Clinical studies on ferric sulphate as a pulpotomy medicament in primary teeth

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ABSTRACT. Aim The purpose of this paper is to review three prospective and two retrospective studies that have been published on the use of ferric sulphate as a pulpotomy medicament and, also, present the results of a recently completed, 3 year comparative study in pulpotomized primary teeth using ferric sulphate and diluted formocresol. The most important finding from the reviewed studies was that ferric sulphate gives very good clinical and radiographic results with high tooth survival rates and with no statistically significant differences from that of formocresol. Internal resorption is a common radiographic finding in both ferric sulphate and formocresol treatments with no statistically significant differences between them. However, internal resorption differs in size and progression rate among teeth. There were cases reported in which the size of the internal resorption was very small and unchanged over time, and even cases where the area of the resorption was self-repaired with hard tissue. Some of the authors considered only teeth with progressing and/or extensive internal resorption as failures, while small size and unchanged with time internal resorption was not considered as failure. Conclusion Based on the data of the reviewed studies it is suggested that ferric sulphate be used, rather than formocresol, for pulpotomies of primary teeth as the latter has been blamed for systemic and local side effects on the developing successors.

KEYWORDS: Ferric sulphate, Pulpotomies, Human studies

Introduction

Pulpotomy is a technique that has been used to treat primary teeth of which only the coronal pulp has been affected or infected by caries or traumatized, while the radicular pulp remains healthy [Fuks and Eidelman, 1994]. Signs or symptoms that indicate extensive inflammation or necrosis of the radicular pulp are against the use of this procedure. Pulpotomy therapy for primary teeth has been developed along three lines [Ranly, 1994]:

- devitalization with the use of formocresol and electrosurgery, where the intent is to destroy the radicular pulp;
- preservation of the remaining radicular pulp with the use of glutaraldehyde and ferric sulphate;
- regeneration of the radicular pulp by stimulation of a dentinal bridge which, in humans, has been accomplished with the use of calcium hydroxide and in animal studies with morphogenetic protein (BMP).

From the above treatments, the formocresol technique is considered the most universally taught and preferred pulp therapy for primary teeth for over sixty years [Avram and Pulver, 1989; Primosch et al., 1997]. Formocresol pulpotomies have, in clinical trials, an overall success rate of 55% to 98%. The success rate is mainly depending on sample size and the length of the observation period of each study.

However, histological studies on formocresol pulpotomies have shown chronic inflammation and necrosis of the radicular pulp [Berger, 1972; Rolling and Lambjerg-Hansen, 1978], while other studies have shown systemic distribution of formocresol from the pulpotomy side [Myers et al., 1978] and allergic or mutagenic properties of formaldehyde in animal models [Judd and Kenny, 1987]. Moreover, Pruhs et al. [1977] have shown a relationship between primary teeth treatment with formocresol and enamel defects in the permanent successors.

Of all the other medicaments that have been used so far, ferric sulphate (FS) seems to be a promising
alternative to formocresol (FC) as, in clinical trials, it has similar success. FS has been used as a hemostatic agent for crown and bridge impressions [Fischer, 1987]. Even though the mechanism of the haemostatic action of FS is still debated, it seems that agglutination of blood proteins results from the reaction of blood with ferric and sulphate ions with the acidic pH of the solution. The agglutinated proteins form plugs that occlude the capillary orifices [Lemon et al., 1993]. The use of FS was recommended on the grounds that it may prevent problems arising from clot formation after the removal of the coronal pulp. It may also minimize the chances for inflammation and internal resorption that, according to Schroder [1978], was an important factor for the failure of pulpotomies with calcium hydroxide.

From the relatively few clinical studies that have been published using FS as a pulpotomy medicament three are comparative prospective [Fei et al., 1991; Fuks et al., 1997; Imbrevic and Al-Jame, 2000], and two are retrospective; one on pulpotomies using FS [Smith et al., 2000] and a comparative one [Burnett and Walker, 2002]. In all the above comparative studies FC was used as the ‘gold standard’.

The purpose of this paper is to review these clinical studies and present unpublished data from a joint, recently completed, 3 year collaborative comparative study in pulpotomized primary teeth using FS and diluted FC carried out in Greece (L. Papagiannoulis, M. Koulatsidou, S. Geki, A. Polychronopoulou) and Israel (A. Fuks). This study will be referred from now on as Papagiannoulis et al. (2002).

**Materials and methods**

The materials and methods that have been used in all these studies are similar and therefore comparable.

**Sample selection.** The sample used consisted of primary molars of healthy children that were selected on the basis of symptomless exposure of vital pulp by caries, absence of clinical or radiographic evidence of pulp degeneration and possibility of proper restoration.

**Pulpotomy technique.** The teeth were treated under local analgesia and isolation with rubber dam. Following caries removal the pulpal chamber tissue was removed and coronal amputation was performed with a slow speed round bur and/or with a spoon excavator. Haemostasis was obtained with cotton pellets. After the completion of the pulpotomy the pulpal stumps were treated in the experimental group by applying a 15.5% solution of FS for 10-15 seconds (Astringent TM Ultradent Products Inc., Salt Lake City, UT.). In the control group 1:5 diluted Buckley’s FC was applied for 5 minutes (Sultan Chemists Inc., Englewood, NJ.).

**Pulp covering - restoration.** After rinsing, the pulpal stumps were covered by a layer of zinc oxide eugenol (ZOE) and a second layer of reinforced ZOE cement and restored, in all published studies, by a stainless steel crown, while in the study by Papagiannoulis et al. a composite resin was also used for small occlusal openings.

**Recall examination - treatment evaluation.** The recall examination period varied among the studies from 3 to 6 months after the pulpotomy for the first recall and from 6 to 12 months for the following ones. The treatment was regarded as a failure when one or more of the following clinical or radiographic findings were present: pain, swelling, sinus tract, furcation radiolucency, periapical bone destruction and internal tooth resorption. Root canal obliteration was recorded but not considered as failure in any of the studies.

In the studies by Fuks et al. [1977] and the present by Papagiannoulis et al., the degree of root resorption of treated teeth was evaluated according to the criteria established by Wright and Widmer [1979], who assessed root resorption by three degrees: 1) one or more roots near complete resorption; 2) resorption within the middle third of the root on one or more roots; 3) less than one third resorption on any root.

**Results**

**Prospective studies.** In the Fei et al. [1991] study the sample size was small. Twenty seven teeth were used in the FC group and twenty nine in the FS group. The recall rate was excellent and in the three and six month intervals no statistically significant difference was found between the two groups. However, at the end of this one year study there was a statistically significant difference in the success rate in favour of FS (97% for FS and 78% for FC). The most frequent evidence of failure in this short term study, in both groups, was furcation radiolucency.

In the Fuks et al. [1997] study the sample consisted of thirty seven teeth in FC group and fifty five in the FS group. The follow up period ranged from six to thirty four months with a mean of 20.5 months. In this very well designed study the sample size was larger and the evaluation period much longer than in the previous one. The total success rate between the two groups over the total period of thirty four months did not present any statistically significant difference and was 92.7% for FS and 83.8% for FC. Calcific metamorphosis and internal resorption were the most common radiographic findings. In this study, internal resorption that was stable and unchanged throughout the study was not recorded as...
failure. Concerning the rate of root resorption, the majority of the teeth, 82% of the FS and 78.3% of the FC group, showed a similar root resorption rate compared with the non-pulpotomized contralateral controls. From the remaining teeth 15.4% of the FS and 14.4% of the FC group showed a faster root resorption rate than the controls and only one tooth in each group resorbed at a slower rate than its control.

In the study by Ibreivic and Al-Jame [2000] thirty four teeth were used in each group and identical results were obtained after twenty four months post operatively. A 97% total success rate was recorded for both groups and there was only one tooth in each group that presented internal resorption and was considered as a failure.

In the study by Papagiannoulis et al. the sample consisted of ninety Greek children, forty six boys and forty four girls, from 3 to 10 years old with a mean age of 6.2 years. Sixty teeth (45%) were treated with FC and seventy three (55%) with FS. The number of teeth restored with either a stainless steel crown or a composite resin material was almost equal within each group. After thirty six months the clinical success rate was 97.3% for FC and 90.3% for FS. Fisher’s exact test did not show any significant difference between the two groups. The radiographic success rate was 78.3% for FC and 74% for FS with no statistically significant difference between them. This success rate seems to be the lowest recorded compared with studies reviewed above. Trying to explain this we realized that it could be due to two reasons. Firstly, the larger sample size and the very good recall rate might have increased the possibility of observing and locating more failures. The second reason regards the very strict definition of radiographic failure. To be more specific, it was realized that internal resorption was the most common radiographic finding for both treatments with no statistically significant difference between FS and FC (Table 1). However, most cases classified initially as internal resorptions remained stable throughout the thirty six month observation period (Fig. 1). In two cases, the respective areas were self-filled with reparative hard tissue (Fig. 2), therefore it was being very strict to classify them as failures. Based on the above observation we reevaluated our data considering failures as only those cases of internal resorption that were either extended in size or progressing in size with time (Fig. 3). After this reevaluation of the results the overall success rate became 78.7% for FS and 85% for FC with no statistically significant difference between them (Fig. 4).

Survival analysis completed for the estimation of tooth survival by time and treatment showed the following (Table 2): the first six months after treatment the survival rate was 98% for both treatments. From seven to twelve months a rate of 97% for FS and 94% for FC was observed. From thirteen to twenty four months the rate dropped to 88% for FS and 83% for FC and, finally, from twenty five to thirty six months the rate was 81% for FS and 78% for FC. Logrank test did not show any statistically significant difference between these values.

Table 1 - Internal resorption observed in FS and FC pulpotomies throughout the 36 month period.

<table>
<thead>
<tr>
<th></th>
<th>FS N</th>
<th>%</th>
<th>FC N</th>
<th>%</th>
<th>Total N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No internal</td>
<td>57</td>
<td>78.1</td>
<td>51</td>
<td>85.0</td>
<td>108</td>
<td>81.2</td>
</tr>
<tr>
<td>Internal</td>
<td>16</td>
<td>21.9</td>
<td>9</td>
<td>15.0</td>
<td>25</td>
<td>18.8</td>
</tr>
<tr>
<td>Total</td>
<td>73</td>
<td>60</td>
<td>133</td>
<td></td>
<td></td>
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</tbody>
</table>

Pearson $\chi^2$, non-significant

Fig. 1 - Radiographs of mandibular primary molar (#85), showing internal resorption unchanged from the 24th to 36th month recall.
The univariate and survival analysis showed no association of any treatment with sample descriptive factors such as sex and age of children, type of teeth (first or second molars), location of teeth (maxilla, mandible) and type of restoration (stainless steel crown, composite resin). Regarding the root resorption rate of the experimental teeth, the majority of the teeth in both treatments were similar to the non pulpotomized controls. Resorptions were few with faster, and only one in the FC group with slower than its control, resorption rate (Table 3).

Retrospective studies. In the study by Smith et al. [2000], FS pulpotomies performed over a period of five years, by a private paediatric dentist, were evaluated. Observation times were grouped in twelve-month increments for the purpose of reporting the findings. This study has, at least for the first two observation periods (4-12 months and 13-24 months) the largest number of teeth examined (112 and 117 respectively) in comparison to the prospective studies. However, for the period 25-36 months only 57 teeth were available for examination and for the next period, 37-43 months, only 31 teeth were examined. The clinical success rate was very high, 99% up to 36 months and 100% for the over the 36 month period. The radiographic success varied from 80% for the 4-12 months period, 74% for the 13-24 month period, 81% for the 25-36 month period and 74% for the over the 36 months period. The Robust log-rank tests that were used to compare tooth survival by arch (maxillary vs. mandibular) and by molar type (first vs. second molar) did not show any statistically significant difference. The estimated tooth survival by time was very high, starting at 99% up to ten months, dropped to 97% up to 26 months and was finally at 80% after 43 months. The two most common radiographic findings in this study were calcific metamorphosis and internal resorption. The records in this study showed that thirteen teeth with internal resorption, the records of which were available for the 43-month period concerned, did not develop osseous lesions.

Fig. 2 - Radiographs of mandibular primary molars (#75) in two different patients (a and b), showing internal resorption on the 12th month recall and self-repaired by hard tissue on the following recall periods.
The second retrospective study was a comparative one in which eighty three FC pulpotomies, forty five FS pulpotomies and seventy four pulpotomies treated with a combination of FS and FC were selected from the records of children treated in a public health clinic at different times and by different practitioners [Barnett and Walker, 2002]. The initial results showed that the total success rate was not different in the three groups of teeth. But in the long term, i.e. in the over the 36 month period, it appeared that the success rate was better for FC than for FS while the result for the combination of the two agents was the worst of all. The last finding is not really surprising as the teeth that were treated first with FS for haemostasis and then with FC were teeth with guarded prognosis (i.e. hyperaemic and/or symptomatic). In this study, as it was pointed out by the authors, there are several shortcomings with the most serious being that the pulpotomies were performed by many practitioners of different level of experience and expertise. In addition, the criteria for the necessity of a pulpotomy were not strictly defined and the radiographs were not always allowing evaluation of the periapical area of the treated teeth. Moreover, the sample size was very small in some observation periods as it can be seen in Table 4, in which the results of the reviewed studies are summarized.

**Discussion**

From the reviewed studies (Table 4) it was noted that higher success rates were obtained in studies with shorter observation times and smaller sample sizes. As the sample size increased and the observation period became longer, the success rate dropped and that held true for both FS and FC pulpotomies. The most important finding is that there were not really statistically significant differences in the success rate between FS an FC, with the exception of the short-term study by Fei et al. [1991], where a statistically significant difference was observed in favour of FS in the one year period. Of course, due to the very small sample size, the performance of even one tooth could make the

**Fig. 3** - a. Radiographs of mandibular primary molar (#85) with internal resorption progressing with time. b. Radiographs of mandibular primary molar (#75) with excessive internal resorption at the 12th month and interradicular and periapical lesion at the 24th month.
difference. In all the reviewed studies (prospective and retrospective) both FS and FC treatments give very good results with high tooth survival rates.

In the study by Papagiannoulis et al. the type of restoration (stainless steel crown or composite resin) did not influence the success rate for both agents. This is an interesting finding as in all the other reported studies stainless steel crown was the only means of restoration.

The most common radiographic finding in the last study was internal resorption with no statistically significant difference between FS and FC. As it was pointed out before, the cases of internal resorption that remained unchanged throughout the 36 month observation period were not considered as failures in the final examination. The same was also found in the Fuks et al. study [1977]. Smith et al. [2000] proposed that internal resorption should not be considered as pulpotomy failure. They based this proposal on the fact that none of the teeth with internal resorption in their sample developed an osseous lesion. Their proposal could be accepted only for cases of minimal and unchanged internal resorption but not for severe or progressive ones. Internal resorption is an indication of pulp inflammation that is expected, anyway, in the amputation side after the pulpotomy. If the inflammation can be restricted and confined to a very small part of the pulp, while the rest of the pulp is healthy, then this internal resorption will cease or even self-heal by hard tissue and therefore will not be a failure. In all the other cases internal resorption is an indication of a non-reversible or extensive inflammation and, therefore, should be considered as failure. Concerning the actual inflammation, the results of the studies reviewed could not be conclusive as to whether this inflammation is a result of a reaction to the amputation of the pulp or to the medicament used or is actually a symptom of a not healthy radicular pulp.

Interadicular and periapical radiolucencies are symptoms of pulp necrosis. Again this is not necessarily a result of reaction of the medicament to the pulp.

The fact is that clinical means and methods today are not so sensitive in diagnosing the exact condition of the pulp after the removal of its coronal part. Therefore, the most difficult task for the clinician remains the evaluation of the pulp condition and not the selection of the medicament to be used. On the other hand, as there are no statistically significant differences between FS and FC we come to the suggestion that FS be used rather than FC as the later has been blamed for systemic and local side effects on the developing succedaneous teeth.

**Conclusion**

Both FS and FC treatments give very good clinical and radiographic results with high tooth survival rates and with no statistically significant differences between

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**TABLE 2 - Estimated survival by time and treatment for ferric sulphate (FS) versus formocresol (FC) pulpotomies.**

<table>
<thead>
<tr>
<th>Time</th>
<th>FS</th>
<th>Failures</th>
<th>Survival</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6</td>
<td>73</td>
<td>1</td>
<td>0.98</td>
<td>0.91 - 1.00</td>
</tr>
<tr>
<td>7-12</td>
<td>71</td>
<td>1</td>
<td>0.97</td>
<td>0.89 - 0.99</td>
</tr>
<tr>
<td>13-24</td>
<td>67</td>
<td>5</td>
<td>0.88</td>
<td>0.78 - 0.95</td>
</tr>
<tr>
<td>25-36</td>
<td>45</td>
<td>2</td>
<td>0.81</td>
<td>0.65 - 0.91</td>
</tr>
</tbody>
</table>

Logrank test, non-significant

**TABLE 3 - Root resorption rate of experimental teeth compared to non-pulpotomized controls.**

<table>
<thead>
<tr>
<th></th>
<th>FS</th>
<th>FC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faster than contralateral</td>
<td>16</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>Similar to contralateral</td>
<td>55</td>
<td>35</td>
<td>90</td>
</tr>
<tr>
<td>Slower than contralateral</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>71</td>
<td>50</td>
<td>121</td>
</tr>
</tbody>
</table>

Pearson χ², non-significant
Internal resorption is a common radiographic finding in both ferric sulphate and formocresol pulpotomies with no statistically significant difference between them in the outcome of the treatments. Internal resorption in most cases does not interfere with tooth survival. The type of restoration, stainless steel crown or composite resin, did not affect the success rate for both ferric sulphate and formocresol treatments. Ferric sulphate can be used instead of formocresol for treatment periods up to 36 months.

### References


