Fracture Resistance of Human Root Dentin Exposed to Intracanal Calcium Hydroxide

Glen E. Doyon, DMD, Thom Dumsha, MS, DDS, MS,* and J. Anthony von Fraunhofer, MSc, PhD[†]*

Abstract

The purpose of the present study was to determine if exposure to intracanal calcium hydroxide [$Ca(OH_2)$] alters the fracture resistance of human root dentin. One hundred and two freshly extracted single rooted human teeth divided into three groups of 34 teeth each. Coronal access and endodontic instrumentation using round burs, stainless steel files, and Profile GT rotary files were completed for each tooth. The prepared root canal system of each tooth was filled with saline solution (group 1), USP $Ca(OH)_2$ (group 2), or Metapaste (group 3). The apicies and access openings were sealed with composite resin and the teeth were immersed in saline. After 30 days, the roots of 17 teeth from each group were sectioned horizontally into 1-mm thick disks and each disk was loaded to fracture at 2.5 mm/min with a SATEC universal-testing machine. After 180 days the same procedure was performed on the remaining 17 teeth in each of the 3 groups. The peak load at fracture was measured for each dentin disk. Data were analyzed using one-way ANOVA and a post hoc Student-New-man-Keuls test. After 30 days exposure to the test solution, there was no difference in the peak load at fracture for the three groups of teeth. However, after 180 days, the roots of the teeth exposed to USP $Ca(OH)_2$ showed a significant decrease in peak load at fracture when compared to the 30-day groups and the 180-day groups exposed to saline or Metapaste.

Key Words

Calcium hydroxide, fracture, dentin, instrumentation, trauma

From the *Department of Endodontics and Periodontics; [†]Department of Oral and Maxillofacial Surgery, University of Maryland Dental School, Baltimore, Maryland.

Address requests for reprint to Dr. Glen E. Doyon, The Center for MicroSurgical Endodontics, 10752 N. 89th Place #117, Scottsdale, AZ 85260. E-mail address: gedoyon@hotmail.com.

Copyright © 2005 by the American Association of Endodontists

The use of calcium hydroxide [$Ca(OH)_2$], in dentistry is well established and widespread. It was introduced to endodontics by Hermann in 1920 (1) and has been used extensively in multiple endodontic applications. $Ca(OH)_2$ has been used in various formulations as a liner beneath restorations and as a pulp-capping agent (2, 3). It is often applied within the root canal system for the control of inflammatory root resorption after luxation and avulsion injuries (4). $Ca(OH_2)$ is widely accepted as an inter-appointment intracanal medicament (5) during endodontic therapy and its use in apexification procedures has been described (6, 7) When placed within the root canal system, $Ca(OH)_2$ disassociates into calcium and hydroxyl ions (8), and the hydroxyl ions diffuse through the dentinal tubules (9, 10).

The high pH and antimicrobial properties of $Ca(OH)_2$ (11), combined with the permeability of dentin (12, 13), may account for its effectiveness as an intracanal inter-appointment medicament, an inhibitor of inflammatory root resorption, and an inducer of apical closure in nonvital immature teeth. However, when $Ca(OH)_2$ is used in these applications, therapy may extend from months to years before the desired effects are achieved (14, 15). Furthermore, it has been observed that $Ca(OH)_2$ treated immature teeth show a high failure rate because of an unusual preponderance of root fracture and it has been suggested that changes in the physical properties of dentin by the $Ca(OH)_2$ medicament may be responsible (16, 17). For example, a 5-wk exposure to $Ca(OH)_2$ resulted in a 32% decrease in the strength of bovine dentin (18). In sheep dentin treated with $Ca(OH)_2$, a marked decrease in fracture strength with increasing storage time was observed (19). Most importantly, when immersed in a saturated solution of $Ca(OH)_2$ for 1 wk, a reduction in the flexural strength of human dentin was demonstrated (20).

Exposure of root dentin to the bioactive effects of $Ca(OH)_2$ may affect its physical characteristics and could have important clinical implications for the treatment of traumatized teeth and immature teeth with nonvital pulps. The purpose of the present study was to determine if intracanal exposure to $Ca(OH)_2$ for 30 days and 180 days alters the fracture resistance of human root dentin.

Materials and Methods

One hundred and two freshly extracted single rooted human teeth consisting of maxillary and mandibular incisors, canines, and premolars were obtained from the Oral and Maxillofacial Surgery Clinic at the University of Maryland Dental School. After extraction, the teeth were immediately stored in sterile saline. The teeth were sorted by size and type and subsequently randomly assigned to one of three groups so that each group was comprised of 34 similar teeth.

Each tooth was accessed coronally with a #4 or #6 round carbide bur (Midwest, Wichita Falls, TX). The canals were instrumented to a size 20 stainless steel K file (Dentsply Maillefer, Johnson City, TN) so that the file extended beyond the apical foramen by 1 mm. The canals were then instrumented with rotary Profile GT files (Dentsply Tulsa Dental, Johnson City, TN) and finished to a size 20/06, 20/08, or 20/10. All files were extended 1 mm beyond the apical foramen and copious irrigation with sterile saline was completed between file systems. The canals were then rinsed with sterile saline using a 27-gauge needle and 3 ml syringe to remove any dentin debris remaining in the canal after instrumentation.

The root canals of the teeth in group 1 were filled with saline and sealed apically with bonded composite resin (Henry Schein, Melville, NY) and coronally with a cotton

Copyright © by the American Association of Endodontists. Unauthorized reproduction of this article is prohibited.

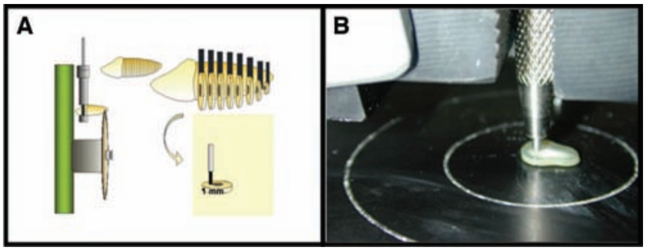

Figure 1. (A) Dentin disk preparation using an Isomet saw, (illustration courtesy of Teixeira FB, Levin LG, and Trope M). (B) A 1.2 mm punch being lowered onto 1.0 mm dentin disk in SATEC universal testing machine.

pellet and bonded composite resin. The root canals of the teeth in group 2 were filled with USP $Ca(OH)_2$ (Henry Schein) mixed to a thick slurry with sterile saline. To insure intimate contact with the canal walls and a dense fill of the canal space, excess $Ca(OH)_2$ was intentionally extruded past the apex using a Lentulo spiral (Henry Schien) (21). The root canals of the teeth in group 3 were filled with Metapaste (Meta Biomed, Korea), a proprietary $Ca(OH)_2$ product, and again, the canals were densely filled by extruding the material through the apex using the syringe and plastic tip supplied (21). As with group 1, the teeth in groups 2 and 3 were sealed apically with bonded composite and coronally with a cotton pellet and bonded composite.

The teeth were maintained at room temperature ($22 \pm 0.5°C$) in saline-soaked gauze throughout the preparation procedures and then stored in sterile 0.9% saline solution at room temperature in plastic containers. After 30 days, 17 teeth from each group were removed from the saline storage containers and the root horizontally sectioned into 1-mm thick specimens with a water-cooled diamond saw (Isomet; Buehler Ltd., Lake Bluff, IL). Depending on the length of the root, 4 to 8 sections were obtained from each specimen (Fig. 1a). Each section was then placed in a universal testing machine (SATEC T5000, Grove City, PA) and a mounted punch with a 1.2 mm cross section was centered between the canal and the outside edge of the dentin disk and lowered onto the specimen at a cross head speed of 2.5 mm/min until the specimen fractured (Fig. 1b). The test machine software automatically recorded the peak load at fracture. After 180 days, the remaining 17 teeth from each group were removed from the saline storage containers and tested in the same manner as the 30 day group.

The mean peak load at fracture for each group was calculated and the results from all groups were compared by a one-way ANOVA and a post hoc Student-Newman-Keuls test (SPSS for Windows Student Version, Release 8.0.0).

Results

Data from 111, 103, and 83 sections were obtained from the 30-day saline, $Ca(OH)_2$, and Metapaste groups, respectively. A computer software error resulted in the loss of 12 data points from the Metapaste group. The mean peak loads at fracture were 61.7, 61.5, and 59.0 kg for the 30-day saline, $Ca(OH)_2$, and Metapaste groups, respectively.

Data from 93, 88, and 93 sections were obtained from the 180-day saline, $Ca(OH)_2$, and Metapaste groups, respectively. The mean peak loads at fracture were 57.8, 49.9, and 56.0 kg for the 180 day saline, $Ca(OH)_2$, and Metapaste groups, respectively (Table 1).

There were no statistically significant differences among the fracture loads for any of the 30-day specimens. A statistically significant decrease in peak load at fracture of the root dentin exposed to USP $Ca(OH)_2$ (group 2) was observed in the 180 day group when compared to the other five groups ($F = 7.039$, $p < 0.05$). Fig. 2 represents a graphical display of the data.

TABLE 1. Mean peak load at fracture

Sample	N	Mean	Std. Deviation
Saline-30 d	111	61.66	17.12
Metapaste-30 d	83	59.02	11.98
$Ca(OH)_2$-30 d	103	61.46	12.76
Saline-180 d	93	57.81	16.33
Metapaste-180 d	93	56.02	17.57
$Ca(OH)_2$-180 d	88	49.99	17.93
Total	571	57.89	16.24

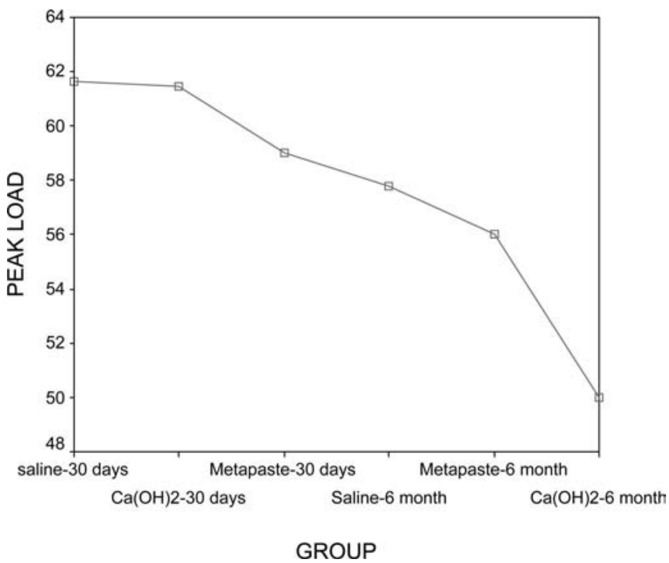

Figure 2. Peak load at fracture of the six experimental groups.

Discussion

The purpose of this research was to examine the possible deleterious effects of $Ca(OH)_2$ on human root dentin. $Ca(OH_2)$ is a material used in endodontic treatment of human teeth, often over extended periods of time. Extracted human teeth were selected because the effects of long term $Ca(OH)_2$ on human dentin have not been previously studied. The forces placed on human teeth in vivo are different than those placed on the dentin disks used in this study. However, it was felt that the current protocol would account for the variability of human dentin, not only between different teeth but also along the length of an individual root. It was assumed that if any of the tested materials affected the structural integrity of human dentin, a change in the compressive forces required to fracture a dentin disk would likely show a commensurate change in the shear forces required to cause a horizontal root fracture in vivo.

In a retrospective study, Cvek (16) investigated 885 luxated nonvital incisors treated with $Ca(OH)_2$ over a period ranging from 3 to 54 months with the mean value for immature teeth being 24 months and 11 months for mature teeth. Of the 885 teeth, 168 suffered a cervical root fracture within the follow-up period, which ranged from 3.5 to 5 yr. Cvek noted a strong relationship between the maturity of the root and the frequency of fractures and also that with immature teeth, the frequency of fractures was highly dependent on the stage of root development. Finally, he observed that immature teeth demonstrating a cervical resorptive defect were significantly more likely to fracture than those without such a defect. It would seem reasonable to conclude that the increase in frequency of fracture resulted from incomplete root development and subsequent thinner dentinal walls, secondary to pulpal

Copyright © by the American Association of Endodontists. Unauthorized reproduction of this article is prohibited.

necrosis. In addition, the effects of coronal access on resistance to fracture must not be overlooked.

The findings of this study appear to support the contention that long term exposure to $Ca(OH_2)$ alters the physical properties of dentin. This may be a result of a change in the organic matrix (19). It has been shown that $Ca(OH_2)$ dissolves pulp tissue (22, 23), a process that may occur by denaturation and hydrolysis. In addition, the pH increase observed after exposure to $Ca(OH_2)$ may also reduce the organic support of the dentin matrix (12, 13). These processes may disrupt the interaction of the collagen fibrils and hydroxyapatite crystals that could negatively influence the mechanical properties of dentin.

It is noteworthy that the dentin disks exposed to Metapaste for 180 days did not demonstrate the same reduction in peak load at fracture as did the disks exposed to USP $Ca(OH)_2$. The authors are unaware of any studies on the use or effectiveness of this material as a long-term intracanal medicament. Additional research is necessary to verify the results of this study and to examine the clinical value of this material.

In the present study, there was a statistically significant difference in the peak load at fracture between human dentin disks exposed to USP $Ca(OH_2)$ for 180 days when compared to teeth exposed to USP $Ca(OH_2)$, Metapaste, and saline for 30 days and to teeth exposed to Metapaste and saline for 180 days. The difference in peak load at fracture between the 180 day USP $Ca(OH_2)$ group and the other experimental groups ranged from 9.9 to 19.0%. It may be that a 10 to 20% decrease in strength is sufficient to significantly increase the likelihood of fracture to already structurally compromised teeth. Further testing is required to examine the clinical relevance of these findings.

References

1. Hermann BW. Calcium hydroxyd als Mittel Zum Behandel und Fullen Von Zahnwurzelkana len. Wuzburg: Med Diss, 1920.
2. Weiner RS. Liners, bases, and cements: a solid foundation. Gen Dent 2002;50:442–6.
3. Stanley HR. Pulp capping: conserving the dental pulp—can it be done? Is it worth it? Oral Surg Oral Med Oral Pathol 1989;68:628–39.
4. Cvek M. Treatment of non-vital permanent incisors with calcium hydroxide. II. Effect on external root resorption in luxated teeth compared with effect of root filling with guttapucha. A follow-up. Odontol Revy 1973;24:343–54.
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 Traumatol 1985;1:170–5.
6. Frank AL. Therapy for the divergent pulpless tooth by continued apical formation. J Am Dent Assoc 1966;72:87–93.
7. Heithersay GS. Stimulation of root formation in incompletely developed pulpless teeth. Oral Surg Oral Med Oral Pathol 1970;29:620–30.
8. Pashley DH. Dentin: a dynamic substrate—a review. Scanning Microsc 1989;3:161–74.
9. Pashley DH, Livingston MJ, Outhwaite WC. Rate of permeation of isotopes through human dentin, in vitro. J Dent Res 1977;56:83–8.
10. Foreman PC, Barnes IE. Review of calcium hydroxide. Int Endod J 1990;23:283–97.
11. Tamburic SD, Vuleta GM, Ognjanovic JM. In vitro release of calcium and hydroxyl ions from two types of calcium hydroxide preparation. Int Endod J 1993;26:125–30.
12. Tronstad L, Andreasen JO, Hasselgren G, Kristerson L, Riiss I. pH changes in dental tissues after root canal filling with calcium hydroxide. J Endod 1980;7:17–21.
13. Nerwich A, Figdor D, Messer HH. pH changes in root dentin over a 4-week period following root canal dressing with calcium hydroxide. J Endod 1993;19:302–6.
14. Sheehy EC, Roberts GJ. Use of calcium hydroxide for apical barrier formation and healing in non-vital immature permanent teeth: a review. Br Dent J 1997;183:241–6.
15. Dannenberg JL. Pedodontic endodontics. Dent Clin North Am 1974;18:367–77.
16. 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.
17. Stormer K, Jacobsen I, Attramadal A. Hvor funkjonsdyktige blir rottfylte unge permanente incisiver? In: Nordisk forening for pedodonti. Bergen, Norway: Aarsmote, 1988.
18. 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.
19. 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.
20. Grigoratos D, Knowles J, Ng Y-L, Gulabivala K. Effect of exposing dentine to sodium hypochlorite and calcium hydroxide on its flexural strength and elastic modulus. Int Endod J 2001;34:113–9.
21. Torres CP, Apicella MJ, Yancich PP, Parker MH. Intracanal placement of calcium hydroxide: a comparison of techniques, revisited. J Endod 2004;30:225–7.
22. Anderson M, Lund A, Andreasen JO, Andreasen FM. In vitro solubility of human pulp tissue in calcium hydroxide and sodium hypochlorite. Endod Dent Traumatol 1992;8:104–8.
23. Hasselgren G, Olsson B, Cvek M. Effects of calcium hydroxide and sodium hypochlorite on the dissolution of necrotic porcine muscle tissue. J Endod 1988;7:17–21.

Copyright © by the American Association of Endodontists. Unauthorized reproduction of this article is prohibited.