A long-term retrospective clinical study on MTA pulpotomies in immature permanent incisors with complicated crown fractures

**ABSTRACT**

**Aim** The study was undertaken to evaluate mineral trioxide aggregate (MTA) clinically and radiographically as a pulpotomy agent in immature permanent teeth whose pulps were exposed by a complicated crown fracture.

**Material and methods** Thirty incisors with exposed pulps in twenty-nine patients were examined for this retrospective study. According to exclusion criteria, only twenty-seven teeth were selected. Each tooth was treated with partial pulpotomy and the wounded pulp was covered with mineral trioxide aggregate. The children were recalled for clinical and radiographic evaluation at 3 months, 6 months, at approximately 12 months and 36 months.

**Results** Out of 27 cases, 22 were categorized as “healed” and 1 as “healing”. The remaining 4 ones highlighted persistent disease and needed further endodontic treatment.

**Conclusion** MTA partial pulpotomy is an effective treatment in maintaining pulpal vitality and allowing physiological root development (apexogenesis).

**Keywords** Crown fracture; Incisors; Mineral Trioxide Aggregate; Pulpotomy.

**Introduction**

Complicated crown fractures represent about 18-20% of all traumatic injuries to permanent teeth and involve enamel, dentine and exposed pulp [De Blanco, 1996]. They may cause necrosis of the pulpal tissue, so that a normal root development cannot occur. During this formative period, if the tooth is traumatised, vital pulp therapy will be necessary to allow the physiologic development of the tooth root, including the apical closure, and thickening of the dentinal walls in order to prevent a future root fracture [Camp, 2008]. The frequency of root fractures ranges from 28% in teeth with most developed root to 77% in teeth with immature root and it depends on the stage of root development. This observation is supported by Cvek [1992] who noted that cervical root fractures were more frequent in immature teeth if compared with mature ones.

Recent studies have suggested that complete root canal treatment may be unnecessary when the apical closure is obtained, if a hermetic seal is ensured and the remaining pulp is protected from bacteria which may cause pulpsitis [Abarajithan et al., 2010]. Dental pulp is able to heal after a traumatic exposure. This depends on several factors like interval between trauma and examination, width of pulp exposure, degree of root formation, intensity of the trauma, prevention of bacterial pulp invasion before and after treatment and the inflammatory pulp status, which is very difficult to diagnose accurately. When a tooth is traumatised, concussion or subluxation occur. concussion is a slight luxation injury without tooth displacement or increased mobility [Lauridsen et al., 2012a]. Subluxation is characterised by damage to the periodontal ligament with bleeding and abnormal mobility of the tooth, but without displacement [Lauridsen et al., 2012b]. Trauma causes damage to the pulpal nerve and vascular supply: the nerve fibers, which are mostly sensory, are compressed or stretched and this may temporarily alter the sensitivity of the tooth. When stimulated, these fibers release vasoregulatory neuropeptides which increase vascular permeability and blood flow to the traumatised area, during the inflammatory reaction [Lauridsen et al., 2012a].

When stimulation is improper, this mechanism of action is altered and a transitory ischemia of the pulp can develop. The risk of necrosis of an ischemic pulp increases when crown fracture, with or without pulp exposure, and subluxation occur simultaneously [Lauridsen et al., 2012b]. This could be due to the impairment of defense mechanism of the traumatised pulp and to the invasion of the ischemic pulp on behalf of bacteria and debris, thus opening dentinal tubules and exposing the pulp to the oral environment. As a matter of fact, contamination of the root canal is reported as the main cause of pulp revascularisation failure after ischemic necrosis [Cvek et al., 1990]. Initially the inflammation and the bacterial invasion are contained within the periphery of the pulp, thanks to the inflammatory reaction, but after approximately 24 hours, the inflammation spreads to the deep layers of the pulp [Nosrat et al., 2010; Cvek et al., 1982]. When the interval between accident and examination is long or the pulp exposure is wide, vital
pulpotomy will be the treatment of choice, because of bacteria penetration in the tissue [Sonmez et al., 2007].

Partial pulpotomy is defined as “a procedure that involves the amputation of the coronal portion of the affected or infected dental pulp” [American Academy of Pediatric Dentistry, 2005-2006], so that approximately 2 mm of inflamed pulp tissue are removed.

Clinically high success rates (96%) for complicated crown fractures in permanent incisors treated by partial pulpotomy are reported [Cvek, 1978]. The treatment is divided into two phases. The initial phase involves removing the diseased and bacterially contaminated tissue. The second phase involves establishing an environment that will prevent any further and future bacterial contamination [Witherspoon, 2008].

The ideal material for vital pulp therapy should be able to promote healing of the remaining pulp tissue, kill bacteria and prevent their further invasion, as well as induce mineralisation. Calcium hydroxide is one of the most commonly used materials in pulpotomy procedures. Its antimicrobial activity depends on its high pH, which prevents bacteria growth, and its ability to induce bacteriolysis. Moreover, the alkaline pH neutralises lactic acid from osteoclasts, thus preventing dissolution of the mineral components of dentine and also activates alkaline phosphatases, which play an important role in hard tissue formation [Moretti et al., 2008]. A dentin bridge is formed when the material is set in contact with the pulp, but often this barrier presents tunnel defects that let bacteria and their byproducts invade the pulp, compromising its vitality. In the last decade, a new material, namely mineral trioxide aggregate (MTA), has been developed for vital pulp therapy. MTA is shown to have an antibacterial effect on some of the facultative bacteria, but no effect on strict anaerobic bacteria [Witherspoon, 2008]. MTA is able to induce dentin, bone and cement formation and produces a thicker dentinal bridge, less inflammation, less hyperemia and less pulpal necrosis compared with calcium hydroxide [Cvek, 1978]. It is biocompatible and able to prevent a further bacterial penetration, thanks to its good marginal adaptation, its effective seal on the tooth-material interface and its ability to harden even in a wet environment (saliva or blood).

**Aim of the work**

The aim of the present study was to find out if MTA is an effective substitute for calcium hydroxide in immature permanent incisors with complicated crown fractures. In this article, the clinical and radiographic outcomes of a series of vital pulpotomies using MTA are presented.

**Materials and methods**

Thirty permanent incisors with complicated crown fractures in twenty-nine patients were treated in an endodontic private practice between 2003 and 2011.

Inclusion criteria were the following.
- Fractured incisors.
- Immature fractured tooth without any previous caries.
- Percentage of fractured crown > 80%.
- Damage to the coronal pulp, but an assumed healthy radicular pulp.
- Restorable crown.
- Panorex at the first examination.
- Periapical radiograph at each recall.
- No radiographic evidence of periapical pathosis.
- At least four recall appointments.
- Availability of documentation.

Exclusion criteria were the following.
- Patients without documentation at one or more recalls (2 teeth were eliminated according to this criterion).
- Use of laser technique (1 tooth was eliminated according to this criterion).

Therefore, three incisors were eliminated from the...
Long-term analysis of MTA pulpotomies

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Tab. 2 Individual patient data.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Patient No.</th>
<th>Age (years)</th>
<th>Tooth No.</th>
<th>Trauma extension (%crown)</th>
<th>Symtoms</th>
<th>Vitality &amp; Percussion**</th>
<th>Mobility degree</th>
<th>Diagnosis Recall (months)</th>
<th>Outcome (at T4)</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>6.1</td>
<td>1.1</td>
<td>90%</td>
<td>P/B/E *</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-37 Healed</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>7.1</td>
<td>2.1</td>
<td>90%</td>
<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-36 Persistent disease</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>7.3</td>
<td>2.2</td>
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<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-36 Healing</td>
</tr>
<tr>
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<td>P/B/E</td>
<td>V – P –</td>
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<td>IP/T/CEDF</td>
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<tr>
<td>5</td>
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<td>90%</td>
<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-42 Healed</td>
</tr>
<tr>
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<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-39 Persistent disease</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>7.3</td>
<td>1.1</td>
<td>90%</td>
<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-35 Healed</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>7.6</td>
<td>2.2</td>
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<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-9-39 Healed</td>
</tr>
<tr>
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<td>7.6</td>
<td>2.1</td>
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<td>P/B/E</td>
<td>V – P +</td>
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<td>IP/T/CEDF</td>
<td>3-6-12-38 Healed</td>
</tr>
<tr>
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<td>1.1</td>
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<td>IP/T/CEDF</td>
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<tr>
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<td>7.7</td>
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<td>90%</td>
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<td>V – P +</td>
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<td>IP/T/CEDF</td>
<td>3-6-12-36 Healed</td>
</tr>
<tr>
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<td>12</td>
<td>7.9</td>
<td>1.1</td>
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<td>V – P –</td>
<td>2</td>
<td>IP/T/CEDF</td>
<td>3-6-12-36 Healed</td>
</tr>
<tr>
<td>13</td>
<td>13</td>
<td>8.1</td>
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<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-9-30 Healed</td>
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<td>V – P +</td>
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<td>IP/T/CEDF</td>
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<tr>
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<td>15</td>
<td>8.1</td>
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<td>90%</td>
<td>P/B/E</td>
<td>V – P –</td>
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<td>3-6-12-36 Persistent disease</td>
</tr>
<tr>
<td>16</td>
<td>16</td>
<td>8.3</td>
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<td>90%</td>
<td>P/B/E</td>
<td>V – P –</td>
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<td>IP/T/CEDF</td>
<td>3-6-12-35 Healed</td>
</tr>
<tr>
<td>17</td>
<td>17</td>
<td>8.4</td>
<td>2.1</td>
<td>90%</td>
<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-37 Healed</td>
</tr>
<tr>
<td>18</td>
<td>18</td>
<td>8.4</td>
<td>1.1</td>
<td>95%</td>
<td>P/B/E</td>
<td>V – P +</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-36 Healed</td>
</tr>
<tr>
<td>19</td>
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<td>8.8</td>
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<td>V – P +</td>
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<td>IP/T/CEDF</td>
<td>3-6-12-24 Healed</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>8.9</td>
<td>2.1</td>
<td>90%</td>
<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-9-35 Healed</td>
</tr>
<tr>
<td>21</td>
<td>21</td>
<td>9.3</td>
<td>1.1</td>
<td>90%</td>
<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
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<tr>
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<td>9.4</td>
<td>2.1</td>
<td>90%</td>
<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-36 Healed</td>
</tr>
<tr>
<td>23</td>
<td>23</td>
<td>9.9</td>
<td>1.1</td>
<td>90%</td>
<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-24 Healed</td>
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<td>24</td>
<td>24</td>
<td>9.9</td>
<td>2.1</td>
<td>90%</td>
<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-24 Healed</td>
</tr>
<tr>
<td>25</td>
<td>25</td>
<td>9.9</td>
<td>1.1</td>
<td>80%</td>
<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-35 Healed</td>
</tr>
<tr>
<td>26</td>
<td>25</td>
<td>10.2</td>
<td>1.1</td>
<td>80%</td>
<td>P/B/E</td>
<td>V – P –</td>
<td>1</td>
<td>IP/T/CEDF</td>
<td>3-6-12-29 Persistent disease</td>
</tr>
</tbody>
</table>

** Vitality: - = negative, + = positive; Percussion: - = pathological response, + = physiological response.
***IP/T/CEDF: irreversible pulpitis/trauma/complete enamel dentin fracture.

Starting group and 27 teeth (cases 1-27) in 26 patients remained. The age of patients ranged from 6.1 to 10.4 years, with an average of 8.3 years (Table 1). At the pre-operative examination (T 0), Panorex and

** TABLE 2 Individual patient data. **
Periapical radiographs were taken to determine the presence of fractured bone and roots, displaced teeth and imbedded foreign objects [Camp, 2008] and to assess the degree of root development and the status of the periradicular tissues. Also thermal, percussion and mobility tests (Table 2) were conducted in order to establish a correct pulpal diagnosis and the extent of the trauma. Each examined tooth was compared with a contralateral control tooth. When the thermal test was performed, it was considered a physiological response when the tooth retained sensitivity and felt a cold sensation. The pathological response occurred when the tooth lost temporarily or permanently its sensitivity. Abnormal mobility was registered on a 0-3 point scale, where 0: no abnormal mobility; 1: faciolingual and/or mesiodistal movement of 1 mm or less; 2: faciolingual and/or mesiodistal movement of more than 1 mm; 3: more than 1 mm faciolingual and/or mesiodistal and axial mobility [Lauridsen et al., 2012b].

The follow-up period was based on four recalls at 3 months, 6 months, and approximately 1 year and 3 years. After administration of local anaesthesia, each tooth was isolated with a rubber dam and treated following partial pulpotomy procedure: approximately 2 mm of inflamed pulp tissue was removed using a coarse high-speed diamond bur with plentiful irrigation. The pulp wound was flushed with a sterile saline in order to achieve haemostasis. The remaining pulp tissue was covered with a layer of MTA of 2 mm, mixed according to the manufacturers’ directions on a glass-mixing pad. MTA was adapted to the cavity using a wet cotton pellet and the excess material was taken away. A restoration with temporary cement was done, a periapical radiograph was taken and the rubber dam was removed. When the dentin bridge was formed, each tooth received a definitive composite resin restoration.

At each recall, patients were screened to evaluate the presence of clinical symptoms, such as pain, altered sensation or discomfort. Pulp vitality, percussion tests and control radiographs were conducted. At T4, the treatment was considered as a failure if there were clinical symptoms, pathological responses to vitality and percussion tests or abnormal root development, inconsistent with the patient’s age. At the end of the follow-up period, the cases were scored into three categories, according to the clinical and radiographic evaluation of the pulp status [Witherspoon et al., 2006].

- **Healed:** no symptoms (pain, discomfort, altered sensation), physiological response to thermal and percussion tests, similar to that of contralateral controls, radiographic appearance of the physiologic tooth root development consistent with patient’s age;
- **Healing:** no clinical symptoms (pain, discomfort, altered sensation), pathological response of the treated tooth to thermal and percussion tests, radiographic appearance of the physiologic development of the tooth root consistent with patient’s age;
- **Persistent disease:** presence of symptoms (pain, discomfort, altered sensation), pathological response of treated tooth to thermal and percussion tests, radiographic appearance of the physiologic tooth root development inconsistent with patient’s age.

### Statistical analysis

The Fisher’s exact test was used to determine if there was a significant difference between the number of patients who had a physiological response respectively to vitality and percussion tests at T2 and T3. For this test the null hypothesis was that there was no significant difference between the results obtained at T2 and T3.

### Results

Central maxillary incisors were more frequently involved in accidents than lateral ones (Table 1). All of

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**TABLE 3** Outcomes for vitality and percussion tests at first examination.

<table>
<thead>
<tr>
<th>First examination (T0)</th>
<th>VITALITY</th>
<th>PERCUSSION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive*</td>
<td>Negative**</td>
</tr>
<tr>
<td>Number of patients</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Percentage of patients</td>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Positive: physiological response to vitality and percussion tests. **Negative: pathological response to vitality and percussion tests.

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**TABLE 4** Outcomes for vitality and percussion tests at recalls.

<table>
<thead>
<tr>
<th>Recall</th>
<th>VITALITY</th>
<th>PERCUSSION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive*</td>
<td>Negative**</td>
</tr>
<tr>
<td></td>
<td>Percentage (N.)</td>
<td>Percentage (N.)</td>
</tr>
<tr>
<td>T1 (3 months)</td>
<td>55.6% (15)</td>
<td>44.4% (12)</td>
</tr>
<tr>
<td>T2 (6 months)</td>
<td>77.8% (21)</td>
<td>22.2% (6)</td>
</tr>
<tr>
<td>T3 (from 9 to 12 months)</td>
<td>81.5% (22)</td>
<td>18.5% (5)</td>
</tr>
<tr>
<td>T4 (from 24 to 42 months)</td>
<td>81.5% (22)</td>
<td>18.5% (5)</td>
</tr>
</tbody>
</table>

*Positive: physiological reaction to vitality and percussion tests. **Negative: pathological reaction to vitality and percussion tests.
them presented an extended trauma, involving a high percentage of the crown, ranging from 80% to 95% (Table 2). The symptoms were the same for all teeth: pain, bleeding and edema (Table 2). The follow-up period was based on four post-treatment recalls and ranged from 3 to 42 months. The first (T1) and the second (T2) recalls were respectively after 3 and 6 months for all patients. The third one (T3) ranged from 9 to 12 months, with an average of 11.7 months and the fourth (T4) recall ranged from 24 to 42 months with an average of 35.1 months (Table 1).

At T0, no tooth had a physiological response to vitality test (Table 3), but 4 of those teeth (14.8%) had a normal reaction to percussion test; the other 23 teeth (85.1%) revealed a pathological response (Table 3); all teeth had slight mobility, except for one (Table 2). The diagnosis for all teeth involved in the study was irreversible pulpitis and complicated enamel dentin fracture (Table 2). At T1, 55.6% of the teeth had a physiological response to vitality test. The percentage increased to 77.8% at T2 and up to 81.5% at T3. Afterwards there was no significant difference between T1 and T3 (Table 4). With regard to the outcomes of the percussion test, 63.0% of the teeth had physiological response at T1. Even in this case the percentage increased to 74.1% at T2 and up to 81.5% at T3. At T3, all teeth were scored into three different categories, according to specific clinical and radiographic criteria (Table 1): 22 teeth (equal to 81.5%) were put into the “healed” group, one case (3.7%) was classified as “healing” and “persistent disease” was noticed in 4 teeth (14.8%).

**Statistical results**

The Fisher’s exact test allowed the calculation of the p-value, which represented the probability of obtaining a result equal or more extreme than that observed, assuming that the null hypothesis was true. The p-value for the teeth which had a physiological response to the vitality test was p=1.00, while the p-value for the percussion test was p=0.74. Since both were higher than 0.05, the null hypothesis was true and there was no significant difference between the values reported for the vitality and the percussion tests at T2 and T3.

**Discussion**

The retrospective clinical study had some points in common with other researches described in literature, but it was different in other respects.

The study had 81.5% success rate, that is slightly lower than that reported by other studies, using MTA as a pulpotomy material. For example, in the study conducted by Whiterspoon et al. [2006] a 100% success rate was reported for MTA pulpotomies. However, the group of patients who received the treatment was not homogeneous with regard to age and preoperative diagnosis. As a matter of fact, patients from 7 to 16 years of age were treated, whereas in the current study a more homogeneous sample, ranging from 6.1 to 10.4 years old, was chosen. Age was a patient-related factor which might affect the healing of the dental pulp and its response to treatment. The resistance of the pulp was decreased with age; in older patients, the teeth which had completed root formation were less able to overcome an injury. This was due to the morphological changes of the pulp revascularisation as the pulp matured or became inflamed [Ward, 2002]. When the root was completely developed, the contact area between the pulp and the periodontium decreased as well as its healing potential [Lauridsen et al., 2012b]. In the same study, the outcomes resulting from the treatment of teeth with different preoperative diagnosis were assessed. In the study of Witherspoon et al. [2006], some steps of the technique were different because haemostasis was achieved using sodium hypochlorite, while in the current study sterile saline was used. Only another clinical study, using MTA as pulpotomy material, has been carried out so far.

El-Meligy and Avery [2006] compared MTA with calcium hydroxide, choosing, even in this case, both traumatised incisors, which were only 4, and premolars and molars with deep caries; a 100% success rate for the MTA pulpotomies and a 87% success rate for pulpotomies using calcium hydroxide were reported.

The technique differed from that used in the current study, because cervical pulpotomies were performed so not only the superficial layers of the inflamed pulp were removed, as it was done in the partial pulpotomy technique [El-Meligy and Avery, 2006]. The teeth included in that study had a fairly intact crown, while in the present study, the trauma was more severe and caused the fracture of about 80% of the crown, even though it was still possible to perform a restoration of the teeth with composite resins. Moreover, pulp amputation was done with a large sterile round bur or with a sharp spoon excavator [El-Meligy and Avery, 2006] and not with a diamond bur at high speed with copious irrigation. This was a variable that could affect the result and which had already been investigated in literature [Granath and Hagman, 1971; Bimstein et al., 1989]. In fact, a gentle surgical technique using a diamond or tungsten bur at high speed for cutting, created a minimal injury to the underlying tissue; by employing a slowly rotating round bur or a manual excavator, the injury to the remaining pulp was greater [Fuks et al., 1993]. According to literature, the extent of pulp exposure [Fong and Davis, 2002] and the interval between trauma and the first examination had little or no bearing on the outcome of the pulpotomy [Andreassen et al., 2002; Fuks et al., 1987]. In the past, high success rate of 94% and 96% were reported by Fuks et al. [1987] and Cvek [1978]. Both used the partial pulpotomy technique, that is the technique chosen for the current study, but calcium hydroxide instead of mineral trioxide aggregate was used as pulpotomy material.

Finally, the patient sample was different. In Fuks’s et
al. trial [1987], the patients’ age ranged from 7 to 22 years and only 10 incisors out of the 63 treated ones had immature roots, so this sample could not be considered homogeneous and these differences might have influenced the prognosis of the teeth and the outcome of the treatment.

In Cvek’s study [1978], the patients’ age ranged from 7 to 16 years old and 28 teeth out of the 60 traumatised incisors were immature, so the same could be said about this trial.

In the current study, the assessment of the possible causes of treatment failure in teeth classified as “healing”, especially in the four ones which had persistent disease, highlighted the fact that in one case there was infiltration of the composite filling and the loss of the seal while in another one there was a further minor trauma involving the restored tooth. In the other three cases any explanation had to be merely speculative.

After about one year from treatment, 22 teeth out of 27 (equal to 81.5%) had physiological reactions to vitality and percussion tests, so they were healed (Table 4); after that no other tooth among those which had abnormal responses appeared to heal completely.

It can be stated that at about one year results were stable: if a tooth was not vital immediately after a trauma, there was 81.5% chance that the tooth might regain vitality in about 12 months. From that moment, non vital teeth should receive a further endodontic treatment to obtain apical closure and root canal filling.

Thanks to the outcome of the Fisher’s exact test, this statement could be already made at 6 months (T2) As a matter of fact, there was no significant difference between the result found at 6 months (T2) and that found at approximately one year (T3).

A similar statement was made by Cvek [1978] who reported that most failures that were already detectable radiographically, like internal dentin resorption and obliteration of the root canal, could be observed within the first year after treatment.

Conclusions

From the results of the present study, the following conclusions can be drawn.

1. Partial pulpotomy was an effective treatment in maintaining pulp vitality in children and young adults with complicated fractures.
2. MTA was a suitable pulpotomy agent in promoting root development and apexogenesis in immature permanent teeth.
3. A well-done restoration and a good coronal seal were needed to prevent further bacterial pulp invasion and pulp necrosis.
4. From a statistical point of view, a tooth could regain vitality in about 6 months. After that a further endodontic treatment is recommended.

References