

Cvek pulpotomy – revisited

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Abstract – Background/Aim: While some studies support the notion that the time elapsed from coronal fracture and treatment with Cvek pulpotomy in permanent teeth plays an important role in minimizing the possibility of pain and discomfort, microbial pulp invasion, and ensuring pulp and periodontal healing, others consider that neither time between the accident and treatment nor size of exposure is critical if the inflamed superficial pulp tissue is amputated to the level of a healthy pulp. This study compares published data in an attempt to assess whether the outcome of Cvek pulpotomies is affected by these factors. **Results and conclusions:** Evidence in the literature suggests to treat a permanent tooth with a complicated crown fracture as soon as possible to diminish the possibility of pain and prevent necrosis and infection of the pulp. Delay of treatment by 9 days or less may have minimal effect on the outcome of Cvek pulpotomies. While the literature indicates that pulp exposures of 4 mm or less may have a good prognosis after a Cvek pulpotomy, the prognosis in teeth with pulp exposures of more than 4 mm has not yet been clarified. Although the literature is not conclusive regarding a difference in the outcomes of Cvek pulpotomies in teeth with open or closed apices, it appears that teeth with open apices have a better prognosis. The outcome of a Cvek pulpotomy may be compromised by a luxation injury that diminishes the tooth's blood supply and innervation. A good restoration that prevents bacterial penetration into the tooth is essential for the success of a Cvek pulpotomy.

Pulpotomy is the surgical removal of part of the dental pulp allowing the rest of the pulp to remain alive and continue with normal function (1, 2). The extent of pulpotomy may be decided based on the type of tooth (primary or permanent), etiology of pulp exposure (caries or trauma), state of tooth development (open or closed apex), extent and severity of tooth fracture (simple or complicated), presence of a concomitant injury to the periodontium and/or alveolar bone, and the condition of the pulp as assessed clinically. In primary teeth, most pulpotomies are performed when carious pulp exposures occur and involve complete removal of the coronal pulp (2). On the other hand, pulp exposures resulting from complicated crown fractures in permanent teeth are mostly treated with Cvek pulpotomy. This includes removal of 1–3 ml of the coronal pulp located adjacent to the pulp exposure (2–5).

Except in special clinical situations, a cervical pulpotomy is no longer indicated for complicated tooth fractures in permanent teeth. This is due to the more favorable prognosis of the Cvek pulpotomy. Unlike cervical pulpotomy, the Cvek pulpotomy involves preservation of cell-rich coronal pulp tissue that is more likely to facilitate healing than the radicular pulp; the latter tissue is fibrous and unicellular with less capacity to respond (6). Clinical and histological findings confirm that the Cvek pulpotomy can be used as a permanent treatment modality for mature and immature permanent teeth with complicated crown fractures (6–10). The reported success rate of Cvek pulpotomies

in permanent teeth with complicated crown fractures ranges from 87.5% to 100% (11). While a clinical study (3) indicates that the Cvek pulpotomy may be successful in teeth with pulp exposures sized 0.5–4.0 mm, the outcome of Cvek pulpotomies in teeth with pulp exposures of more than 4 mm has not yet been fully elucidated. Nevertheless, the benefits of performing a Cvek pulpotomy outweigh the deleterious effects of performing a cervical pulpotomy or a pulpectomy such as crown discoloration, tooth fragility, and the need for apexification or apexogenesis in teeth with open apices.

The severity of injury, concomitant injuries caused by the same trauma, extent of pulp exposure, interval between the time of accident and treatment, and the stage of root development may play an important role in pulp and periodontal healing of traumatized teeth (3, 12–14). Accordingly, it has been suggested that a direct correlation exists between lack of treatment of extensive proximal fractures with pulp exposures in young permanent teeth and subsequent pulp necrosis (13). The *American Academy of Pediatric Dentistry (AAPD) Guideline on Pulp Therapy for Primary and Immature Permanent Teeth* states that with Cvek pulpotomy 'neither time between the accident and treatment nor size of exposure is critical if the inflamed superficial pulp tissue is amputated to a healthy pulp' (5). However, this guideline cites only one research study on pulp capping in dog's teeth, in which cavity preparations with carbide burs were carried out until

0.5-mm pulp exposures were created, without penetrating the pulp. They were then immediately covered with calcium hydroxide (15). Furthermore, the AAPD guideline does not imply any specific time limit (days, months, or years), exposure size (1–5 ml or more), or the possible limitations or contraindications for treatment (5).

In the present review, peer-reviewed publications were explored to clarify the applicability and limitations of the concept that for Cvek pulpotomy 'neither time between the accident and treatment nor size of exposure is critical if the inflamed superficial pulp tissue is amputated to a healthy pulp', and the effect of root development on the success of this treatment.

Basic concepts

The success of the Cvek pulpotomy technique is based on the assumptions that: (i) by removing 1–3 mm of the exposed pulp, the inflamed superficial pulp tissue is amputated up to the level of a healthy pulp; (ii) in permanent teeth with complicated coronal fractures, the exposure of the pulp permits salivary rinsing and prevents impaction of contaminated debris; (iii) the young coronal pulp tissue does not become necrotic after a traumatic exposure because of its natural defenses and the rich blood supply that resist bacterial invasion; (iv) the traumatically exposed pulp may have a beneficial defensive hyperplastic tissue reaction; (v) the most coronal pulp is more cellular than the radicular pulp, whereas the radicular pulp is fibrous and unicellular with lower healing capacity; (vi) the pulp dressing material is placed directly (without an intermediate blood clot) over non-inflamed tissue after easily achieving hemostasis with either a sterile saline solution, chlorhexidine, or sodium hypochlorite; (vii) it allows physiologic apposition of dentin in the coronal area, reducing the risk of cervical fracture that is more likely to occur following cervical pulpotomy; and (viii) a restoration that prevents bacterial contamination of the remaining pulp is achieved (3, 5–7, 9, 16–19).

Another important factor to consider in the treatment decision process for crown fractures is the presence of concomitant root fractures and/or luxation injuries, as it has been indicated that subluxation or luxation injuries may cause damage to the blood and nerve supply entering the apical foramen, thus facilitating the development of pulp necrosis (14, 20).

Time factor

Few studies have examined the relationship between delay of treatment and pulp and periodontal ligament healing. However, from a clinical standpoint, it appears that complicated crown fractures yield tooth sensitivity elicited by mechanical insults, such as mastication as well as drying and thermal changes. Therefore, complicated crown fractures should be treated on an emergency basis, to alleviate symptoms, and to reduce the possibility of wound healing complications (13).

A review of the literature revealed that while there is agreement that early treatment (within 24 h) is crucial

for the success of a cervical pulpotomy (12, 21), there is no consistency in the opinions regarding the effect of treatment delay of Cvek pulpotomies. Some authors have suggested that the time elapsing from the fracture to pulpotomy, followed by coronal restoration of the exposed pulp and dentinal tubuli, was important to minimize the possibility of microbial pulp invasion, thus ensuring pulp and periodontal healing (1, 9, 13, 14, 17, 22–26). Others have suggested that the time between injury and treatment has limited influence on the long-term outcome of partial pulpotomy, and therefore, the treatment of an exposed pulp due to trauma in a permanent tooth does not need not take place on the same day as the injury (3, 6–8, 19, 27, 28).

Malone & Massler (1) recommended that teeth with a pinpoint pulp exposure should be treated within 15–18 h of the accident. On the other hand, Cvek (3), in a clinical report of partial pulpotomy in 60 children's teeth with treatment delay between 1 h to 90 days, concluded that time was not critical for healing of an initially healthy pulp, based on treatment success rate of 96.7% (Table 1). However, the clinician must take into consideration that the vast majority of the teeth were treated ≤ 100 h (4.2 days) after trauma, the two teeth that did not heal included one tooth treated 17 h after trauma whose pulp became necrotic 4 days after treatment, and the second tooth which was treated 30 h after trauma developed pulp necrosis 40 months after treatment. Heide & Kerekes (22) studied monkey's teeth with open apices in which pulps were exposed by grinding the teeth with water-cooled high-speed burs and treated with pulp capping. The pulps were left exposed for four or 48 h. Results showed that most teeth (17 of 22) exhibited hyperplastic reactions associated with either superficial or no inflammation, and in pulps with necrotic areas adjacent to an inflammatory reaction, sound pulp tissue was achieved with pulpotomies that extended to a depth of about 4 mm. Furthermore, there was radiographic evidence of continued apical development in all teeth (Table 1). Cox et al. (26) in a study in which monkey tooth pulps were mechanically exposed to the oral environment emphasized the concept that early treatment of complicated crown fractures is required. Pulps exposed for 0 or 1 h presented damage due to the mechanical exposure alone. Teeth left open for 24 h and 7 days exhibited pronounced inflammatory infiltration, and several teeth with 7 days exposures showed partial or total necrosis (Table 1). Cvek et al. (17) studied complicated fractures in monkey teeth and found that after 3 h, hemorrhage and damage to the odontoblastic layer did not exceed 2 mm from the pulp exposure surface. After 48 h, it ranged from 1.5 to 2 mm, and after 168 h (7 days), it ranged from 0.8 to 2.2 mm. A study by Cvek (9) on the effect of treatment delay on the success of Cvek pulpotomy showed that among 178 pulpotomized teeth, there was no statistical significant difference in success rate between teeth treated within 32 h after the accident and those treated after a longer interval (96% and 87.5%, respectively). Among teeth treated within a day of trauma ($n = 138$), four pulps (2.9%) became necrotic and two were calcified (1.4%).

Table 1. Studies on success rates of partial pulpotomy or pulp capping applicable to treatment of partial pulpotomy

| | Reference | Year | Treatment | Follow up | Apex | Delay | No. of teeth | Success rate (%) |
|------------------|------------------------------------|-------------------|-------------------|-----------------------------|---------------|-----------------------|--------------|------------------|
| Children studies | Cvek (3) | 1978 | Partial pulpotomy | 14–60 months | All | 9–30 h | 60 | 96 |
| | | | | | Open | | 28 | 100 |
| | | | | | Closed | | 32 | 92.3 |
| | Cvek & Lundberg (7) | 1983 | Partial pulpotomy | 3, 6 and 12 months | All | 1 h to 8 days | 21 | 100 |
| | | | | | Open | | 13 | 100 |
| | | | | | Closed | | 8 | 100 |
| | Fuks et al. (8) | 1987 | Partial pulpotomy | 6–12, 13–24 or 25–50 months | 10 open | <1 h 1–4 h >4 h | 44 | 95.4 |
| | | | | | 53 closed | | 10 | 90 |
| | | | | | | | 8 | 87.5 |
| | Cvek (9) | 1993 | Partial pulpotomy | 36–180 months | All | 1 h to 41 days | 178 | 96.6 |
| Open | | | | | 90 | | 96.7 | |
| Closed | | | | | 88 | | 96.6 | |
| de Blanco (6) | 1996 | Partial pulpotomy | 1, 2, 8 years | Open | 1 h to 9 days | 10 | 100 | |
| | | | | Closed | | 20 | | |
| | | | | | | | | |
| Animal studies | Cox et al. (26) ¹ | 1982 | Pulp capping | 5 weeks | Closed | 1 h | 27 | 96.3 |
| | | | | | | 1 day | 28 | 96.6 |
| | | | | | | 7 days | 27 | 66.6 |
| | Heide & Kerekes (22) ¹ | 1986 | Pulp capping | 1 and 6 months | Open | 4 or 48 h | 31 | 100 |
| | | | | | | | | |
| | Demicheri et al. (23) ² | 1987 | Partial pulpotomy | 14, 30, 60 days | Closed | 1 h 7 days | 14 | 100 |
| | | | | | | | | 8 |

¹Monkey's teeth.²Dog's teeth.

Among teeth treated 2 days after trauma ($n = 17$), one pulp (5.9%) became necrotic. None of the pulps in teeth treated either 3 days after trauma ($n = 7$) or between 4 and 7 days after trauma ($n = 8$) became necrotic. The pulp space of one tooth of eight teeth treated 4–7 days after trauma became calcified (12.5%), and one of eight pulps of teeth (12.5%) treated between 8 and 41 days after trauma became necrotic (Table 1). Fuks et al. (8), in a study of children's teeth after Cvek pulpotomy, performed less than 1 h, between 1 and 4 h, and more than 4 h after the trauma reported a success rate of 95.4%, 90%, and 87.5%, respectively, with the number of teeth in each group being 44, 10, and 8, respectively (Table 1). Demicheri et al. (23) in a study of fractured dog teeth ($n = 14$) concluded that when a Cvek pulpotomy was performed within an hour after trauma, there were no cases of pulp necrosis. However, when treatment was performed 1 week after trauma ($n = 8$), 25% of the pulps necrosed (Table 1). de Blanco et al. (6), in a study on 30 teeth in 28 patients undergoing Cvek pulpotomy, concluded that the time period between pulp exposure and treatment did not appear to influence the success rate of treatment. However, it should be taken into consideration that in this study, five teeth were treated within an hour of trauma, 23 within 24 h, and only two teeth were treated 9 days after trauma. McIntyre et al. (29) quoted Cvek's conclusion from 1978 (3) that the time from injury to treatment was not important 'up to 30 h'. A successful Cvek pulpotomy was reported in a 16-year-old female treated 4 years after trauma, but this case is unique and should not lead to any general conclusion (30). Jones et al. (19) stated that even in cases of small pulp exposures, if the patient seeks treatment several hours or days after the trauma, the treatment of choice should be a Cvek pulpotomy as long as

the coronal pulp inflammation is not widespread and deeper access is not required for restorative purposes.

The above-mentioned findings indicate that a general statement claiming that the time period between the accident and Cvek pulpotomy is not critical if the inflamed superficial pulp tissue is amputated to a healthy pulp may have limited value. Clearly, it is not critical to perform the treatment of complicated crown fractures immediately after trauma in all cases. However, if the patient is in pain, immediate treatment is indicated. Furthermore, the inconsistency in the literature suggests that while some teeth may develop a hyperplastic reaction and the inflammation remains superficial, some traumatically exposed pulps may become progressively inflamed and eventually necrotic. Regarding the length of a 'safe' interval between trauma and Cvek pulpotomy in a permanent tooth with a complicated crown fracture, the limited information provided in the literature suggests that the success will most likely take place when the delay in treatment is within 9 days (Table 1). Nonetheless, the clinician's judgment is crucial and must be based on the proper depth of the pulpotomy and the need to perform it, based on the pulp's clinical appearance, the amount and color of the bleeding from the pulp stump (11, 18), and future restorative needs (31). If a tooth has a closed apex and requires a post and crown restoration, then pulpotomy is the treatment of choice.

Exposure size and capping material

Some authors state that the size of the pulp exposure has no influence on the outcome of direct pulp capping in children, and animal studies have indicated that the size of the pulp exposure plays a limited role in treatment decision of complicated tooth fractures (26, 32).

On the other hand, it has also been suggested that the size of the exposure may be a determining factor when deciding between performing pulp capping and pulpotomy; pulp capping being recommended only for cases with pin point exposures in fractured permanent teeth that are treated within a few hours after the accident (2, 3). However, in cases where the trauma involves extensive complicated proximal fractures, a significant direct correlation was found between no treatment and pulp necrosis (33). When trying to establish a guideline for pulp exposure size that most likely will have a successful outcome for a Cvek pulpotomy, it has been reported that exposure size of up to 4 mm is not critical for healing of a healthy pulp (3). There are no research studies assessing the success rate of Cvek pulpotomy in teeth with pulp exposures larger than 4 mm. The operator's clinical judgement should include not only the size of the exposure and the advantages of a Cvek pulpotomy over a cervical pulpotomy or a pulpectomy, but also the presence of concomitant periodontal injury (19), degree of root development, restorative needs, and patient compliance.

Calcium hydroxide (Ca(OH)₂) or bioceramic materials such as mineral trioxide aggregate (MTA) should be placed gently and directly in contact with non-inflamed pulp tissue with only passive contact with the pulp (17, 19, 34). When using Ca(OH)₂, the key factor in determining the prognosis of a partial pulpotomy is not the specific form of Ca(OH)₂, but its presence, along with the ability to seal it well in the root canal system thus minimizing microbial invasion to the remaining pulp (29). The same principles apply to the use of MTA. There is no statistical difference between the success rates of teeth treated with calcium hydroxide (91%) and those treated with MTA (93%) when used for partial pulpotomy in permanent teeth with carious exposures (35).

Open vs closed apex

The notion that changes in the tissue of traumatically exposed pulps in permanent teeth may be destructive and lead to pulp necrosis following mechanical injury and contamination underscores the need for preserving the pulp in permanent teeth with open apices. It has been suggested that the age of the patient may negatively affect the outcome of conservative pulp treatments as in older patients, the pulp is more fibrotic and has a diminished healing capacity (11). A study by Cvek (9) of complicated crown fractures in children and adolescent teeth ($n = 178$) reported that among teeth with immature roots ($n = 90$), the pulps of three teeth became necrotic and three became calcified. Among teeth with mature roots ($n = 88$), three pulps became necrotic (9). Hecova et al. (27) studied 889 permanent teeth of 384 children and adult patients, in which 22 teeth were treated with pulpotomy (13 teeth had immature apices and nine had mature apices). Higher percentages of normal pulps were found after a 5-year follow up in teeth with immature apices as compared to teeth with mature apices (76.9% and 66.7%, respectively), and pulp necrosis was observed more

frequently in mature teeth (22.2%) than in teeth with immature apices (7.7%). These findings were consistent with an additional study (20) reporting that the risk of pulp necrosis in teeth after a subluxation injury and an enamel:dentin fracture with pulp exposure is 3.9% in teeth with immature roots ($n = 9$ teeth), and 6.9% in teeth with mature roots ($n = 12$ teeth), suggesting that as the root develops, the contact area between the pulp and the periodontium decreases, possibly affecting the healing capacity of the pulp. Not consistent with these findings, de Blanco (6) reported a 100% success rate of Cvek pulpotomy performed in 30 teeth, 10 of them with open apices and 20 with closed apices at the time of treatment, suggesting that the success rate of Cvek pulpotomies is not affected by the presence of an open or closed apex at the time of treatment.

Summary

The degree of inflammation of the pulp tissue is a critical factor for the success of a pulpotomy. Therefore, the operator must make a clinical decision regarding the treatment of a complicated crown fracture based on the following factors:

- 1 The ability to treat the tooth as soon as possible to diminish the possibility of pain and prevent necrosis and infection of the pulp. Current literature suggests that up to 9 days delay between the time of trauma and treatment may have minimal effect on the outcome of Cvek pulpotomies (3, 6).
- 2 The outcome does not appear to be affected by the exposure size as long it is less than 4 mm (3).
- 3 A Cvek pulpotomy will have a better prognosis in a tooth with an open apex than in a tooth with a closed apex (3, 9). This is even more relevant in cases with a concomitant luxation injury (20).

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Conflict of interest

The authors confirm that they have no conflict of interest.

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