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Long-term calcium hydroxide as a root canal dressing may increase risk of root fracture

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Abstract – It has been proposed (Cvek 1992) that immature teeth are weakened by filling of the root canals with calcium hydroxide dressing and gutta-percha. The aim of the present study was to test the hypothesis that dentin in contact with calcium hydroxide would show a reduction in fracture strength after a certain period of time. Immature mandibular incisors from sheep were extracted and divided into two experimental groups. Group 1: the pulps were extirpated via the apical foramen. The root canals were then filled with calcium hydroxide (Calasept®) and sealed with IRM® cement, and the teeth were then stored in saline at room temperature for 0.5, 1, 2, 3, 6, 9, or 12 months. Group 2: the pulps were extirpated and the root canals were filled with saline and sealed with IRM® cement. The teeth were then stored in saline for 2 months. Intact teeth served as controls and were tested immediately after extraction. All teeth were tested for fracture strength in an Instron testing machine at the indicated observation periods. The results showed a markedly decrease in fracture strength with increasing storage time for group 1 (calcium hydroxide dressing). The results indicate that the fracture strength of calcium hydroxide-filled immature teeth will be halved in about a year due to the root filling. The finding may explain the frequent reported fractures of immature teeth filled with calcium hydroxide for extended periods.

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The endodontic treatment of teeth with immature root formation has always been a challenge due to the wide open apices that make obturation difficult. The introduction of apexification by the use of calcium hydroxide was pioneered by Heithersay (1) and Frank (2). This treatment gave adequate apical healing due to the induction of an apical barrier and due to the agent's antibacterial capability caused by a high pH.

In 1966, the etiology of inflammatory resorption was clarified as the combined effect of periodontal injury and a simultaneous presence of an infected necrotic pulp inducing osteoclast resorption (3). Furthermore, a possible intervention with conventional endodontic therapy with gutta-percha was discovered for teeth with mature roots (3). Soon after, a similar healing of inflammatory resorption of immature teeth by the use of calcium hydroxide with or without adding antibiotics to the dressing was published (4, 5). Since then, various clinical studies have shown initial optimal healing results of teeth with immature root development treated by a combination therapy of a long-term calcium hydroxide dressing followed by a gutta-percha root filling (6–9).

In 1988, a very disturbing observation was presented by Størmer et al. (10) at a Paedodontic Meeting in Norway claiming that 60% of all endodontically treated teeth with immature root formation have had cervical fractures due to minor impacts. Sometimes even spontaneous fractures occurred, and Cvek (11) published a similar finding in 1992. Such reports lead to the suspicion that the endodontic treatment had weakened the tooth structure. This suspicion was supported by histological demonstration of circumpulpal dentin changes of replanted teeth after treatment with calcium hydroxide (12).

The flexural strength of dentin might, in part, depend on an intimate link between its two main components, the hydroxylapatite crystals and the collagenous network. Part of the organic matrix is composed of acid proteins and proteoglycans containing phosphate and carboxylate groups. These substances may act as bonding agents between the collagen network and the hydroxylapatite crystals. Calcium hydroxide may, due to its alkaline nature, neutralize, dissolve, or denature some of the acidic components acting as bonding agents and thereby weaken the dentin.

The aim of the present study was to test the hypothesis that dentin in contact with calcium hydroxide would show a reduction in mechanical properties after a certain period of time.

Materials and methods

Mandibular incisors with immature root formation were extracted from young slaughtered sheep, approximately 4 months of age. Care was taken not to damage the teeth during extraction, and they were stored in 1% chloramin-T until use. The pulps were extirpated using an apical approach with a barbed broach, and the teeth were divided into two experimental groups.

- *Group 1.* The root canal was filled with calcium hydroxide paste (Calacept®) using a syringe and a cannula, and the paste was carried to the coronal part of the pulp cavity using a Lentulo® spiral at slow speed. The calcium hydroxide was further condensed from the apical foramen, and the canal was sealed with 2 mm long zinc oxide eugenol cement (IRM®). Then the teeth were immersed in saline at room temperature for 0.5, 1, 2, 3, 6, 9, and 12 months. The saline was exchanged with a fresh sterile solution once a week.
- *Group 2.* The root canal was filled with sterile saline and the apex sealed with IRM®. The teeth were stored in saline for 2 months at room temperature and the saline was exchanged with a fresh sterile solution once a week.

Teeth without root filling were tested. For this purpose, results from a previous investigation (13) were used.

The above-mentioned nine groups comprised 90 teeth, with 10 in each group. After storage in saline, as described above, the root of each teeth was embedded in a block of plaster, 2.7 cm × 1.3 cm × 4 cm, in such a way that the long axis of the tooth was aligned with the central axis of the plaster block and with the root part in the plaster up till and covering part of the enamel. The embedded specimens were kept in water for 24 h to ensure complete setting of the plaster. Then the top surface of the plaster was ground with a scalpel to a level exposing the enamel located 2.5 mm from the incisal line and the specimen was mounted in an Instron testing machine (Instron, High Wycombe, UK). A spade was placed on the facial surface of the specimen parallel with the incisal edge and close to the plaster, e.g. 2.5 mm from the incisal edge. A force was applied with the spade at a speed of 1 mm/min until fracture and the fracture strength (force/area) was calculated in MPa (13, 14). The mean (SD) for each group was calculated and the results from all the groups were compared by ANOVA and Newman–Keuls' multiple-range test at a 5% level of significance (15).

Results

Table 1 shows the mean fracture strength (SD) representing the various measurements. The ANOVA analysis gave, $F = 20.5$ and $P = 10^{-16}$, and the results from Newman–Keuls' test are shown as vertical lines in Table 1. It is seen that the fracture strength of the 2-month saline-treated teeth was not significantly different from the control value (0 days in saline), but it was significantly different from the 2-month calcium hydroxide-treated group. The results from all the teeth in the calcium hydroxide-treated group showed a decline by time in the saline solution.

Figure 1 illustrates the marked decrease in fracture strength with immersion time in saline for the teeth treated with calcium hydroxide. The line in the Fig. 1 follows the equation, $FS = 7.2 + e^{(2.16 - 0.0068d)}$, where FS is the fracture strength, d the days of storage in saline and e the logarithmic constant. This equation

Table 1. Mean fracture strength (SD) of teeth with the root canal either untreated or filed with saline or calcium hydroxide. The teeth were then stored in sterile saline for various periods of time before testing. The vertical lines designate means which are not significantly different

Material in root canal	Days in saline	Fracture strength, MPa (SD)
None	0	16.6 (4.9)
Saline	60	15.7 (1.3)
Calcium hydroxide	14	16.9 (1.4)
Calcium hydroxide	30	14.5 (3.5)
Calcium hydroxide	60	12.1 (1.4)
Calcium hydroxide	90	10.4 (1.9)
Calcium hydroxide	180	10.1 (1.8)
Calcium hydroxide	270	9.0 (1.4)
Calcium hydroxide	360	7.9 (1.2)

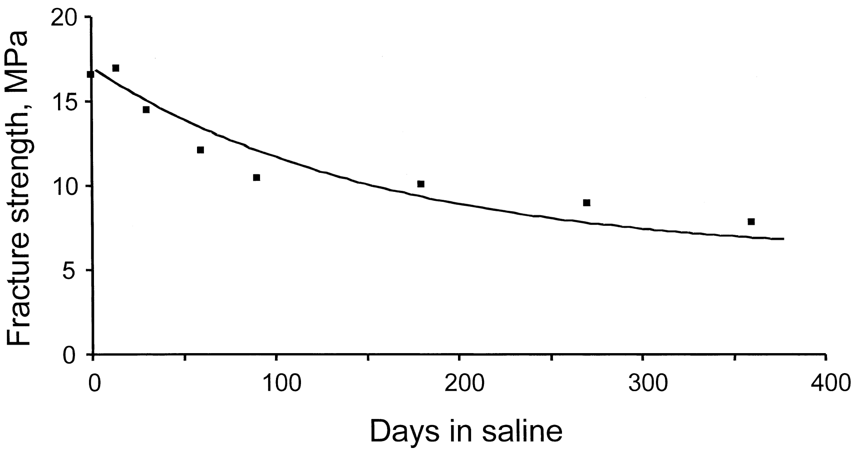

Fig. 1. Reduction in fracture strength of immature sheep teeth filled with calcium hydroxide. The line follows the equation, $FS = 7.2 + e^{(2.16-0.0068d)}$, in which FS is the fracture strength, *e* the logarithmic constant, and *d*, days of storage in saline. The coefficient of estimation, R^2 was 0.95.

was obtained by assuming a first order kinetic and with the assumption that the strength with time reached a certain plateau. The plateau is 7.2 MPa according to the equation, and this value was estimated as the value giving a coefficient of estimation, R^2 closest to 1; in this case 0.95. According to the equation, the fracture strength for teeth containing calcium hydroxide as root filling would be halved in about 1 year.

Discussion

Extracted mandibular incisors from sheep were used in the experimental model because these types of teeth are easily obtainable and have a root anatomy comparable to human mandibular incisors. Furthermore, sheep are usually slaughtered at an age where all permanent incisors are present with incomplete root formation.

The present study showed that the calcium hydroxide placed in the root canal had a significantly negative effect on the strength of the root.

The decrease in fracture strength with time of the teeth with the root canals filled with calcium hydroxide may be explained by its reaction with dentin, apparently following a first order kinetics. According to the equation described in the figure legend and under Results, the strength will reach a lower level at infinity. The level represents about 45% of the strength at zero and it was calculated that the 50% value was reached within a year.

The experimental findings in this study appear to explain the frequent cervical fracture of immature teeth treated with calcium hydroxide and gutta-percha (11). The mechanism by which dentin was weakened may be related to a change in the organic matrix. A dissolving effect by calcium hydroxide on pulp tissue in just one week has been reported (16, 17). This action is supposed to take place by denaturation and hydrolysis. If the phenomenon is related to the pH-changes in dentin observed after calcium hydroxide treatment (18, 19) an extensive alteration of dentin by calcium hydroxide could be expected. This would leave the dentin structure with reduced organic support, which may influence the mechanical properties of dentin. It has recently been published that sodium hypochlorite irrigation of root canals reduced the modulus of elasticity and flexural strength of dentin (20), and the finding was explained by a loss of organic substance from the dentin (21). Furthermore, the flexural strength of dentin specimens was reduced due to treatment with calcium hydroxide (22).

The results presented in the Fig. 1 and Table 1 might be explained by a disruption of the link between the hydroxylapatite crystals and the collagenous network in dentin due to the calcium hydroxide. The disruption could take place due to neutralization, dissolution, or denaturing of the acid proteins and proteoglycans that in dentin might serve as bonding agents between the collagen network and the hydroxylapatite crystals.

The strength of the root was not significantly reduced with a 30-day application of calcium hydroxide. Therefore, it appears that the standard protocol of up to 30-day application of calcium hydroxide for infected mature teeth with apical periodontitis is safe and need not be adjusted.

Conclusion

The present experiment appears to support the hypothesis that a calcium hydroxide dressing in the root canal for an extended time weakens the root structure. If this finding is confirmed in further studies, alternative treatment procedures for root canal filling than those using calcium hydroxide should then be considered.

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