Response of the primary pulp to inflammation: a review of the Leeds studies and challenges for the future

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**ABSTRACT. Aim** The purpose of this paper is to consider evidence for the early involvement of the pulp in primary molars following a proximal caries attack and to consider the evolution of ferric sulphate as the possible alternative to formocresol for pulp therapy in primary molars. Concerns have been expressed over the wisdom of using products containing formaldehyde in children and alternatives should be considered, even though there is no substantive data to support the claims of formocresol toxicity. Pulp therapy is still often required in the management of large proximal caries in primary molars. General dental practitioners often comment on the futility of restoring primary teeth with the common perception being that restorations more often than not fail in the primary teeth. One common cause is abscess formation following proximal restorations. The main reason why this occurs is that proximal restorations in primary teeth are often carried out without consideration being paid to the state of the pulp. We have shown in a series of studies in Leeds that pulp inflammation in primary molars precedes its exposure. Most primary molars where caries had involved more than half inter-cuspal distance manifested pulp inflammation involving the entire pulp horn, but rarely the root canal tissue. This would mean that in most primary teeth with proximal caries, which are indicated for a pulpotomy, the removal of the coronal pulp alone would render them free of inflammation. This would then bring into question the use of formocresol on an otherwise uninfamed radicular tissue, which has a viable blood supply. **Conclusion** Pulp inflammation in primary molars sets in at an early stage of a proximal carious attack. Also, in most cases, a medicament that would achieve haemostasis, such as ferric sulphate, rather than achieve fixation of the tissues is all that would be required for the preservation of the primary tooth until exfoliation.

**Introduction**

Recently, in the United Kingdom the value of restoring primary teeth has been questioned. This has indeed made sad reading for dental practitioners, who strive to provide high quality restorative and preventive care for those children who still develop caries in their primary dentition. A recent article in the British Dental Journal [Tickle et al., 2002] reported that, irrespective of the intervention, or the lack of it, there was no difference in the outcome as measured by the proportion of teeth extracted due to pain or sepsis. In this study restorations placed by some general dental practitioners (GDPs) in one part of Northern England were identified retrospectively from the dental records. The outcome of these restored teeth was followed up and compared with those teeth that were left unrestored by the GDPs. The study concluded that the fate of the primary teeth studied was not different for restored or unrestored teeth with a similar number in both groups being extracted. It was also interesting to note in this study that some 23% of the first molars that had never been restored and nearly 20% of the ones that had been restored were extracted due to pain or sepsis. Similar figures were reported for two surface lesions. Importantly, the authors did not report on the restorative technique practiced by the GDPs and did not comment on the quality of the restorations that they had followed up.

It is certain that most teeth restored in general dental practice are restored without the use of local...
analgesia and rubber dam, and it is well known that the routine use of these is low in general dental practice [Curzon et al., 1986]. In our view the findings of the study reported by Tickle et al. [2002] should alert us to the fact that there are fundamental flaws in the restorative technique being practiced by the general practitioners for the restoration of teeth with proximal caries and therefore the outcome of teeth restored using poor restorative techniques is no different from those left unrestored. Certainly, if they had compared the fate of unrestored teeth with those restored properly with due consideration to the principles of pulp involvement and using techniques such as pulpotomies and stainless steel crowns, their results would probably be very different. Indeed, excellent outcome for primary teeth, free from pain or sepsis, have been reported when primary teeth were restored using such techniques [Papathanasiou et al., 1994; Roberts and Sheriff, 1990]. There can be no doubt that untreated caries in the primary dentition can cause abscesses, pain and suffering in children. It has been reported that severe caries affects the quality of life of preschool children [Low et al., 1999; Shepherd, 1999] and this can be improved by eliminating dental disease [Low et al., 1999].

The 1993 Child Dental Health survey in the United Kingdom showed that the proportion of filled teeth for the primary dentition has decreased despite an increase in the decayed component [OPCS, 1994]. This is partly due to the poor remuneration for GDPs in the British National Health Service (NHS) system. However, many dentists do comment on the futility of restoring primary teeth due to what they perceive to be a high failure rate of restorations they place in primary teeth. This seems to be in conflict with the reported longevity for many newer materials used in primary teeth [Marks et al., 1999; Welbury et al., 2000; Fuks et al., 2000]. However, in all these studies, reporting high survival rates, restorations were placed by specialists in Paediatric Dentistry accounting for a much better outcome compared with restorations that might be placed by GDPs.

Also, the response of the primary pulp to carious attack is poorly understood. The anatomy of the primary molars differs from that of permanent teeth in that they are smaller, the enamel is thinner, permeable, less calcified and more easily worn down. The dentine too is permeable, less in thickness and the pulp chambers larger than in the permanent teeth, with prominent pulp horns, which further decrease the depth of dentine [Mortimer, 1970; Beek, 1983; McDonald and Avery, 1994; Hillson, 1996]. This, together with thin enamel and large pulp horns, with broken marginal ridge, can lead to an early pulp involvement. Early studies [Hobson, 1970] showed that in over 50% of the primary molars with the loss of the marginal ridge, pulp inflammation was irreversible. However, there is little further evidence in the last three decades which relates the extent of the carious lesion, especially proximal caries with the onset of pulp inflammation.

**Summary of the Leeds studies.** Studies which aimed to correlate the onset of pulp inflammation to the extent of the proximal carious lesion were carried out in Leeds [Nooh, 1998]. These studies investigated the pulp pathology in primary molars with proximal caries, both with and without a clinical exposure and also correlated pulp pathology with the extent of the carious lesion as measured in relation to the buccolingual inter cuspal distance (ICD) involved in the carious process.

**Materials and methods**

Extracted teeth were collected and fixed in formalin. The inter cuspal distance that was involved in the proximal carious process was measured using electronic digital calipers as a measure of the total buccolingual inter cuspal width of the molar. Teeth were grouped as <1/2 ICD or >1/2 ICD as involved in the carious process. Caries was then removed with a slow speed bur to establish whether a clinical exposure was discernible on the axial wall. The teeth were then examined histologically after preparation and staining using standard histological techniques.

**Results**

A total of 79 teeth were included in these studies. The results are presented in Figure 1. This summarises the relationship between the extent of caries in relation to ICD and the status of the pulp. It can be seen that where <1/2 ICD was involved in the carious process, out of 19 teeth only one had normal pulp histology with most teeth (12) showing inflammation extending to the pulp horn. For teeth where >1/2 ICD was, 60 teeth, only one had normal pulp histology and 42 teeth manifested inflammation extending to the pulp horn. It should be noted, however, that only 7 teeth with evidence of >1/2 ICD involvement showed evidence of inflammation in the radicular pulp with none of the teeth with <1/2 ICD involvement showing evidence of inflammation beyond the coronal pulp. In addition, the study also showed that inflammation of the pulp horn had manifested well before the pulp was found to be clinically exposed.

**Clinical implications.** The results of the study reviewed above suggest that inflammation of the
Pulp inflammation in primary teeth develops at an early stage of proximal caries attack and by the time most proximal caries is manifest clinically pulp inflammation is quite advanced. Thus, large restorations in primary molars carried out, without due consideration to the state of the pulp, are doomed to failure (Fig. 2). In addition it was quite apparent that, in most of the teeth, inflammatory changes in the primary pulp were evident only in the coronal pulp, and mainly in the pulp horn adjacent to the carious lesion. Inflammatory changes in the radicular pulp were only evident in a very small number of the teeth with >1/2 ICD involved in the carious process. This would mean that for most carious primary molars with proximal carious lesions where the clinician suspects pulp involvement, the removal of coronal pulp would in most cases leave behind an uninflammed radicular tissue. In the authors opinion this is an important clinical implication and would put into question the wisdom of using formocresol, which is a fixative, on an otherwise uninflammed vital tissue with an intact blood supply.

**Pulp fixation versus haemostasis.** It would seem that in a primary molar with proximal caries and suspected pulp involvement the removal of the coronal pulp alone would in most cases render the pulp free from inflammation (Fig. 3). The clinician would, of course, assess the history of pain and other signs and symptoms including the intensity of bleeding from the amputation site to aid in diagnosing the state of the radicular tissue.

**FIG. 1 - Extent of caries and pulp status.** The extent of caries was measured as the amount of the buccolingual inter cuspal distance (ICD) involved in the carious process. It can be seen that most teeth had evidence of pulp inflammation with the pulp horn being involved in most teeth with <1/2 or >1/2 ICD involved in the carious process.

**FIG. 2 - Asymptomatic buccal abscess related to 64 which had been previously restored with amalgam.**

**FIG. 3 - a) Histological changes in the dental pulp around the point of exposure.** The rest of the pulp is healthy and free from inflammation. If the inflamed tissue is removed from the pulp chamber (b), the radicular pulp that is left behind should be free from inflammation in most cases.
However, if the radicular pulp is diagnosed as normal then we have to question the use of formocresol (FC). The pulp in the root canal has a viable blood supply which is uncompromised and this, together with its uninflamed status, would be able to sustain the primary tooth without resorting to the use of a tissue fixative such as FC. There have been concerns about the possible toxicity of FC, especially systemically [Myers and Pashley, 1983]. There are, however, no substantial data to support any toxicity claims, and given the widespread use of FC since 1930s there is little reason to doubt its safety. However, it is an aldehyde based fixative and it is the duty of the profession to continually review evidence and new research data in order to either justify or limit its use. From the data reviewed here, it would seem questionable whether a healthy radicular pulp with a viable blood supply should have a fixative applied to it. The use of a haemostatic agent, such as ferric sulphate, in order to achieve haemostasis prior to restoration would seem more appropriate.

Ferric sulphate as a pulpotomy medicament. Ferric sulphate (FS) has been used widely to control gingival bleeding prior to impression taking and in endodontics. It is an excellent haemostatic agent, forming ferric ion-protein complex on contact with blood which stops further bleeding by sealing the cut vessels. It is commercially available in a concentration of 15.5% as Astringident [Ultradent, USA]. It has now been shown to be effective as a pulpotomy medicament in the medium term [Fuks et al., 1997; Smith et al., 2000].

However, it must be remembered that FS has no fixative effect. For this reason an accurate diagnosis of the state of the pulp tissue that is left behind, and on which FS is being applied will need to be made.

FC remains the most widely used medicament for pulpotomies in primary molars. In light of current knowledge on the reaction of primary pulp to proximal carious attack, use of FS can be recommended for cases where, after the amputation of the coronal pulp, the radicular pulp is deemed to be free from inflammation.

References


