The Effect of Long-term Dressing With Calcium Hydroxide on the Fracture Susceptibility of Teeth

Sam L. Kahler, BBioMedSc, Sowmya Shetty, MDS, PhD,† Frances M. Andreasen, BS, DDS, Dr Odont,‡ and Bill Kahler, DClinDent, PhD†*

Abstract

Introduction: Calcium hydroxide has been widely used to treat immature teeth to achieve periodontal healing and to promote the formation of an apical barrier. However, retrospective clinical studies have shown a high incidence of cervical root fractures with long-term calcium hydroxide dressing. The alkalinity of calcium hydroxide has been suggested to weaken the root. *In vitro* studies using ovine teeth show conflicting results on fracture strength of dentine, although different commercial products may have influenced the results. The purpose of this study was to investigate the effects of 2 commercial products used in prior studies (Calasept Plus and UltraCal XS), as well as a new product (Calmix) that uses a nonaqueous vehicle that allows for a higher pH, on the fracture strength of dentine over time. **Methods:** A total of 330 lamb incisor teeth were collected and the canals prepared so that 3 commercial calcium hydroxide products as well as a positive control of pure calcium hydroxide slurry that filled the root canal from the open apex and a negative control of saline was tested. The teeth were loaded until fracture with a universal testing machine at time points 0, 3, 6, and 9 months and the force to fracture was calculated. The data were analyzed with Friedman analysis of variance and Mann-Whitney *t* tests. **Results:** No statistical differences were observed between the different calcium hydroxide products and the negative controls. **Conclusions:** Thin and fragile roots could be the cause of fracture rather than the calcium hydroxide dressing. *(J Endod 2017;■:1–6)*

Key Words

Calcium hydroxide, cervical root fractures, fracture strength, immature teeth, pH

Significance

Long-term use of calcium hydroxide in immature teeth has been reported to leave teeth prone to cervical root fracture. However, root fracture may be more related to stage of root development than to the long-term use of calcium hydroxide.

Calcium hydroxide has been used in the treatment of immature teeth to achieve periodontal healing and to promote the formation of an apical barrier to facilitate the placement of a root canal filling (1–3). Systematic reviews and clinical cohort studies have shown apexification techniques using calcium hydroxide to have similar results to either apical barrier techniques with mineral trioxide aggregate or treatment with regenerative endodontic protocols (4, 5). However, 2 retrospective clinical studies reported a high incidence of cervical root fractures in immature teeth when calcium hydroxide was used as an intracanal medicament. The incidence of fracture was 40% and 32%, respectively (6, 7). An *in vitro* study of ovine teeth reported that the fracture strength of sheep teeth treated with calcium hydroxide was reduced by approximately 50% after 1 year (8).

A number of other *in vitro* studies measuring the effect of calcium hydroxide on teeth using different methodologies have supported the premise that teeth with calcium hydroxide have a higher fracture susceptibility. The microtensile fracture strength of permanent human incisor teeth was reduced by 23.0% to 43.9% when canals were filled with calcium hydroxide after 7 to 84 days (9). White et al (10) machined 10 dentine cylinders from bovine teeth, which were then soaked in calcium hydroxide in a Petri dish. Fracture strength of the dentine was reduced by 32%. Grigoratos et al (11) prepared dentin bars from human teeth that were exposed to saturated calcium hydroxide, which reduced the flexural strength of dentin. It was suggested this could result in crack initiation and propagation from root canal wall dentin. Doyon et al (12) reported that human roots prepared into 1-mm-thick disks exposed to calcium hydroxide significantly decreased the fracture load after 180 days. In a study of mature human teeth, prepared root cylinders in teeth where calcium hydroxide was placed in the canal for 30 days required significantly less force until breakage when compared with untreated teeth (13). These clinical and experimental studies appear to suggest that short- and long-term use of calcium hydroxide in the treatment of immature teeth weakens the roots and increases the risk of cervical root fracture. Long-term use of calcium hydroxide was therefore not advised and alternative treatment options, such as apical barrier techniques with placement of mineral trioxide aggregate (14, 15) or regenerative endodontic protocols have been recommended (16).

A recent study found that ovine teeth dressed with 3 different commercial calcium hydroxide medicaments (Vitapex [Neo Dental Chemical Products Co. Lt, Tokyo, Japan],

From the *School of Biomedical Sciences, and †School of Dentistry, The University of Queensland, Herston, Queensland, Australia; and ‡University Hospital (Rigshospitalet), Department of Oral and Maxillofacial Surgery, Copenhagen, Denmark.

Address requests for reprints to Dr Bill Kahler, School of Dentistry, The University of Queensland, 288 Herston Rd, Herston QLD 4006, Australia. E-mail address: w.kahler@uq.edu.au

0099-2399/$ - see front matter

https://doi.org/10.1016/j.joen.2017.09.018

UltraCal XS [Ultradent Productions, Inc., South Jordan, UT], and Pulpdent [Pulpdent Corp, Watertown, MA]) for 6 months showed no statistical differences between the treated and negative saline control groups. In fact, the saline control group exhibited the greatest fracture susceptibility (17). Similarly, another study of ovine teeth found that the untreated teeth also exhibited the greatest fracture susceptibility when compared with teeth dressed with UltraCal XS for 12 months (18). These results differ from Andreasen et al (8, 14) in which the teeth were dressed with Calasept (Nordiska Dental, Angelholm, Sweden). In the study by Andreasen et al (8), the saline control was discontinued after 2 months, so it is not known whether further fracture susceptibility would have occurred over a similar observation period as the treated teeth. Hawkins et al (17) postulated that the different formulations of calcium hydroxide were the most likely reason for the different results. Calcium hydroxide with different vehicles affects the rate of diffusion of Ca^{2+} through dentine (19).

Calasept consists of 41.07% calcium hydroxide mixed with isotonic saline and has a pH of 12.4. UltraCal XS consists of 35% calcium hydroxide in an aqueous vehicle with a pH of 12.5. Pure calcium hydroxide has a pH of 12.5 to 12.8 (15). Placing calcium hydroxide into water in amounts above the solubility limit will not increase the pH, as no further calcium hydroxide will dissolve (20); however, the undissolved material will thicken the calcium hydroxide paste and act as a reservoir making further hydroxyl ions available (20). The pH of calcium hydroxide is important, as it has been suggested that calcium hydroxide, due to its alkaline properties, may neutralize, dissolve, or denature the acidic components, such as acid proteins and proteoglycans, in the organic matrix of dentin, which act as bonding agents within the root, and thereby weaken the dentin (8). Therefore, it is of interest that a new calcium hydroxide material has been released, Calmix, which uses polyethylene glycol (PEG) as an alternative vehicle to aqueous materials. When PEG is used as the solvent for calcium hydroxide, a higher pH is achieved and more hydroxyl ions are available than aqueous-based calcium hydroxide products (20). In addition, hydroxyl ion penetration into dentin roots was greater when PEG was used as the vehicle (20). Calmix uses 37.5% calcium hydroxide with 45.5% PEG 400 and reaches a pH of 15.16 with the manufacturer stating a pH of greater than 13.5 (20).

Pure calcium hydroxide was not tested as a positive control in any of the aforementioned studies (8, 14, 17, 18). Hawkins et al (17) stated that a positive control was not used due to the large body of evidence confirming the weakening effect of calcium hydroxide. The authors suggested that this was a limitation. Another limitation of that study was the sample size of the saline negative control test group of only 5 teeth. The other studies all had control test groups of 10 or fewer teeth (8, 14, 18). The sample size of the calcium hydroxide groups was also small in the other studies. Andreasen et al (8) loaded only 10 teeth at the 1-year test point. In the Andreasen et al 2006 study (14), the calcium hydroxide group consisted of only 6 teeth with a standard deviation of 35% at the final test point.

It would appear that the fracture strength resistance as the result of long-term dressing with calcium hydroxide requires further investigation due to the conflicting results of prior studies and different formulations of calcium hydroxide used. Therefore, the purpose of this study was to test Calasept, UltraCal XS, and the recently released Calmix. An ovine model similar to prior studies was used with both positive and negative controls and with larger sample sizes than prior studies. The research question was: Does calcium hydroxide weaken teeth over a long time period?

Methodology

This study broadly followed the methodology of the prior ovine studies (8, 14, 17, 18) (Table 1). University of Queensland's Animal welfare unit provided ethics approval for collection of lamb jaws from the abattoir (Animal Ethics Approval certificate no. ANRFA/DENT/556/15). A total of 330 mandibular incisor teeth were extracted from 9-month-old lambs immediately after slaughtering and placed in 10% buffered formalin solution at room temperature. All teeth were visually inspected for cracks or damage before being included as specimens. One week later, the apical section of the root was sectioned 10 mm from the cemento-enamel junction (CEJ) with a diamond bur. The remaining radicular pulp was removed with a barbed broach. Root canal preparation was undertaken through the open apex to a size Profile #30 and a 0.04 taper (Dentsply Australia Pty Ltd, Mt Waverley, Victoria, Australia). Each canal was irrigated with 5 mL NaOCl, 5 mL EDTA, flushed with 5 mL sterile saline and then dried with paper points. Seventy-five roots were randomly assigned to the 3 brands of calcium hydroxide and 45 roots for each of the positive and negative controls. A further 15 teeth were assigned to test the fracture strength of the teeth at time point zero being the commencement of the experiment (see later in this article) (Table 2). The commercial calcium hydroxide paste assigned to each group was spun into 75 teeth with a lentulo-spiral placed in a slow-speed hand piece. A slurry of pure calcium hydroxide powder mixed with a minimum of sterile saline was spun and packed into 45 teeth to act as positive controls. The canals of 60 teeth consisting of 45 teeth to act as negative controls and 15 teeth to test time point zero were filled with saline. In all teeth, 4 mm of Cavit (3M, North Ryde, NSW, Australia) was placed into the apex to seal the calcium hydroxide or saline within the canal. The samples were stored in

TABLE 1. A Comparison of the Methodologies Used in the Ovine Studies That Test the Effect of Long-Term Dressing With Calcium Hydroxide

Study	Lamb age at extraction, mo	Storage	Instron spade placement in load to failure test	No. of teeth, control | calcium hydroxide	Test duration
Andreasen et al, (2002)	4	Room temperature in saline	2.5 mm from incisal edge on facial aspect	10 | 10	12 mo
Andreasen et al, (2006)	4	Frozen, then stored at 6°C in saline	2.5 mm from incisal edge on facial aspect	9 | 6	100 d
Hatibović-Kofman et al, (2008)	9	4°C in saline replaced monthly	3 mm from incisal edge on facial aspect	9 | 9	12 mo
Hawkins et al, (2015)	2	Frozen, then stored at 37°C in saline replaced weekly	1 mm from buccal cemento-enamel junction on facial aspect	5 | 25	6 mo
Current study	9	Room temperature, then stored at 37°C in saline replaced weekly	1 mm from buccal cemento-enamel junction on facial aspect	15 | 25	9 mo