

Retrospective study on direct pulp capping with calcium hydroxide

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Objective: To evaluate the success rate of a calcium hydroxide-based direct capping agent in permanent teeth. **Method and Materials:** A total of 1,075 permanent teeth were treated in this study. All patients received direct pulp capping with a calcium hydroxide-based agent. Inclusion criteria were teeth with healthy pulps, pulps with signs of reversible pulpitis, and a pulp chamber roof opening smaller than 2 mm². Pulps with severe degenerative processes or necrosis were excluded. After direct capping, all teeth were definitively restored with amalgam, composite, glass-ionomer cement, or other dental materials. The teeth were observed up to 9 years with a first visit after 3 months followed by an annual routine visit. **Results:** The success rate of direct capping was 80.1% after 1 year, 68.0% after 5 years, and 58.7% after 9 years. Substantial differences were found regarding the number of tooth surfaces affected by the causal event ($P = .0005$). The subsequent definitive restorations also significantly influenced the survival rate ($P = .0035$). **Conclusion:** Direct pulp capping with calcium hydroxide is a successful therapy when the respective indications and restorative materials are employed. (*Quintessence Int* 2011;42:165–171)

Key words: calcium hydroxide, clinically healthy pulp, definitive restoration, direct pulp capping, retrospective study, survival rate

In recent decades, a considerable change in the pattern of oral health behavior in the developed industrialized countries has been observed. As a general tendency,

patients as well as dental professionals are in favor of tooth preservation rather than extraction of disputable teeth. The long-term preservation of a clinically normal pulp during restorative procedures or in case of trauma is a matter of equal concern in general dentistry.¹ Pulp exposure with mild, reversible pulpal inflammation can occur as a result of carious exposure, caries excavation, or trauma.

Direct pulp capping is defined as a wound dressing of the exposed clinically normal pulp with the absence of signs and symptoms of severe pulpal disease. This procedure is a noninvasive, comparatively simple, and inexpensive treatment, with the overall aim to preserve healthy pulp tissue. Despite precise knowledge about the etiology and progression of caries and the development of numerous preventive programs, caries lesions have not yet been eradicated. In the treatment of all carious

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lesions, the pivotal goal is thorough removal and maintenance of a clinically normal pulp. It has to be considered that during mastication, both the dental hard and pulpal tissue experience significant changes. Besides dentin formation and an increasing volume of peritubular dentin, tertiary dentin is built as a result of microbiological and traumatic stimuli.¹ The maintenance of a healthy pulp, after accidental pulp chamber roof opening, is dependent on numerous factors such as age of the patient and carious lesions with bacterial infections. The composition and dimension of the remaining dentin bridge as well as the capacity of new dentin formation are equally discussed.² There have been many attempts to find a substance that will predictably induce a hard tissue barrier after pulp exposure. Numerous dental materials have been developed for this specific application. Calcium hydroxide (one of the most established materials), as well as mineral trioxide aggregates, have proven to induce histologically a bridge formation.³⁻⁵ However, adhesive systems showed less expression of the proteins that are essential for pulpal repair.⁶ Moreover, several authors have demonstrated that pulp alterations under different restorative materials were related to the presence of bacteria from microleakage.^{7,8}

However, calcium hydroxide is still described as the gold standard capping material with well-documented clinical success rates.^{8,9} Zander¹⁰ discussed that strong alkaline properties are responsible for the etching and disinfecting effect of calcium hydroxide on the pulp tissue. This effect may be a good precondition for successful clinical outcome, thus healing the pulp tissue. In the following decades, different authors claimed that this assumption is actually in antagonism with an undisturbed wound healing.^{11,12} Since the indication for direct pulp capping is controversially discussed in the literature, and the described success rates fluctuate between 40% and 94%,¹³⁻¹⁵ the aim of this retrospective study was to evaluate the long-term success of direct capping with a calcium hydroxide based material in permanent teeth.

METHOD AND MATERIALS

Study subjects were recruited from the pool of patients referred to the Department of Operative Dentistry between March 1998 and September 2008. Within this 10-year time period, a total of 2,164 direct pulp cappings in 1,752 patients (49% male and 51% female) were performed by numerous dental students and dentists, but only 1,075 cases were able to be tracked over the entire investigative period.

The indication for direct pulp capping was given when a tooth pulp was exposed on account of caries lesions, caries excavation and trauma, or definitive restoration. Only teeth with clinically normal pulps or reversible pulpitis, without recognizable radiologic changes, were included in this study.

The lesion of the pulp had to be in caries-free dentin with a pulp chamber roof opening smaller than approximately 1 mm² with no persistent bleeding after pulp exposure. Additionally, a radiograph was taken to exclude signs of apical lesions. In case of remarkable radiographic lesions and signs of irreversible pulpitis or pulp necrosis, the respective tooth was excluded from this study. After pulp exposition, the respective tooth was treated according to a predetermined protocol. The tooth was isolated with rubber dam and disinfected with 3% hydrogen peroxide. After complete cessation of bleeding and removal of the blood coagulum with sterile cotton, direct pulp capping was performed. This treatment included the application of a soft calcium hydroxide-based agent, Calxyl (OCO Präparate), and the more solid Kerr Life (Kerr), followed by the definite restoration of the respective cavity. The definitive restoration materials were amalgam (Dispersalloy, Dentsply), compomers (Dyract AP, Dentsply), glass-ionomer cement (Ketac Molar, 3M ESPE), and various composite materials (eg, Charisma and Venus). During the 10 years, most (819) of the pulp cappings were performed by dental students under the close surveillance of experienced dentists, while the remaining 156 teeth were treated by dentists. The definitive restoration material, the defect size, and the location were recorded. The observational time period for this study was initiated on the day the

capping was performed; a second visit was set after 3 months, and all subsequent visits followed during the annual routine examinations. At all visits, clinical signs of the pulp such as response to cold stimulus (carbon dioxide snow), percussion, palpation, bite tests, radiographic appearance, and the definite restoration were investigated. If a restoration proved to be insufficient, it was replaced with an alternative material.

Statistical methods

To assess a clinically normal pulp after direct pulp capping, Kaplan-Meier estimates for survival probabilities were calculated. The subgroups were compared by means of the log-rank test. The joint influence of age, sex, type of treatment, type of material used for direct pulp capping, and type of restoration was assessed using a Cox regression model. The statistical analysis was performed using SPSS 15.0 (IBM) and SAS 9.2 (SAS Institute).

RESULTS

From a total of 2,164 documented direct pulp cappings, only 1,075 (49.7%) directly capped permanent teeth of 533 male and 542 females (mean age 37.1 ± 15.3) met the inclusion criteria and were able to be recorded and tracked over this long time period. Reasons for exclusion were unavailable/missing records, relocation of patients, and death or lack of compliance regarding control appointments.

The numbers of patients in various age ranges were as follows: 12 (up to 9 years), 78 (10 to 19 years), 333 (20 to 29 years), 242 (30 to 39 years), 154 (40 to 49 years), 127 (50 to 59 years), 110 (60 to 69 years), and 19 (70 to 79 years). The teeth were 175 incisors (147 maxillary, 28 mandibular), 263 premolars (154 maxillary, 109 mandibular), and 637 molars (322 maxillary, 315 mandibular).

For the definitive restoration, composite/composomers were used in 41.7% of all cases, amalgam in 14.9%, glass-ionomer cement was applied in 38.3%, and other restoration techniques were chosen (crowns or partial gold or ceramic crowns) in 5.1%. The success of direct capping was defined as total

cessation of pain with clinically normal pulp and a normal radiographic appearance. From a total of 1,075 teeth, severe degenerative processes with necrosis of the pulp tissue were recorded in 226 cases. After 1 year, 80.1% of all teeth showed signs of normal pulp; the survival function was rated 75.2% at the end of the second year. It dropped to 72.0% after 3 years and to 68.0% after 5 years. At the end of the sixth year, a survival rate of 62.5% was observed, decreasing to 58.7% after 8 years (Table 1). A slight non-significant difference in the survival rate of male patients' teeth ($n = 533$ teeth; an endodontic treatment or extraction in 115 teeth) and female patients' teeth ($n = 542$, failure in 111 teeth: endodontic treatment or extraction) ($P = .763$) was observed. The survival probabilities are given in Table 1. The majority of teeth ($n = 819$) were treated by dental students under close supervision. Failure rates such as irreversible inflammation of the pulp with pulp necrosis followed by apical periodontitis were recorded in 172 cases. Two hundred seventeen teeth were treated by graduate operators. Fifty failures defined as the presence of severe degenerative process of the pulp tissue and pulp necrosis were observed. There was a slight difference in treatment outcome between different types of treatment ($P = .908$) (Table 2). The highest percentages of teeth that required endodontic treatment after initial pulp capping was found in the 50 to 59 and 60 to 69 years age groups. The remaining age groups displayed no statistically significant differences regarding the success/failure rate of direct capping ($P = .6295$).

The defect size area in relation to the tooth surface significantly influenced the maintenance of normal pulp tissue (Fig 1). In 73 teeth, only one surface was affected, and severe degenerative processes of the pulp with necrosis of the pulp tissue were recorded in 15 teeth. In 274 teeth with two affected surfaces, an irreversible inflammation could be observed in 57 cases. Among the 353 teeth with three involved surfaces, a failure rate of the normal pulp tissue could be observed in 66 teeth. Thirty-two out of 190 teeth with four affected surfaces showed degenerative process of the pulp tissue, and 31 out of 78 teeth with five surfaces involved resulted in pulpal necrosis. These observations display significant differences between

Table 1	Outcome of pulp capping in relation to patients sex		
	Survival probability (%)		
Observation time (y)	Male	Female	Total
1	80.0	80.3	80.1
2	74.2	76.2	75.2
3	70.1	73.8	72.0
4	67.1	71.0	69.1
5	64.9	71.0	68.0
6	61.3	63.7	62.5
7	58.5	63.7	61.1
8	58.5	59.1	58.7
9	58.5	59.1	58.7

Table 2	Outcome of pulp capping in relation to the operators (dentists or dental students)	
	Survival probability (%)	
Observation time (y)	Dentists	Students
1	75.9	80.9
2	73.6	75.1
3	71.4	71.4
4	68.5	68.9
5	68.5	67.3
6	68.5	58.8
7	62.7	56.5
8	62.7	56.5
9	62.7	56.5

Table 3	Outcome of pulp capping in relation to the dental restorative material placed immediately after pulp capping			
	Survival probability (%)			
Observation time (y)	Amalgam	Glass-ionomer cement	Composite	Crowns/partial crowns
1	89.3	77.3	80.6	50.0
2	86.2	71.7	76.3	50.0
3	84.2	67.4	72.7	50.0
4	84.2	63.5	69.5	50.0
5	84.2	60.7	69.5	50.0
6	84.2	54.7	60.1	50.0
7	84.2	51.5	60.1	50.0
8	84.2	51.5	54.1	—
9	84.2	51.5	54.1	—

the number of tooth surfaces affected by the causal event ($P = .0005$).

The type of definitive restoration after the direct pulp capping equally influenced the percentage of clinically normal pulp tissues (Table 3, Fig 2). A definitive restoration with glass-ionomer cement was performed in 412 teeth, 104 of which resulted in irreversible inflammation with pulp necrosis. After 2 years, the survival rate was at 71.7%. The long-term survival rate for this group after 7 and more years was 51.5%. Composite materials were used in 409 teeth, and in 81 teeth, irreversible inflammation of the pulp could be observed after 2 years (76.3%);

after 8 and more years, this rate rose to 54.1%. Amalgam was used in 146 teeth, and in 15 cases, necrosis of the pulp tissue could be observed. This restoration technique yielded markedly better results in respect to clinically normal pulp, with a smaller percentage of irreversible inflammation of the pulp after the third year and a long-term survival probability of 84.2%. Crowns were placed in 12 teeth, half of which resulted in necrosis of the pulp tissue. A ceramic inlay was used in one tooth, and in this case, irreversible pulpitis was observed. Therefore, the selected restorative material significantly correlated with





Fig 1 Percentage of clinically normal pulps (Kaplan-Meier survival rate) regarding the number of tooth surfaces affected by the causal event.

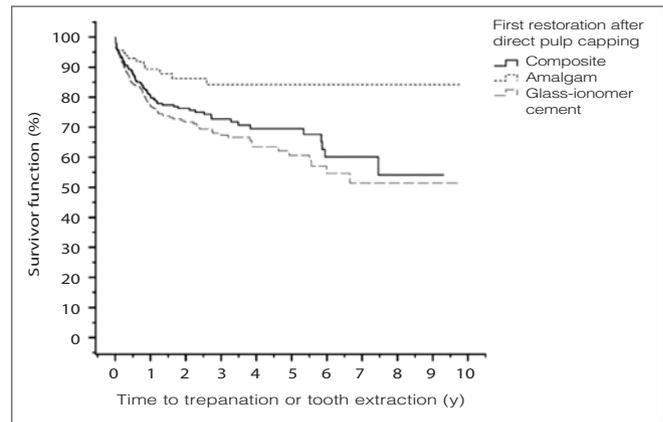


Fig 2 Outcome of pulp capping (Kaplan-Meier survival rate) in relation to the selected definitive restoration material.

the pulp survival rate of the respective tooth ($P = .0035$). Regarding localization and type of teeth (molars, premolars, or anterior teeth), no significant differences in the pulp survival rate ($P < .295$) were found. The common influence of the explanatory variables was assessed using a Cox regression model. The teeth with rare treatments and cases with missing data were excluded for one or more explanatory variables. This left a total of 877 teeth for analysis, of which 154 teeth showed irreversible inflammation with necrosis of the pulp. The Cox regression demonstrated that age, sex, and type of treatment had no influence on treatment outcome. Restorations with amalgam showed significantly better results than glass-ionomer cement restorations (hazard ratio [HR] = 0.43, $P = 0.006$). Composite also led to better results than glass-ionomer cement (HR = 0.89); however, this could also be due to chance ($P = .174$).

The defect size also had an influence on treatment outcome, which was more favorable when fewer than five surfaces were affected; all resulting hazard ratios were below 1 when compared to the treatment outcome of teeth with five surfaces involved. However, no monotone relation between

number of affected surfaces and treatment outcome was established. The most favorable treatment outcome was observed in teeth with four affected surfaces (HR = 0.39 when compared to five affected surfaces, $P = .02$).

DISCUSSION

The pivotal goal of direct pulp capping is the long-term maintenance of clinically normal pulp tissue. The potential healing of a pulp depends on its condition at the time of treatment, such as carious exposure, caries excavation, malocclusion, and prior trauma. Therefore, the success of a direct pulp capping is discussed controversially in the literature, due to multiple causes that may lead to pulp exposure.^{16,17} In most cases, the prognosis of teeth directly capped after trauma would appear to be more favorable in contrast to pulp exposure due to deep carious lesions.^{2,18} In the present retrospective study, the success rate of direct pulp capping was evaluated without taking into consideration the reason for pulp exposure.



The healing capacity of pulp tissue will depend on a number of factors such as patient age, tooth localization, and the precipitating event leading to the exposure.^{4,9,12} In the present retrospective study, a total of 1,075 pulps were capped; after 3 months, the success rate was 82% and 68% after 5 years.

There are numerous reports about a positive outcome of direct pulp capping, with success rates of 93% 1 year after direct pulp capping with Calxyl.¹⁹ In this case, the high success rate might have resulted from the low number of treated cases and a non-randomized patient collective. In a similarly small patient collective, a success rate of 55.5% after 5 years and 13% after 10 years was found.²⁰

A poor outcome of direct capping is equally observed, with a success rate of only 27% after 5 years in 132 teeth.²¹ The authors assumed that this high failure rate resulted from nonuniform inclusion criteria and treatment by dental students. In another retrospective study,²² a total of 204 direct pulp cappings were performed also by dental students. Success was defined as the absence of periapical radiolucencies and endodontic treatment. After 3 years, success rates of approximately 59% were found. The assumption that the lacking experience of dental students might lead to higher failure rates could not be verified. These findings are in accordance with the present study, which was not able to show significant differences between students and dentists.

Regarding the age-dependent success rate of direct capping, a statistically significant difference was reported by some authors.²³ While a success rate of 76% was found for patients aged between 10 and 19 years, lower success rates were reported with increasing age of the patients. However, there are also studies that found no correlation between the patients age and the success rate of direct pulp capping.^{12,21}

Concerning the location of a tooth within the mouth and a possible treatment outcome, our study was not able to establish a correlation, a fact that was refuted by other authors.^{18,22,23} They determined that the incisors had the highest success rate with a continuous decrease within the tooth

location, resulting in the lowest prognosis for third molars with a cumulative vitality survival rate of only 39%. The high incidence of traumatically exposed pulps in incisors with a relative small exposition surface might be an explanation for this phenomenon. Deep caries is the main reason for exposed pulps in molars with an exposition site, which is generally more expanded.¹³ Teeth with smaller defects are reported to have significantly greater survival rates than teeth with larger defects.^{13,19} Likewise, a statistically significant difference in the outcome of direct capping in Class 1, 2, and 3 defects is observed.²¹

The different dental materials used for direct capping are equally discussed in the literature.^{8,9,24,25} Besides the conventional calcium hydroxide-based materials, mineral trioxide aggregate (MTA) is also described as successful.^{26,27} In a split-mouth design, Nair et al²⁸ investigated human third molars that were capped with both calcium hydroxide and MTA. As a general rule, the specimens treated with MTA proved to have fewer signs of irreversible inflammation of the pulp and greater new dentin formation. Yet, Sawicki et al⁵ found no significant differences in the success performance between MTA and calcium hydroxide regarding the degree of severe degenerative pulp inflammation. In the present study, calcium hydroxide was used exclusively since it is a well-established and widely used pulp capping material.^{24,26,29-31} There are numerous reasons justifying the usage of calcium hydroxide as a capping material in the present study. It is easy to handle and is a relatively inexpensive material.

All in all, the present study emphasizes that numerous parameters are capable of influencing the success rate of direct capping, ie, the right indication, employed capping material, defect size, and localization of the respective tooth in the mouth. However, the type of definite restoration placed after direct capping is an equally decisive parameter regarding the clinical outcome.

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