Dental Traumatology

Dental Traumatology 2013; **29**: 461–464; doi: 10.1111/edt.12037

The long-term effect of calcium hydroxide application on dentin fracture strength of endodontically treated teeth

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Abstract – *Objective*: The aim of this *in vitro* study was to evaluate the long-term effect of calcium hydroxide (CH) on the microtensile fracture strength (MTFS) of endodontically treated human teeth. *Materials and Methods*: A total of 105 caries-free extracted human mandibular incisors were used. The teeth were divided into seven experimental groups of 15 teeth each. The root canals of all the teeth were rotary instrumented. The teeth in the control group were immediately obturated and tested for MTFS. The rest of the teeth were vertically compacted with CH and a sterile saline solution mixture and sealed with temporary filling. The teeth were stored in a moist environment for 30, 90, 180, 270, 360, and 540 days. On scheduled dates, the root canals were obturated and then the teeth were tested for MTFS with an Instron testing machine. The Kruscal–Wallis test and a *post hoc* Dunn's multiple comparison test was utilized. The statistical significance level was established at $P < 0.05$. *Results*: The introduction of CH into the root canals seems to decrease the MTFS of teeth statistically significantly through the 180th, 270th, 360th, and 540th days, respectively, compared with the control group. The results clearly indicated that there are statistically significant differences between group 2 and group 7 ($P < 0.001$) and between group 3 and group 7 ($P < 0.05$). There were no statistically significant differences between the rest of the groups ($P > 0.05$). *Conclusions*: The results indicate that long-term CH treatments can significantly reduce the strength of the teeth, causing an increase in fracture risk.

Key words: calcium hydroxide; root fracture; microtensile fracture strength

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Accepted 19 January, 2013

Introduction

Calcium hydroxide (CH) is used for both short- and long-term endodontic treatment for various pathologies (1–3). In the short term, as an intracanal dressing, CH is frequently used for disinfection of root-canal systems (4). In the long term, it is widely used as a pulp capping material to promote the production of reparative dentin over exposed pulp tissue (1); it is also used for the prevention, arrest, and healing of the inflammatory resorption of both mature and immature teeth (5, 6). According to Heithersay (7) and Frank (8), CH is also preferred for the induction of apexogenesis and apexification (4). Various studies have shown that long-term CH dressing achieves optimum healing results (9). The repair of internal root resorption perforations (10) and treatment of periradicular lesions (11) are also very common indications for the use of CH compounds. Although some alternative new materials such as the most popular mineral trioxide aggregate (MTA) have been introduced (12), CH is still preferred due to its superior activity and reduced cytotoxicitic effects to the periradicular tissues (13).

Calcium hydroxide is generally mixed with water to form alkaline-reacting aqueous slurry. Its pH is 12.4 when fresh (14). Due to its high pH level, CH has a strong antibacterial effect the elimination of remaining microorganisms following canal instrumentation (14, 15). This high pH level is due to the diffusion of hydroxide ions from the CH compound (15) continuing across the dentin, causing a pH elevation that may lead to a decrease in osteoclastic activity at the cemental layer (4). Calcium ions also diffuse from CH material into dentin, which may lead to remineralization (16). As an intracanal interappointment medicament, CH is also important for neutralizing the bioactivity of bacterial lipopolysaccharides, making necrotic tissue more soluble to sodium hypochlorite (NaOCl) (17).

Root fractures of permanent teeth, with their low incidence range in all dental trauma cases ranging from 0.5% to 7%, are not common (18). However, when it comes to endodontically treated teeth, the statistics change. Due to the nature of the treatment, such as access preparation, removal of the dentin tissue during canal preparation, and irrigation with (NaOCl), the root becomes more susceptible to fractures (2). It was also stated by researchers that more than half of all the endodontically treated permanent teeth with immature root formation have had cervical fractures due to minor trauma (19). It has also been observed that 11% of luxated incisors fractured with minimal trauma too (19).

A microtensile fracture strength (MTFS) test can be used to measure the strength of the teeth. Because there is minimum contact between the spade of the testing machine and the surface of the teeth, it is estimated that the stress caused by the load applied to the sample is well distributed, resulting in measurement of the bond strengths of the sample regardless of the structural failure of the dentin (20).

Various studies have suggested that CH use for endodontic treatment might lead to weakening of the dentin (13, 21–23). The purpose of this study is to compare the effects of CH on MTFS for different periods to find new data for a better understanding of the safe usage of this material.

Materials and methods

One hundred five extracted, caries-free single-canal human mandibular incisors were used in this study. To avoid any age effect, the teeth were collected from adult patients (mean age, 34.7 years; range, 30–40 years) requiring extraction for periodontal reasons during a period of several months. The teeth were stored in 1% chloramine-T solution at 4°C until they were used for the experiment. Soft tissue and calculus were removed mechanically. All the teeth were examined with a microscope (Leitz, Wetzlar, Germany) under ×20 magnification for pre-existing cracks or fractures, and only intact teeth were included. Coronal access cavities of all teeth were prepared with a no. 4 round bur under sufficient water cooling. To establish the working length, a size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was placed into the canal until it was seen at the apical foramen. The working length was calculated at 1 mm short of the apical foreman. The root canals of all the teeth were instrumented using a .04 taper rotary nickel-titanium EndoSequence Rotary Files (Brasseler, Savannah, GA, USA) to size 30 at the apex. During instrumentation for lubrication of the files in the canal, Glyde gel (Dentsply Maillefer, Ballaigues, Switzerland) was used. After each instrument, the root canals were flushed with 2 ml 5.25% NaOCl solution. At the end of instrumentation, the root canals were finally irrigated with 10 ml of 17% EDTA (pH: 7.4), which was allowed to remain in the canals for 3 min to remove the smear layer. The final irrigation was made with 10 ml of distilled water (24).

After that, the canals were dried with paper points, the teeth were matched for size and dentin thickness and then they were evenly distributed among seven groups of 15 teeth each. These groups are as follows:

Group 1: Control group (no CH application)
Group 2: 30 days (CH application)
Group 3: 90 days (CH application)
Group 4: 180 days (CH application)
Group 5: 270 days (CH application)
Group 6: 360 days (CH application)
Group 7: 540 days (CH application)

In group 1 (control group), after the root-canal preparation, the canals of the teeth were immediately obturated with EndoSequence BC Sealer (Brasseler, Savannah, GA, USA), and gutta percha (DiaDent Group International, Almere, Holland) with a lateral condensation technique. Following the obturation of the canals, the access cavities of the teeth were sealed with a minimum 3-mm thickness of Cavit (Kerr, Orange, CA, USA). Then the teeth were stored in a humidifier at 37°C to mimic the oral conditions of the mouth, and for the sealer to fully set according to the manufacturer's instructions, the teeth were rested for 7 days.

After the preparation of the root canals of the teeth in groups 2, 3, 4, 5, 6, and 7, the canals were filled with a paste of CH and a sterile saline solution mixture to the level of cemento-enamel junction (CEJ). The paste was applied with the help of a lentulo (Mani Inc., Tochigi, Japan). For the vertical condensation of CH, paper points and pluggers (Mani Inc.) were used. Following the CH application, all the access cavities of the teeth were sealed with a minimum 3-mm thickness of Cavit. The teeth were matched for size and dentin thickness and evenly distributed into seven groups of fifteen teeth each. After this, all the teeth were stored in a humidifier at 37°C until the day they were to be tested for MTFS (13, 25).

On scheduled days, the teeth to be tested for MTFS were removed from the humidifier. With the help of 5.25% NaOCl and 17% EDTA solutions for irrigation and the last rotary instrument that was used for apical preparation, the CH was removed from the root canals. 10 ml of distilled water was used for the final irrigation (26). After the removal of CH, the canals were obturated with the same protocol used for group 1 and stored in a humidifier at 37°C for 7 days.

All the teeth to be tested were immersed in cold-cure acrylic blocks (Caulk/Dentsply, Milford, DE, USA), leaving the crown outside starting from the cervical CEJ, with the roots embedded in the acrylic block (13). By this way, tooth sample was reinforced to prevent formation of any root fracture (13). The MTFS of the teeth were measured in an Instron universal testing machine (Instron Corp., Canton, MA, USA) that applied the load until fracture at a rate of 1 mm/min from the cervical surface of the tooth parallel to the incisal edge using a blunt, chisel-type custom jig. The results were recorded in MPa.

Statistical analysis

Statistical calculations were performed using NCSS (Number Cruncher Statistical Systems) 2007 statistical software (Utah, USA) program for Windows. The results were primarily analyzed using Kolmogorov–Smirnov test to test for normal distribution. When Kolmogorov–Smirnov analysis results did not show normal distribution, a nonparametric Kruskal–Wallis test was used in comparing the groups besides the standard descriptive statistical calculations (mean, standard deviation, median, and IQR), and a *post hoc* Dunn's multiple comparison test was utilized in the comparison of subgroups. The statistical significance level was established at $P < 0.05$.

Results

There were statistically significant differences between the mean MTFS of all the groups ($P < 0.0001$; Table 1; Fig. 1). The fracture strength of group 1 (42.7 MPa) was significantly greater than those of group 4 (30.35 MPa; $P = 0.012$), group 5 (28.51 MPa; $P = 0.003$), group 6 (26.93 MPa; $P < 0.001$), and group 7 (22 MPa; $P < 0.001$; Table 2). The fracture strength after 30 days was 36.6 MPa, and after 540 days, it was 22 MPa, which is statistically significant. This result indicates that there is 14.6 MPa difference between the two groups, meaning a 40% reduction in the fracture strength of the dentin: on average, a 0.0286 MPa reduction per day ($P < 0.001$). Between 90 days (31.86 MPa) and 540 days (22 MPa), a significant 31% reduction in the fracture strength of the dentin was found ($P = 0.035$), a 0.022 MPa reduction in fracture strength per day (Table 2). No statistically significant differences were observed between the other periods ($P > 0.05$).

Discussion

Numerous studies have addressed the success and failure of root canal–treated teeth. Based on case reports, recall of patients for prosthetic reasons, evaluation of radiographs, and extracted teeth that are endodontically treated, and the prevalence of vertical root fractures varies from 2% to 11% (27). Among all the endodontically treated teeth, mandibular incisors are the most common ones to suffer from vertical root fractures (28).

Dentin is a mineralized connective tissue, and 22% of its content is organic materials. This organic matrix contains phosphate and carboxylate groups that work like a bonding agent between the hydroxyapatite and collagen fibers. The use of an alkaline chemical such as CH as an intracanal medicament can dissolve, denaturate, or neutralize these acidic organic components in the dentin tissue, which act like bonding agents between hydroxylapatite crystals and collagenous fibrils, resulting in weakening of the dentin (13) and making the tooth more susceptible to fractures (22).

Although it is still debatable whether endodontic treatment should be finished in single or multiple sessions (29), in different studies, researchers have suggested that totally eliminating the remaining microorganisms from the root-canal system after chemomechanical preparation, the use of an intracanal medicament is favorable (30).

CH is used for extended periods. For apexification purposes, CH can be left in the canal system for 1 year or more. Research has shown that immature teeth treated with CH for extended periods are more susceptible to fracture and can be lost during or after the treatment is completed (22, 31). In a long-term study in which immature sheep incisors filled with CH were tested for fracture resistance, a reduction of 22% was found after 100 days (23). In another study carried out with bovine dentin that was maintained in Petri dishes for 5 weeks, it was reported that CH could reduce the fracture strength of dentin by 32% (21). In a long-term study carried out with immature teeth, the researchers concluded that CH weakened the teeth and led to fracture (22). One year after CH application, the reduction in the strength of sheep dentin was up to 50% (22).

Unfortunately, limited data are available regarding the long-term effects of CH on the MTFS of teeth, especially human teeth. It has been frequently stated by

Table 1. Microtensile fracture strength (MPa) and standard deviation (SD) for each group

Fracture strength	Mean ± SD	Median	IQR
Group 1	42.70 ± 6.39	40.63	(39.21–49.45)
Group 2	36.64 ± 8.77	35.97	(31.19–46.29)
Group 3	31.86 ± 7.83	30.80	(29.23–39.76)
Group 4	30.35 ± 7.52	29.69	(28.20–37,20)
Group 5	28.51 ± 6.82	28.03	(24.18–35.12)
Group 6	26.93 ± 6.59	27.90	(23.74–32.42)
Group 7	22.00 ± 5.99	20.68	(19.18–28.45)
KW	45.66		
P	0.0001		

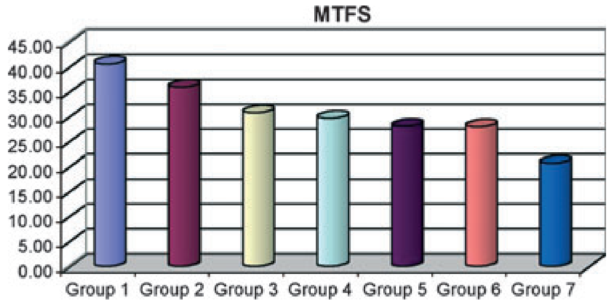

Fig. 1. Mean microtensile fracture strength (MPa) of the tested groups.

Table 2. Multiple comparison test of the subgroups

Dunn's multiple comparison test	Fracture strength
Group 1/Group 2	0.250
Group 1/Group 3	0.102
Group 1/Group 4	0.012
Group 1/Group 5	0.003
Group 1/Group 6	0.001
Group 1/Group 7	0.001
Group 2/Group 3	0.537
Group 2/Group 4	0.211
Group 2/Group 5	0.139
Group 2/Group 6	0.126
Group 2/Group 7	0.001
Group 3/Group 4	0.997
Group 3/Group 5	0.859
Group 3/Group 6	0.497
Group 3/Group 7	0.035
Group 4/Group 5	0.992
Group 4/Group 6	0.848
Group 4/Group 7	0.131
Group 5/Group 6	0.997
Group 5/Group 7	0.177
Group 6/Group 7	0.498

researchers that, after 5 weeks, the strength of dentin start to drop significantly, threatening the fracture resistance of the tooth. In one long-term MTFS study of human teeth treated with CH, it was found that, between day 7 and day 84, CH reduced the MTFS by 50% (13).

In our study, which is one of the few long-term research studies carried out on human teeth, the results clearly indicate that long-term CH treatment can significantly reduce the strength of the teeth, causing an increase in fracture risk. According to our findings, to avoid the loss of endodontically treated teeth due to fracture, long-term intracanal CH medication should be avoided. It seems important and necessary to search for alternative materials for this purpose. However, in the mean-time, after long-term application of CH, with appropriate additional treatments, structural fortification of the remaining dentinal tissue must be provided (32).

Conclusion

Within the limitation of the present *in vitro* study, it can be concluded that long-term CH treatment weakens the tooth structures and can significantly reduce the strength of the teeth, causing an increase in fracture risk. Further human teeth studies are necessary to confirm these results and further alternative treatment procedures for root-canal filling should also be considered than using CH treatment.

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