a post space needs to be prepared or root canal retreatment must be performed (17). Teixeira et al. (17) showed that teeth obturated with Resilon/Epiphany exhibited greater resistance to vertical root fracture compared to similar teeth filled with gutta-percha. If true, this bonded system may have the potential to reinforce the thin roots of immature teeth.

The purpose of this study was to compare the reinforcement and strengthening ability of a new resin root canal filling material (Resilon), gutta-percha, and flowable composite resin in endodontically treated roots of immature teeth.

Materials and Methods

Sixty recently extracted maxillary anterior teeth as well as mandibular canines and premolars without root fracture were collected and placed in 0.5% chloramine-T. The facial-lingual dimension of each tooth was measured with a Boley Gauge at a point 2 mm below the facial CEJ. Based on this dimension, the teeth were divided into three experimental groups and two control groups using a randomized-stratified design. Twelve teeth were not instrumented and served as negative controls. The remaining 48 teeth were prepared as follows: The root of each tooth was standardized to a length of 12 mm as measured from the apex to the facial CEJ by cutting off the root end. Coronal access was made using a #245 bur and an Endo Z bur (Dentsply Maillefer, Tulsa, OK) in a high-speed handpiece. Canals were instrumented with K3 files (Sybron Endo, Orange, CA) and Peeso reamers until a #5 Peeso could be passed 1 mm beyond the apex. After instrumentation, each root was irrigated with 5 ml 6.0% NaOCl and 5 ml 17% EDTA using a 25 gauge Max-i-Probe (Dentsply Rinn MPL, Elgin, IL) to remove the smear layer. Five ml of sterile water was used as a final rinse. Calcium hydroxide (UltraCal XS, Ultradent, South Jordan, UT) was placed in the canals and the teeth were temporized using a cotton pellet and Cavit (ESPE-3M, USA). All teeth were stored at 37°C and 100% humidity. After 7 days, the calcium hydroxide was removed by flushing the prepared canals with 5 ml 6.0% NaOCl, 5 ml 17% EDTA, and 5 ml sterile water, respectively. After drying the canals with paper points, a Messing Gun (Roydent, Rochester Hills, MI) was used to place a 4 mm apical plug of tooth-colored ProRoot MTA (Dentsply Tulsa Dental, Tulsa, OK) in each tooth. Teeth were placed in flower arrangement foam (Aquafoam, Syndicate Sales, Inc., Komo, IN) to aid in handling and to prevent MTA extrusion. The MTA was packed and ultrasonically activated with a Schilder plugger to aid condensation and remove voids. The teeth were radiographed and stored at 37°C and 100% humidity for at least 72 h.

The roots of all 60 teeth were covered with a self-curing rubber (E-6000, Eclectic Products, Inc., Eugene, OR) to simulate the PDL. The apical 10 mm of the root was mounted in orthodontic resin utilizing a surveyor to ensure a perpendicular relationship between the long axis of the tooth and the top of the acrylic block (Fig. 1*A*). The physiologic relationship between the bone crest and tooth was simulated by leaving a 2 mm gap between the top of the acrylic and the facial CEJ. Unprepared controls were also mounted perpendicular to the top of the acrylic block utilizing intact tooth structure as a guide.

Before filling the root canals and restoring the access openings, all teeth except the unprepared controls received one final rinse of 5 ml 6.0% NaOCl, 5 ml 17% EDTA, and 5 ml sterile water. The canals of all prepared teeth were dried with paper points. The teeth in the experimental and control groups were treated as follows.

Group 1 (negative controls, *n* = 12)

Teeth received no treatment and served as negative controls .

Group 2 (positive controls, *n* = 12)

No obturation, other than the apical MTA barrier, was performed. A cotton pellet was placed at a level just below the facial CEJ.

Group 3 (backfill with thermoplasticized gutta-percha and ThermaSeal Plus sealer, *n* = 12)

ThermaSeal Plus sealer (Dentsply Tulsa Dental) was mixed according to manufacturer's instructions and a thin layer was applied using paper points. The canals were backfilled with thermoplasticized gutta-percha to the level of the facial CEJ using an Obtura II (Obtura Spartan, Fenton, MO) set at 200°C. The gutta-percha was vertically compacted with Schilder pluggers. Excess sealer was removed from the chamber using a dry cotton pellet.

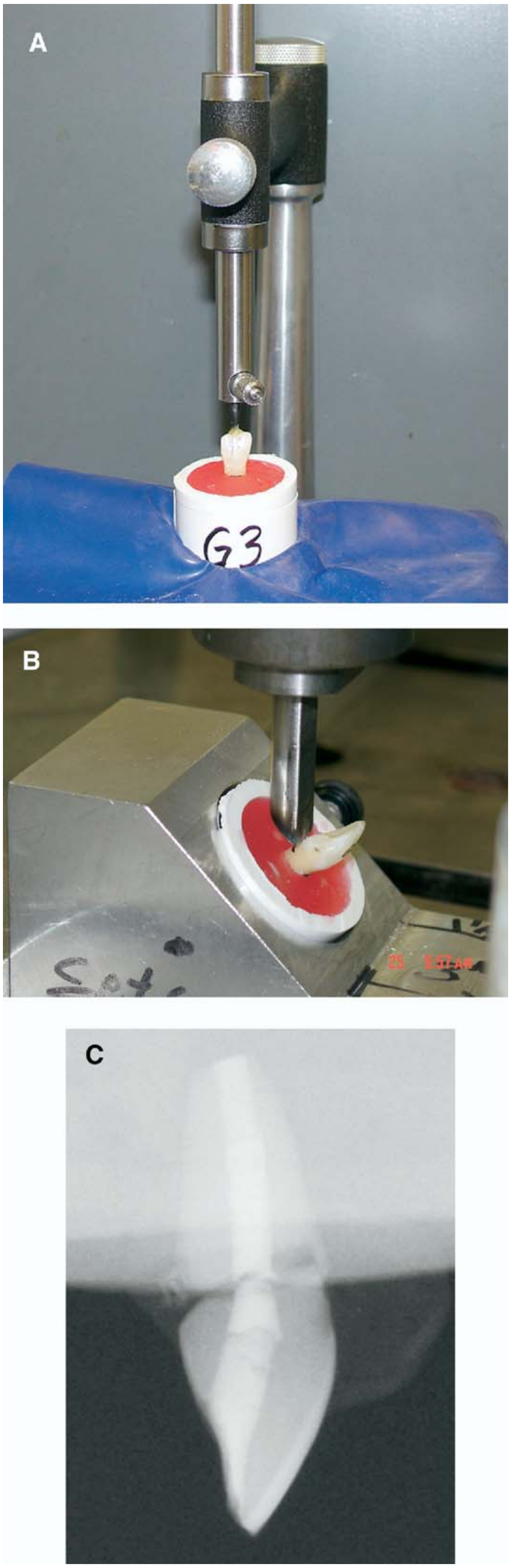

Figure 1. (*A*) Mounting tooth perpendicular to the acrylic resin utilizing a surveyor. (*B*) Chisel shaped Instron tip positioned at lingual CEJ before fracture. Note: 130 degree angle to long access of the tooth. (*C*) Tooth fracture through cervical root structure and root canal filling material.

Group 4 (backfill with Resilon and Epiphany sealer, $n = 12$)

All materials were mixed and applied according to manufacturer's instructions. Epiphany self-etching primer was applied with a microbrush. Epiphany sealer was then mixed and applied to the canal walls using a paper point. The canal was backfilled to the level of the facial CEJ with heat-softened Resilon using the Obtura II set at 200° C and then vertically compacted. Excess sealer was removed from the chamber with a dry cotton pellet. The material was light-cured for 30 s to facilitate setting.

Group 5 (backfill with flowable composite, $n = 12$)

The canals were etched with 32% phosphoric acid for 15 s. Canals were thoroughly rinsed with sterile water, dried, and lightly coated with All-Bond 2 (Bisco, Schaumburg, IL), a self-curing dentin bonding agent. The canals were backfilled to the facial CEJ with BisFil 2B (Bisco), an unfilled, flowable, self-curing composite using a Centrix syringe (Centrix, Shelton, CT).

In groups 2 through 5, the access openings were acid-etched with 32% phosphoric acid for 15 seconds, rinsed with water, lightly air dried, and then filled using Opti-Bond Solo Plus adhesive (Kerr, Orange, CA) and Prodigy composite (Kerr). The specimens were then stored in 100% humidity at 37° C until fracture resistance testing. A jig was fabricated to fit each tooth/polyvinyl ring. An Instron Universal Testing Machine (Instron Corp., Norwood, MA) was used to apply a load to each specimen at a crosshead speed of 5.0 mm/min. The specimens were fixed in the jig and the load was delivered at 130° to the long axis of the tooth in a lingual-labial direction at the level of the lingual CEJ with a chisel-shaped tip (Fig. 1*B*). The peak load to fracture was recorded and statistical analysis was completed using a one-way ANOVA.

Results

All 60 teeth tested showed horizontal fractures through the cervical portion of the root (Fig. 1*C*). In group 1 the fractures extended through the noninstrumented canal space. In group 2 the fractures extended through empty, instrumented canal space. In groups 3 through 5 the fractures extended through the gutta-percha, Resilon, and flowable composite materials, respectively. Groups 1 and 5 (negative controls and BisFil 2B canals) exhibited the highest load to fracture values. The mean peak load required to cause cervical root fracture in all five groups is presented in Table 1 and Fig. 2. ANOVA revealed no significant differences between treatment groups.

Discussion

When restoring immature teeth, immediate apexification using an MTA barrier offers several advantages over conventional apexification. These include fewer appointments for the patient, development of an immediate apical seal, and less potential to weaken tooth structure with long-term calcium hydroxide (7–9). Studies indicate that an effective apical seal in an immature root can be obtained with a 4 mm plug of MTA that has been placed ultrasonically (12) or a 5 mm plug of MTA that has been hand condensed (20). Conversely, a 4 mm MTA plug placed without ultrasonic condensation has resulted in a poor apical seal (21). Several factors require consideration when selecting a material or combination of materials to fill the remaining portion of the root canal coronal to the MTA barrier. A major consideration is to select a material that has potential to reinforce the root structure and protect it against cervical root fracture. According to Cvek (18) this type of fracture is common among immature teeth treated with long-term calcium hydroxide, with an incidence of 28 to 77% depending upon the stage of root development.

TABLE 1. Force required to cause cervical root fracture

Groups	Mean	Standard Deviation
Group 1 (negative controls)	1612.42 N	369.66
Group 2 (positive controls)	1469.25 N	431.20
Group 3 (gutta-percha)	1535.75 N	297.94
Group 4 (Resilon)	1463.17 N	420.92
Group 5 (composite)	1681.17 N	417.70

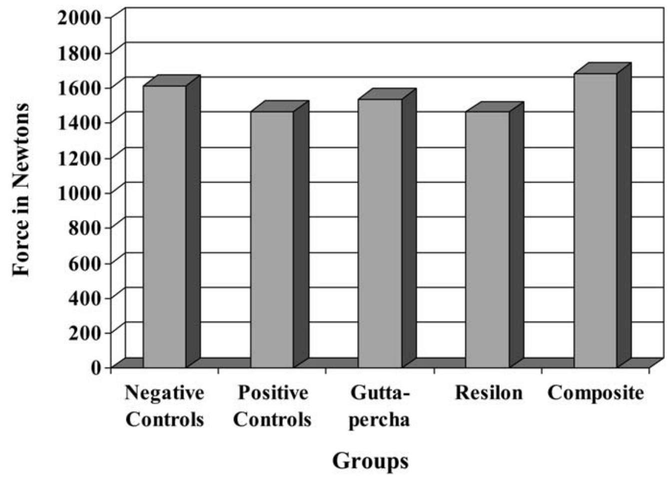

Figure 2. Mean force necessary to cause cervical root fracture.

Our study incorporated a design similar to Lawley et al. (12). Each experimental and control group contained a combination of maxillary anterior teeth as well as mandibular canines and premolars. Tooth groupings were made by a blinded observer utilizing a randomized stratified design resulting in very similar tooth dimensions and equal tooth types among groups. We attempted to simulate an immature tooth by reaming out the roots of mature teeth with a #5 Peeso. This technique has potential shortcomings in that it does not fully replicate the structure of an immature root. The angle used to fracture teeth was selected based on previous studies (11, 12) and a pilot study. In the pilot study, placing the chisel-shaped Instron tip at the lingual CEJ resulted in a consistent fracture through the root and root canal filling material only, whereas placing the tip coronal to the CEJ commonly led to an oblique fracture through the crown and coronal access filling material.

Composite resins exhibit great potential to reinforce and strengthen the remaining root (10–12). One drawback to the use of composite resin is difficulty in removal when endodontic retreatment or placement of a post is required. Teixeira et al. (17) recently reported that Resilon has the ability to strengthen the root against vertical fracture. Resilon has the added benefit of easily being removed from the root canal leaving retreatment or post placement as future restorative options. In the present study BisFil 2B, a flowable composite, provided the greatest resistance to horizontal root fracture. However, BisFil 2B did not prove to be significantly stronger than the gutta-percha, Resilon, or unfilled canal groups. Several observations may help explain these results.

First, Cvek (18) demonstrated that the incidence of cervical root fracture was dependent upon the stage of root development. Immature teeth, in later stages of development, will have adequate dentin wall thickness to protect them against horizontal fracture. Teeth in early stages of development possess little dentin wall thickness and are more prone to fracture. Thus assessment of the stage of root development and/or remaining root wall thickness should be the major factor in selection of root filling materials. As the dentin wall thickness decreases, the resistance to fracture becomes more dependent upon the reinforcing capability of the materials used to restore the tooth. In the present study, tooth specimens were instrumented to a #5 Peeso reamer (1.5 mm diameter). The average facial-lingual diameter (2 mm apical to the CEJ) of all specimens in the study was 6.76 mm leaving an average of 2.63 mm of dentin wall thickness on both the facial and lingual of the canal space. A cervical preparation diameter of 1.5 mm in this study may have been insufficient to adequately weaken tooth structure and thus test the materials or achieve significance among groups. Perhaps future studies could provide guidelines relating the choice of restorative materials to remaining dentin wall thickness.

Secondly, two common factors existed among all experimental groups and the positive control group. In the access opening of each specimen, a coronal composite was bonded in place to the level of the CEJ and each specimen received a 4 mm apical barrier of MTA. No studies have demonstrated that MTA has the ability to reinforce and strengthen teeth. In fact, MTA may lead to a weakening of root dentin (19). On the other hand, composite resin bonded within the coronal access to the level of the CEJ has the potential to reinforce cervical root structure. However, Trope et al. (10) demonstrated that composite bonded within the access opening does not provide as much strength to the root as when it is bonded within the entire canal. Perhaps extending the access composite several millimeters apical to the CEJ would provide additional root strength necessary to minimize cervical root fracture.

Investigators are currently evaluating an innovative technique that results in the revascularization of immature teeth with necrotic, infected pulps (22, 23). Using this novel approach it may be possible to prevent root fracture by strengthening the thin dentinal walls of these immature teeth with continued dentin/hard tissue deposition. Additional research is needed, however, before this technique can become a predictable part of our armamentarium for strengthening pulpless teeth with immature roots.

In conclusion, assessment of the stage of root development and remaining root wall thickness should be a major consideration in the selection of materials to restore immature, nonvital teeth. For more developed teeth (<1.5 mm canal diameter), Resilon and gutta-percha placement coronal to the MTA barrier in combination with a coronal access composite may provide sufficient root strength. This may also allow for future post and core placement. Further study is needed for less developed teeth (>1.5 mm canal diameter) as composite resin placed coronal to the MTA barrier may strengthen the roots of these teeth.

Acknowledgments

This article is the work of the United States government and may be reprinted without permission. Opinions expressed herein, unless otherwise specifically indicated, are those of the authors. They do not represent the views of the Department of the Air Force or any other department or Agency of the United States Government.

References

1. Andreasen JO, Andreasen FM, Bakland LK, Flores MT. Traumatic dental injuries, a manual, 2nd ed. Oxford: Blackwell Munksgaard 2003;9:58–60.
2. Frank A. Therapy for the divergent pulpless tooth by continued apical formation. J Am Dent Assoc 1966;72:87–93.
3. Cvek M. Endodontic management of traumatized teeth. In: Andreasen JO, Andreasen FM, eds. Textbook and color atlas of traumatic injuries of the teeth, 3rd ed. Copenhagen: Munksgaard 1994;543–52.
4. Kerekes K, Heide S, Jacobsen I. Follow-up examination of endodontic treatment in traumatized juvenile incisors. J Endod 1980;6:744–8.
5. Selden HS. Apexification: an interesting case. J Endod 2002;28:44–5.
6. Whittle M. Apexification of an infected untreated immature tooth. J Endod 2000;26:245–7.
7. Andreasen JO, Farik B, Munksgaard EC. Long-term calcium hydroxide as a root canal dressing may increase risk of root fracture. Dent Traumatol 2002;18:134–7.
8. Shabahang S, Torabinejad M. Treatment of teeth with open apices using mineral trioxide aggregate. Pract Periodont Aesthet Dent 2000;12:315–20.
9. Steinig TH, Regan JD, Gutmann JL. The use and predictable placement of Mineral Trioxide Aggregate in one-visit apexification cases. Aust Endod J 2003;29:34–42.
10. Trope M, Maltz DO, Tronstad L. Resistance to fracture of restored endodontically treated teeth. Endod Dent Traumatol 1985;1:108–11.
11. Pene JR, Nichols JI, Harrington GW. Evaluation of fiber composite laminate in the restoration of immature, nonvital maxillary central incisors. J Endod 2001;27:18–22.
12. Lawley GR, Schindler WG, Walker WA III, Kolodrubetz D. Evaluation of ultrasonically placed MTA and fracture resistance with intracanal composite resin in a model of apexification. J Endod 2004;30:167–72.
13. Goldberg F, Kaplan A, Roitman M, Manfre S, Picca M. Reinforcing effect of a resin modified glass ionomer in the restoration of immature roots in vitro. Dent Traumatol 2002;18:70–3.
14. Rabie G, Trope M, Garcia C, Tronstad L. Strengthening and restoration of immature teeth with acid-etch resin technique. Endod Dent Traumatol 1985;1:246–56.
15. Saupe WA, Gluskin AH, Radke RA. A comparative study of fracture resistance between morphologic dowel and cores and a resin-reinforced dowel system in the intraradicular restoration of structurally compromised roots. Quintessence Int 1996;27:483–91.
16. 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;30:342–7.
17. Teixeira FB, Teixeira EC, Thompson JY, Trope M. Fracture resistance of endodontically treated roots with a new type of resin filling material. J Am Dent Assoc 2004;135:646–52.
18. 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;8:45–55.
19. White JD, Lacefield WR, Chavers LS, Eleazer PD. The effect of three commonly used endodontic materials and the strength and hardness of root dentin. J Endod 2002;28:828–30.
20. Al-Kahtani A, Shostad S, Shifferle R, Bhambhani S. In-vitro evaluation of microleakage of an orthograde apical plug of mineral trioxide aggregate in permanent teeth with simulated immature apices. J Endod 2005;31:117–9.
21. Hachmeister DR, Schindler WG, Walker WA III, Thomas DD. The sealing ability and retention characteristics of mineral trioxide aggregate in a model of apexification. J Endod 2002;28:386–90.
22. Banchs F, Trope M. Revascularization of immature permanent teeth with apical periodontitis: new treatment protocol? J Endod 2004;30:196–200.
23. Windley W, Teixeira F, Levin L, Sigurdsson A, Trope M. Disinfection of immature teeth with a triple antibiotic paste. J Endod 2005;31:439–43.