Therapeutic pulpotomies in primary molars with the formocresol technique

A clinical and histological follow-up

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The results of therapeutic pulpotomies in primary molars with formocresol technique were studied by systematic follow-up. Of 84 primary lower molars in the clinical study, 56 became available for histological examination. The radiographic follow-up revealed periradicular osteitis in 10 per cent of the teeth treated. Internal root resorption was seen in 37 per cent of the teeth, or one-fifth of the roots treated.
The histological examination revealed a very capricious diffusion of the medicament throughout the pulp tissue. Vital pulp remnants in the apical part of the treated roots showed no signs of healing. All pulps presented a varying number of inflammatory cells in the border zone adjacent to the formocresol-fixed region. In 80 per cent of the roots the histological sections revealed signs of internal resorption with or without incomplete repair tissue formation.

Key-words: Deciduous teeth; endodontics

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Because of the complicated anatomy of the root canals in primary molars, the proximity of the permanent tooth germ and the difficulties in finding a root-canal filling material compatible with physiological root resorption, pulpotomy has become the dominating pulpal therapy for the deciduous dentition. In permanent teeth the healing rate of pulpal wounds is reasonably high, both clinically and histologically, when a calcium hydroxide compound has been used as a wound dressing. In contrast, pulpotomies in primary teeth with the same technique result in a high percentage of failures. Acute clinical symptoms are seldom present, and the incidence of periradicular changes seen in radiographs is modest, but internal root resorptions are frequently observed (4, 5, 11, 24). These internal root resorptions are related to the presence of chronic inflammation in the residual pulp tissue (8). Clinicians' search for alternative methods without this complication resulted in a revival of the formocresol technique, a "semi-mortal"

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method that has gained widespread popularity, especially in the U.S.A. (21, 23).

The fundamental purpose of treating the pulp with a mortal technique is to cause devitalisation of the damaged tissue and invading microorganisms. Healing is then thought to occur in an unaffected area. The disadvantage of such a technique is the difficulty in controlling the spread of the medicament and also the fact that the compound, or the necrotic tissue itself, may cause chronic irritation in the proposed area of healing. Follow-up of pulpotomies in the primary dentition performed with classical mortal technique has shown discouraging results even on clinical evaluation (15). The proponents of the formocresol technique maintain that this compound is less toxic and irritant than medicaments utilized in previous mortal techniques, and reports on clinical follow-up observations of primary molars treated with formocresol have been favourable (for reference, see 1 and 16). Histological studies have been less satisfactory and have also been subjected to varying interpretations (1, 2, 3, 4, 6, 7, 18, 22).

There are several versions of the formocresol-technique, the varying factor being the time of application to the pulp that has been amputated in vital condition. Application of formocresol for several days – a two-appointment procedure – is practised as well as application of the medicament for a few minutes only. Consequently, it was considered appropriate to carry out a clinical and histological follow-up of therapeutic pulpotomies with two formocresol techniques under similar conditions and using the same criteria as used in earlier studies of vital pulpotomies with calcium hydroxide or zinc oxide-eugenol as wound dressing (8, 10).

MATERIAL AND METHODS

The material consisted of 84 lower primary molars from 78 children in the age group 4 to 9 years. The 34 first and 50 second primary molars were treated by pulpotomy under the diagnosis "symptomless exposure of the pulp by caries" (laesio pulpae carie). Radiographs had shown no intra- or periradicular changes and there had been no clinical signs of pulpitis. The bleeding of the pulp that had been exposed with avoidance of salivary contamination was moderate and light red in colour. After establishing the diagnosis, the lesion had been covered with a temporary dressing of calcium hydroxide paste (Calxyl®). The subsequent pulpotomy was performed within one week.

After application of a rubber dam and establishment of a proper occlusal cavity, the coronal pulp tissue was excised with an excavator. The level of the wound was placed immediately below the orifice of the root canal. In some cases a round bur with a diameter slightly greater than the width of the canal had to be used to create a smooth wound surface. The pulpal cavity was cleansed with a solution of a quartenary ammonium compound. In 36 molars half a standard cotton pellet saturated with formocresol (Sol. formaldehydi conc. 19, Tricresol 35, Glycerol 15, and Aqua dest. ad 100) was placed above each root canal. The cavity was then sealed with zinc oxide-eugenol cement. After 3 to 5 days the cotton pellets were removed, and the root canals and the bifurcation area were sealed with zinc oxide-eugenol cement covered by a thin layer of phosphate cement followed by an amalgam restoration or a stainless steel crown.

For the following 48 molars the procedure was identical, but the formocresol-saturated pellets were only left for 5 minutes above the root canals. The cavity was then sealed as described above, but at the same sitting.

Radiographs of the molar were taken immediately after the pulpotomy and thereafter at intervals of about 6 months. In

Table 1. *Length of clinical follow-up and time for histological examination*

Months (± 2)	6	12	18	24	30	36
Clinical (No. = 84)	28	19	17	6	9	5
Histological (No. = 56)	20	15	13	4	4	–

Table 2. *Radiographic follow-up. Occurence of osteitis and internal root resorptions. Figures in brackets denote percentages*

	Osteitis	Teeth	Internal root resorption		Both roots
			Mesial root	Distal root	
First molars (No. = 34)	5 (15)	12 (35)	8 (24)	4 (12)	–
Second molars (No. = 50)	3 (6)	19 (38)	9 (18)	13 (26)	3 (6)
Total (No. = 84)	8 (10)	31 (37)	17 (20)	17 (20)	3 (6)

Table 3. *Histological observations. 56 primary lower molars – 110 roots*

	No. of roots	%
Healing	0	0
Necrosis	16	15
Internal root resorption with or without repair	89	81
Slight infiltration of inflammatory cells	13	12

most cases the tooth was also examined one month after the pulpotomy. The length of the clinical follow-up varied from 6 to 36 months (Table 1).

The following criteria were used in the evaluation of internal root resorptions:

I. Diffuse widening of the root canal. The walls appear irregular.
II. Manifest widening of the root canal. The internal resorption has not reached the outer surface of the root.
III. Advanced widening of the root canal. The internal resorption has reached the outer surface of the root.

The reliability of the evaluation has been elucidated by Magnusson & Ringqvist (11).

The children belonged to a population at that time being treated according to a compromise scheme of the Swedish Public Dental Service, extractions only being performed in the primary dentition. Their parents were informed that the pulp treatment was a temporary measure to postpone the otherwise necessary extraction. Unless contraindicated by orthodontic considerations, the pulpotomized molars were extracted after varying intervals, ranging from one month to three years (Table 1). In total 60 molars became available for histological examination. Four of them exhibited such an advanced physiological root resorption that no observations regarding the pulpotomy were possible.

The extracted teeth were immediately fixed in neutral buffered formalin and demineralised in a mixture of 35 % formic acid and 7 % formate solution. They were embedded in paraffin and serially sectioned in a mesio-distal direction through the root canals with a microtome set to 5 μ. Every other section was set aside for examination. Sections were stained in Mayer's haemalum-eosin and Hansen's iron trioxy haemateinpicrofuchsin.

RESULTS

Clinical and radiographic observations

None of the patients reported any pain and none of the teeth became tender to percussion. The radiographs revealed periradicular osteitis at one of the roots in 8 teeth (Table 2). Four of them were diagnosed within the first year after the pulpotomy, but in one case not until after 2 1/2 years.

Out of the 8 observed osteitic processes, 7 appeared in the group in which formocresol had been applied for 5 minutes.

Internal root resorption was noted in 31 teeth or 34 roots, with an equal distribution in mesial and distal canals and between first and second molars (Table 2). In one root the resorption was already visible after one month. More than half of the resorptions were diagnosed within six months and only two were detected after two years or later.

Internal root resorption of grade I was seen in 11 roots, grade II in 20 and grade III in only 3 roots. Because of the successive extractions, the follow-up is not strictly representative, but the progress of the root resorptions appeared slow. The majority of the resorptions were situated in the middle or lower part of the canal (Fig. 1). The type and frequency of internal root resorptions were equal in the groups with long and short application of formocresol – they appeared in 36 and 38 per cent, respectively. None of the teeth exhibited walling off in the root canals by hard tissue formation. In one canal the radiographic follow-up indicated a possible formation of hard tissue.

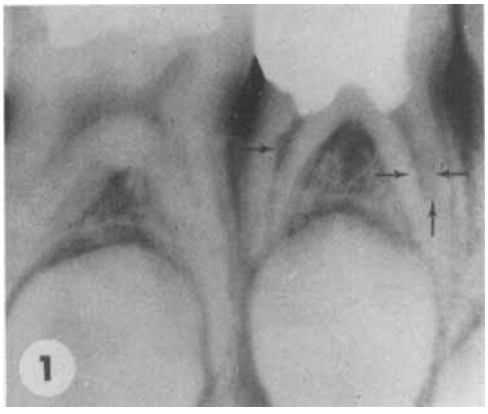


Fig. 1. Radiograph of a lower first molar 7 months after pulpotomy with the formocresol technique. Moderate internal root resorptions in both roots (arrows).

Histological observations

Out of the 56 teeth (23 first and 33 second molars) that became available for histological examination, 29 were from the group in which formocresol was applied for several days and 27 from the group with five minutes application. Altogether 110 roots allowed histological observations regarding the contents of the root canal. Radiographically diagnosed internal root resorptions were present in 25 per cent of these roots as compared to 20 per cent in the entire clinical material. Seven out of the eight teeth with a radiographically observed osteitis became available for histological examination. There was a marked variation in the penetration of formocresol into the residual root pulp. The exact depth of diffusion is difficult to estimate histologically, but there were very obvious differences in the amount of tissue seemingly fixed by the medicament during treatment. This capricious character of the diffusion was not only noticed in comparison between different teeth, or between the two roots of the same molar, but also within individual roots. There was no difference in this respect between the teeth in which a formocresol-saturated pellet had been left for days and those in which it had been applied for five minutes only. The diffusion of formocresol appeared unpredictable (Fig. 2).

The most coronal part of the root pulp was totally necrotized by the formocresol, with loss of structure and marked eosinophilia. Most canals also had a short intermediate zone with preserved structure but lysis and weak staining reactions of the cells. In this zone capillaries appeared thrombotic and endothelial cells and pericytes were markedly thickened (Fig. 3).

In five roots the penetration of formocresol was so deep – or the physiological resorption so advanced that the eosinophilic zone reached the apex. In a further 16 roots (15 per cent) the tissue below the fixed

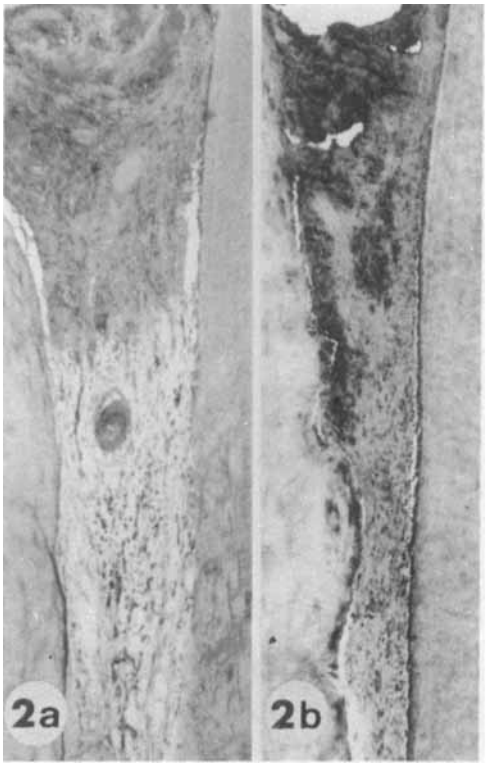


Fig. 2. The penetration of formocresol appeared unpredictable as judged by the loss of structure and eosinophilia caused by the medicament. *a* superficial changes; *b* deep changes. Mayer's haemalum-eosin. X 30.

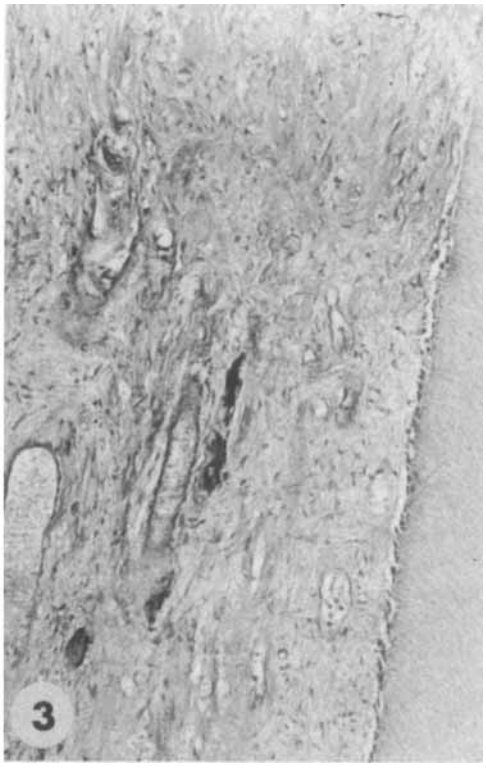


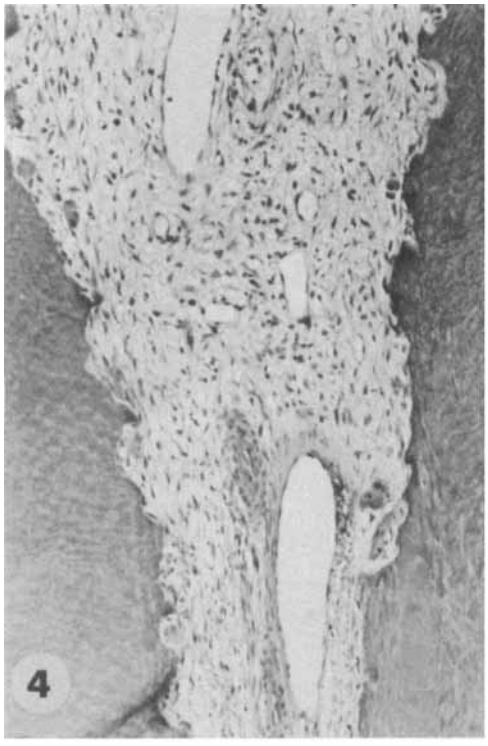
Fig. 3. Intermediate fixed zone with preserved structure. The capillaries are thrombotic and endothelial cells are markedly thickened. Mayer's haemalum-eosin. X 100.

eosinophilic zone was necrotic (Table 3). Extracted teeth do not warrant firm conclusions about periradicular spread, but granuloma-like structures adhered to 10 of these roots.

When "vital" residual tissue was observed below the eosinophilic, or an intermediary zone, there was always a certain degree of inflammation. Inflammatory cells, seemingly lymphocytes, were accumulated next to the formocresol-affected tissue, but mostly there was also some apical spread in the centre of the canal accompanying the vessels. In 13 root canals out of 89 the accumulation of inflammatory cells was subjectively classified as slight.

The occurence of internal root resorption on some occasion between the treatment and the extraction (Table 3) was noticeable in the dentin of 89 roots (81 %). Where the resorption was active, it appeared in areas with minor changes in the cellular picture bordering on to zones with a more marked inflammation. In the majority of roots the resorption was confined to small areas and appeared to be arrested where the inflammatory changes were severe (Fig. 4).

Reparative hard tissue formation in areas of internal root resorption was observed in 77 out of the 89 roots. The tissue had the character of cellular root cementum or trabecular bone (Fig. 5). The hard tissue formation observed radiographically in one canal proved to be an extensive area of repair. Amorphous mineralizations were frequently observed in the formocresol-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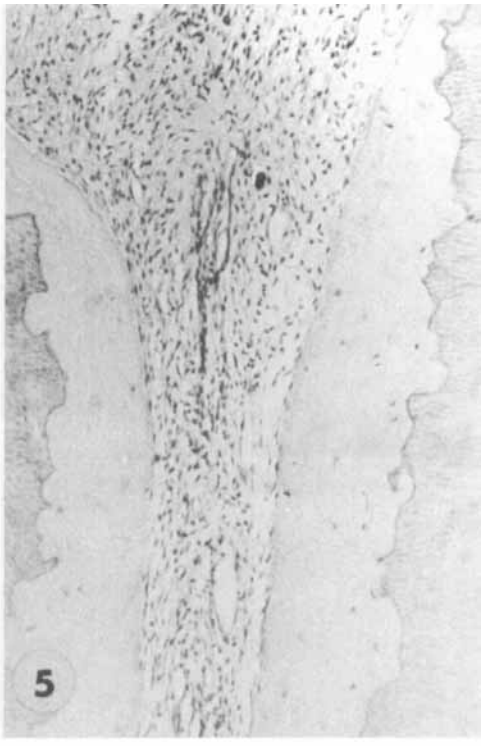
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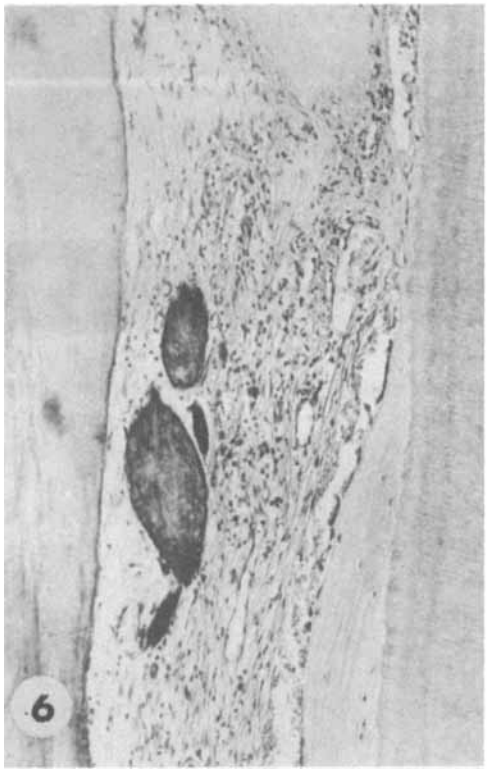
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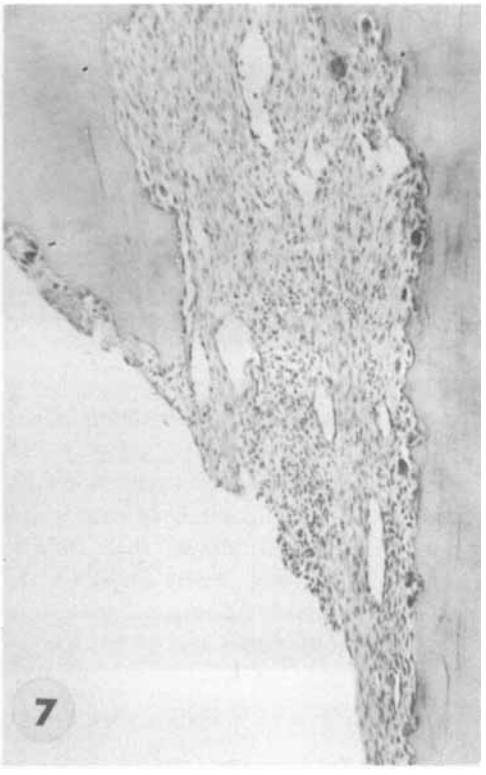
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Fig. 4–7. Mayer's haemalum-eosin. X 100.

Fig. 4. First molar 12 months after treatment. Vital part of the pulp. Active internal root resorption.

Fig. 5. Second molar 6 months after treatment. Vital pulp in the apical part of the root. Repair tissue resembling root cementum in area of previous internal root resorption.

Fig. 6. Second molar 12 months after treatment. Vital tissue bordering to fixed pulpal tissue (top). Accumulation of inflammatory cells. Amorphous mineralizations (dark).

Fig. 7. Second molar 6 months after treatment. The external physiological resorption approaches an area of internal root resorption. Moderate accumulation of inflammatory cells (center).

affected tissue, but there was never any walling off or bridge-formation in the pulp (Fig. 6).

The physiological external root resorption appeared to continue unimpeded upon reaching pulpal areas fixed by the formocresol. A moderate "periapical" accumulation of inflammatory cells was often noted in such cases (Fig. 7).

DISCUSSION

The radiographic observations confirmed the impression that internal root resorptions are less dramatic and less frequently observed in follow-up examinations of pulpotomies with the formocresol-technique than in vital techniques with calcium hydroxide or zinc oxide-eugenol as wound dressing. Radiographically demonstrable internal root resorptions have earlier been reported as very scarce or even non-existent after pulpotomies with formocresol (3, 17, 25). The fact that internal root resorptions were diagnosed in one-fifth of the roots treated in the present material may be due to the detailed criteria used, and to the fact that this material consisted of lower primary molars only, where radiographic changes are more readily discerned than in the upper molars. The histological study confirmed the presence of internal resorptions in a majority of treated roots. The histological techniques do not warrant any firm conclusions as regards the penetration and immediate effect of the formocresol (4, 12). However, shades in staining and changes in the cellular picture gave a definite impression of a capricious penetration of the drug, such as has been demonstrated in animal experiments (22). The amount of tissue fixed *in vivo* appeared to be independent of the length of application and totally unpredictable. It has to be considered, that in roots with a very superficial penetration of the medicament, the observations on the remaining pulpal tissue may be representative for reactions to the zinc oxide-eugenol cement rather than to the formocresol (1).

Healing in the proper sense, *i.e.* a pulpal tissue without inflammation, was not achieved in any root. The treatment with formocresol resulted in chronic inflammation in the residual tissue. In a few roots the chronic inflammation could be described as slight and perhaps comparable to the reactions accepted in connection with *e.g.* root canal filling materials such as guttapercha (13). This does not alter the fact that healing never occurred. From a biological standpoint the formocresol technique is inferior to pulpotomy with calcium hydroxide, where healing may occur, although in a limited number of roots. It should also be kept in mind that the frequency of necrosis in the residual tissue and of periapical involvement was higher in the present material than in earlier reports on pulpotomy with calcium hydroxide (8).

The length of observation could not be correlated to the extent or severity of the inflammatory reactions of the residual pulp. Neither was the length of application of the medicament found to have any

influence. Consequently, there appears to be little advantage in a two-appointment technique (16).

Internal root resorptions accompanied the chronic inflammation as has also been described by Rölling, Hasselgren and Tronstad (18). Active resorption was only observed in areas with little or no accumulation of inflammatory cells, but bordering on to areas with more severe changes. Obviously, the pulp had no capacity to resorb in those areas where inflammatory changes had become manifest. The observations on resorption and formation of repair tissue were identical to those observed with vital techniques (8). The fact that internal root resorptions remain small in primary molars treated with formocresol and seldom become visible to the clinician is thus due to severe damage to the residual tissue, interfering with its capacity to resorb – a parallel to the conditions created by zinc oxide-eugenol (10). A "symptomless" exposure of the pulp by caries in primary molars is generally accompanied by inflammatory changes in the pulp tissue, also involving the upper part of the root canals (9). Consequently, in a partial pulp treatment the wound surface or the intended area of healing should be placed in the root canal. From a biological point of view, it is a contradiction to try to achieve these conditions by using a toxic and irritant drug like formocresol (20).

The obvious disadvantage of the formocresol technique is that a chronic inflammation is immediately carried down to deeper parts of the root canal. Pulpotomy with calcium hydroxide as a wound dressing may lead to healing, although in a low percentage of cases. If not, mild inflammatory changes in the upper part of the root canal will very likely give rise to internal root resorption. One treatment philosophy may be to try to improve the success with calcium hydroxide, *e.g.* by creating an exact wound surface and by avoiding the formation of a blood clot that separates the tissue and the dressing and thereby inactivates the calcium hydroxide (19).

To the clinician the formocresol technique will be attractive because of the few complications seen in radiographs. From a strictly scientific point of view, attempts must be made to minimize the toxic and irritant effects of the formocresol (7, 14).

Whether the clinician should accept a chronic, "silent" inflammation in the residual pulp at all, is debatable. At present, it must be admitted that for several reasons pulp treatment in the primary dentition constitutes an unsolved problem. Experience from the Scandinavian Public Dental Services now shows that systematic and early prevention of caries is one realistic and practicable alternative to pulp treatment in the primary dentition.

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