Dental Traumatology 2007; doi: 10.1111/j.1600-9657.2006.00453.x

DENTAL TRAUMATOLOGY

The effect of calcium hydroxide root filling on dentin fracture strength

Rosenberg B, Murray PE, Namerow, K. The effect of calcium hydroxide root filling on dentin fracture strength. © Blackwell Munksgaard, 2006.

Abstract – This *in vitro* study measured the effect of calcium hydroxide root filling on the microtensile fracture strength (MTFS) of teeth. A total of 40 extracted human disease-free permanent maxillary incisors were hand and rotary instrumented and vertically compacted with United States Pharmacopeia (USP) calcium hydroxide. The teeth were stored in a moist environment for 7, 28, and 84 days. As a control group, 10 teeth were vertically compacted with gutta percha and sealer. The MTFS of the teeth was measured (Mpa) using an Instron machine. Data were assessed statistically using an unpaired *t*-test (*P* value). The intracanal placement of calcium hydroxide weakened the MTFS of teeth by 13.9 Mpa per 77 days: an average of 0.157 MPa day^{-1}. Between 7 and 84 days, the MTFS of the dentin was reduced by 43.9%. This difference was statistically significant ($P < 0.05$). A statistical difference ($P < 0.05$) was observed between the mean MTFS of the calcium hydroxide-filled dentin between 7 days (45.7 MPa) and 28 days (35.6 MPa) and also between 7 and 84 days (31.8 MPa). There was also a significant difference ($P < 0.05$) between the MTFS of the calcium hydroxide-filled dentin after 84 days (31.8 MPa) and the gutta percha-filled dentin (41.3 MPa) when used as a control root filling material. The weakening of the dentin by 23–43.9% following root canal filling with calcium hydroxide provides compelling evidence to re-evaluate the daily usage of this material in endodontic therapy.

Brett Rosenberg, Peter E. Murray, Kenneth Namerow

Department of Endodontics, College of Dental Medicine, Nova Southeastern University, Fort Lauderdale, FL, USA

Key words: calcium hydroxide; endodontics; root fracture

Dr Brett Rosenberg, College of Dental Medicine, Nova Southeastern University, 3200 S. University Dr., Fort Lauderdale, FL 33328-2018, USA
Tel.: (954) 262 1743
Fax: (954) 262 1782
e-mail: rosenbergendo@adelphia.net

Accepted 20 September, 2005

Calcium hydroxide is the most commonly used endodontic material and pulp capping agent (1). It is also a short- or long-term intracanal dressing material and may be included in some root canal sealers (2). Although a number of other root canal medicaments have been advocated (3), calcium hydroxide remains the compound of choice because of its superior activity and reduced cytotoxicity to the periradicular tissues. The routine application of calcium hydroxide products in dentistry has resulted in considerable degrees of success in the treatment of various pathological conditions of the tooth. These include: assisting in the production of reparative dentin to bridge a pulp exposure (4), induction of apical closure in incompletely developed pulpless teeth (5), healing of large periradicular lesions (6, 7), to prevent or arrest root resorption (8), and to repair perforations resulting from internal root resorption (9). A major factor in the therapeutic success of calcium hydroxide is its antibacterial activity (10, 11). The efficiency of this antibacterial action is directly proportional to the ability of hydroxide ions to diffuse from the calcium hydroxide compound (10).

Root fractures are generally defined as those that involve the dentin, cementum, pulp, and periodontal ligament. Root fractures of permanent teeth are uncommon. Their incidence ranges from 0.5% to 7.0% for all cases of dental trauma (12, 13). However, the incidence of root fracture in teeth following root canal filling appears to be much greater. It has been observed that 11% of luxated non-vital incisors fractured with minimal trauma (14).

It has been proposed that root canal filling with calcium hydroxide will lead to weakening of endodontically-treated teeth (15). Dentinal strength is determined by the link between hydroxyapatite and collagenous fibrils. Due to its strong alkalinity, calcium hydroxide may denature the carboxylate and phosphate groups leading to a collapse in the dentin structure. Many current endodontic procedures involve the use of long-term calcium hydroxide although its effects on permanent mature teeth has not been studied.

The strength of the teeth can be measured using the microtensile fracture strength (MTFS) test. The MTFS test allows bond strengths to be measured without cohesive failure of the dentin (16). Specimens used in the microtensile test are prepared with a minimal surface area that will theoretically produce a more uniform distribution of stress to the sample (17). The purpose of this study was to evaluate the longitudinal effect of calcium hydroxide root canal filling on the MTFS of human permanent teeth.

Materials and methods

Forty human maxillary incisor teeth without decay or fillings, which had been stored in 0.5% chloramine-T solution at 4°C for <6 months, were randomly assigned to four treatment groups. Teeth were matched for size and dentin thickness to reduce possible deviation. To prepare the teeth for root canal filling with calcium hydroxide, an access cavity was prepared using a no. 4 round bur. The working length was established by visualizing a file protruding beyond the apical foramen and subtracting 0.5 mm from this measurement (18). Gates Glidden burs nos 2, 3, and 4 (Tulsa Dentsply, Tulsa, OK, USA) were used for coronal access. All teeth were instrumented to an apical size of 45 using a Profile .06 rotary file (Tulsa Dentsply). Root canals were irrigated with a 6% solution of sodium hypochlorite (Tulsa Dentsply) after instrumentation. The teeth were dried using paper points and packed with calcium hydroxide (Kerr, Orange, CA, USA) mixed with saline, the placement was accomplished by the use of pluggers (19), or alternatively as a control, the root canals were filled using the warm vertical filling technique with gutta percha (Kerr). All the samples had a minimum of 3 mm Cavit seal (Kerr) placed coronally to mimic the *in situ* endodontic procedures. The MTFS of 10 gutta percha root-filled teeth were tested immediately. The other 30 calcium hydroxide root-filled teeth were stored in a humidor at 37°C to replicate the oral environment (20). At each of three time intervals: 7, 28, and 84 days, 10 tooth samples were removed from the humidor for MTFS testing.

MTFS was measured in a universal testing machine (Instron Model 1122; Instron Corp., Canton, MA, USA) at a cross-head speed of 1 mm min^{-1}. The tooth samples were prepared for MTFS testing by mounting them in acrylic resin blocks (Fig. 1). The tooth specimens were orientated with the crown submerged in acrylic resin to the cemento-enamel junction, leaving the root protruding from the block. The acrylic resin block and tooth sample was reinforced to prevent non-root fracture. The samples were loaded into a vice and the Instron had a customized cross-head spade that struck the cervical surface of the tooth at 1 mm min^{-1} (Fig. 2). The MTFS results were analyzed by a *t*-test to evaluate pairwise comparisons at $P < 0.05$. Statistical calculations were performed using Statview (SAS Institute, Cary, NC, USA).

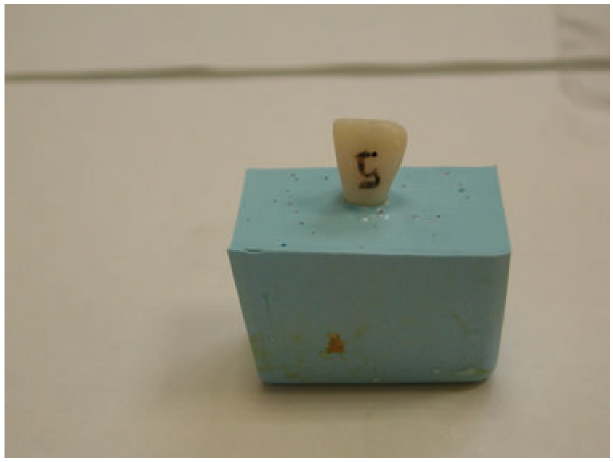

Fig. 1. Experimental tooth mounted in blue acrylic.

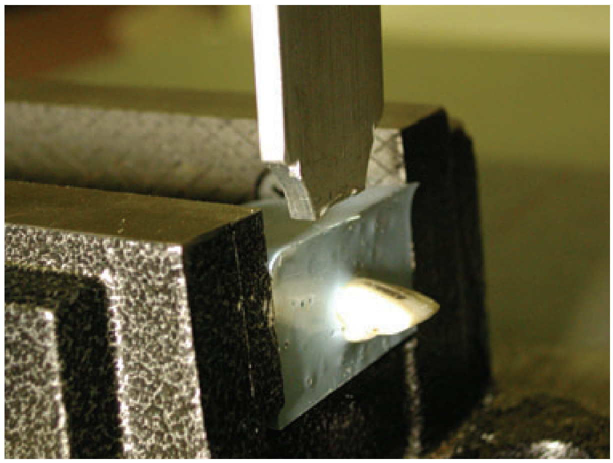

Fig. 2. Instron universal testing machine with custom jig.

Results

The mean MTFS of the gutta percha-filled teeth was 41.2 MPa. The mean MTFS of the calcium hydroxide-filled teeth was 45.7 MPa after 7 days,

Table 1. Test results (Moa)

Group 1 (control)	Group 2 (7 days)	Group 3 (28 days)	Group 4 (84 days)
46.23	40.13	36.25	35.44
37.23	44.83	18.99	39.83
45.84	66.85	30.82	33.50
37.84	41.27	24.99	30.11
49.60	61.45	34.11	28.18
48.60	43.74	40.99	29.65
32.35	41.87	34.97	28.39
30.41	32.58	48.84	29.88
39.04	38.91	43.51	43.20
45.33	45.17	42.62	19.37
Mean: 41.247	Mean: 45.68	Mean: 35.61	Mean: 31.76
SD: 6.795	SD: 10.46	SD: 9.01	SD: 6.68

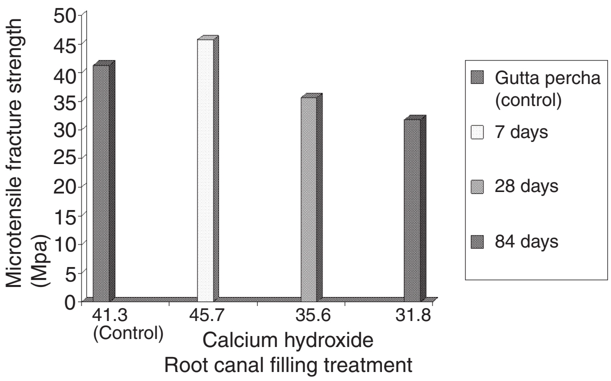

Fig. 3. Bar graph summarizing test results.

35.6 MPa after 28 days, and 31.8 MPa after 84 days (Table 1).

There was a significant difference ($P < 0.05$) between the MTFS of the calcium hydroxide-filled dentin after 84 days (31.8 MPa) and the gutta percha-filled dentin (41.3 MPa) when used as a control root filling material (Fig. 3). Little statistical difference in MTFS was found between the gutta percha control group and the 7 days ($P < 0.257$) and 28 days calcium hydroxide groups ($P > 0.05$). There was also a significant difference ($P < 0.05$) between the MTFS of the calcium hydroxide-filled teeth between 7 and 28 days ($P < 0.0331$), and between 7 and 84 days ($P < 0.0023$), but not between 28 and 84 days ($P < 0.2914$). The intracanal placement of calcium hydroxide weakened the MTFS of the dentin by 13.9 MPa per 77 days: an average of 0.157 MPa day^{-1}. Between 0 days (control) and 84 days the fracture strength of the dentin was reduced by 23% and between 7 and 84 days, the fracture strength of the dentin was reduced by 43.9%.

Discussion

Root canal filling with calcium hydroxide reduced the MTFS of teeth by almost 50% between 7 and 84 days. A weakening of root-filled teeth may predispose these teeth to fracture. It is estimated that there are 15 million root canal therapies each year in the USA (21). Surveys of the success and failure studies of root canal-treated teeth are numerous. The reported prevalence of vertical root fractures in various populations is between 2% and 11%, based on case reports (22, 23), recall of patients treated prosthetically (24, 25), evaluation of radiographs from dental records (26), or assessment of root fractures extracted endodontically-treated teeth (27).

Information about the MTFS of endodontically-treated human teeth is scarce. This study is one of a few studies that examines the effect of endodontic materials on MTFS. It has been reported that long-term treatment with calcium may weaken roots and contribute to the fracture failure of immature teeth (8, 13). The long-term root filling of teeth with calcium hydroxide is commonly accepted. Traditional apexification procedures may take up to 1 year or more. It has been shown that these teeth are prone to fracture and may be lost before or after completion of a lengthy calcium hydroxide apexification (15).

Few reports of human dentin fracture strength changes in response to endodontic materials are available in the literature. Comparisons of the present MTFS observations are limited to reports of animal dentin fracture strength. A study of bovine dentin maintained in petri dishes for 5 weeks reported that calcium hydroxide could reduce the fracture strength by 32% (28). The fracture strength of sheep dentin was reduced by 50% following calcium hydroxide treatment after 1 year (13). The 50% reduction in the fracture strength of sheep dentin is comparable with the 43% (from 7 to 84 days) reduction in MTFS observed in the present study. However, it should be noted that the 50% reduction in MTFS was observed after only 84 days. In the absence of a long-term MTFS testing of human teeth filled with calcium hydroxide or other endodontic materials, it is unclear how the MTFS will change up to 1 year or more. Some other endodontic materials have the potential to weaken the MTFS of teeth. Mineral trioxide aggregate and sodium hypochlorite reduce the fracture strength of bovine dentin by 33% and 59%, respectively (28). Not all materials weaken tooth structure. An *in vitro* study reported that composite resin and glass ionomer can increase the fracture resistance of endodontically-treated roots (29). The limited information available highlights the requirement to further evaluate the effects of endodontic materials to weaken or strengthen the tooth structure.

In the meantime, in order to avoid the failure of teeth following endodontic treatment it is important to warn patients to avoid causing trauma to teeth at risk from fracture. The best current treatment is a short-term dressing of calcium hydroxide for canal disinfection, a 6-mm apical plug of MTA, followed by restoration with a dual cure composite resin (30). In the longer term, it seems necessary to develop endodontic materials, which will not weaken the tooth structure. The 23–43.9% reduction in MTFS of root-filled teeth with extended use of calcium hydroxide provides compelling evidence to re-evaluate the traditional use of calcium hydroxide in long-term treatment.

References

1. Yoshiba N, Iwaku M. Histological observations of hard tissue barrier formation in amputated dental pulp capped with a-tricalcium phosphate containing calcium hydroxide. Endod Dent Traumatol 1994;10:113–20.
2. Holland R, D'Souza V. Ability of a new calcium hydroxide root canal filling material to induce hard tissue formation. J Endod 1985;11:535–43.
3. Steinberg D, Friedman M, Saskolne A, Sela MN. A new degradable controlled release device for treating periodontal diseases, an in vitro release study. J Periodontol 1990;61:393–8.
4. Zander HA. Reaction of the dental pulp to calcium hydroxide. J Dent Res 1939;18:373.
5. Fava LRG. A clinical evaluation of one and two-appointment root canal therapy using calcium hydroxide. Int Endod J 1994;27:47–51.
6. Crabb HS. The basis of root canal therapy. Dent Pract 1965;15:397–401.
7. Kennedy GD, Simpson MS. The hollow tube controversy. J Brazilian Endod Soc 1969;3:51–7.
8. Andreasen JO. Treatment of fractured and avulsed teeth. J Dent Child 1971;38:29–31.
9. Frank AL, Weine FS. Non-surgical therapy for the perforation defect of internal root resorption. J Am Dent Assoc 1973;87:853–68.
10. Fisher FJ, McCabe JF. Calcium hydroxide base materials: an investigation into the relationship between chemical structure and antibacterial properties. Br Dent J 1978;144:341.
11. Brannstrom M, Vojinovic O, Nordenvall KJ. Bacteria and pulpal reactions under silicate cement restorations. J Prosthet Dent 1979;31:290–5.
12. Andreasen FM, Andreasen JO. Root fractures. In: Andreasen JO, Andreasen FM, editors. Textbook and color atlas of traumatic injuries to the teeth. Copenhagen: Munksgaard; 1994. p. 279–314.
13. Andreasen FM, Andreasen JO, Bayer T. Prognosis of root-fractured permanent incisors-prediction of healing modalities. Endod Dent Traumatol 1989;5:11–22.
14. Cvek M. Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta percha. Endod Dent Traumatol 1992;8:45–55.
15. Andreassen 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.
16. Sano H, Shono T, Sonada H, Takatsu T, Ciucchi B, Carvalho R et al. Relationship between surface area for adhesion and tensile bond strength—evaluation of a microtensile bond test. Dent Mater 1994;10:236–40.
17. Pashley DH, Sano H, Ciucchi B, Yoshiyama M, Carvalho RM. Adhesion testing of dentin bonding agents: a review. Dent Mater 1995;11:117–25.
18. Kim-Park MA, Baughan LW, Hartwell GR. Working length determination in palatal roots of maxillary molars. J Endod 2003;29:58–61.
19. Estrela C, Mamede Neto I, Lopes HP, Estrela CR, Pecora JD. Root canal filling with calcium hydroxide using different techniques. Braz Dent J 2002;13:53–6.
20. Millett DT, Cummings A, Letters S, Roger E, Love J. Resin-modified glass ionomer, modified composite or conventional glass ionomer for band cementation? – an in vitro evaluation. Eur J Orthod 2003;25:609–14.
21. American Association of Endodontics. Annual report 2002. Chicago, IL: American Association of Endodontics; 2002.
22. Meister F, Lommel TJ, Gerstein H. Diagnosis and possible causes of vertical root fracture. Oral Surg Oral Med Oral Pathol 1980;49:243–53.
23. Testori T, Badino M, Castagnola M. Vertical root fractures in endodontically treated teeth: a clinical survey of 36 cases. J Endod 1993;19:87–90.
24. Bergman B, Lundquist P, Sjögren U, Sundquist G. Restorative and endodontic results after treatment with cast posts and cores. J Prosthet Dent 1989;61:10–5.
25. Torbjörner A, Kalsson S, Odman PA. Survival rate and failure characteristics for two postdesigns. J Prosthet Dent 1995;73:439–44.
26. Morfis AS. Vertical root fractures. Oral Surg Oral Med Oral Pathol 1990;69:631–5.
27. Fuss Z, Lustig J, Tamse A. Prevalence of vertical root fractures in extracted endodontically treated teeth. Int Endod J 1999;32:283–6.
28. White JD, Lacefield WR, Chavers LS, Eleazer PD. The effect of three commonly used endodontic materials on the strength and hardness of root dentin. J Endod 2002;28:828–30.
29. Trope M, Maltz DO, Tronstad L. Resistance to fracture of restored endodontically treated teeth. Endod Dent Traumatol 1985;1:108–11.
30. Shabahang S, Torabinejad M, Boyne PP, Abedi H, McMillan P. A comparative study of root-end induction using osteogenic protein-1, calcium hydroxide, and mineral trioxide aggregate in dogs. J Endod 1999;25:1–5.