A clinical guide to endodontics – update part 2

P. V. Carrotte¹ and P. J. Waterhouse²

IN BRIEF

- An overview of the recent changes relating to pulp therapy for children, particularly concerning the primary dentition.
- Discusses the issues surrounding the use of formaldehyde in dentistry.
- Discusses the clinical pulp therapy techniques which can be used for extensively carious primary teeth.
- Highlights the growing evidence base that has provided an increased understanding of the healing capacity of the pulp.

PRACTICE

This second update paper aims to provide a review of changes and developments that have occurred within the field of pulp therapy for primary teeth since the publication of the *BDJ*'s series and textbook *A clinical guide to endodontics*. The biological basis of pulp therapy is an area where much recent research has taken place, particularly linked to the healing capacity of pulp tissue. This has led to the adoption of treatment techniques aimed at maintaining pulp vitality. Such techniques are introduced here as a more contemporary, biological approach to pulp management in the primary dentition.

INTRODUCTION

This is the second of two papers reviewing the changes and developments that have occurred in the four years since the *BDJ*'s textbook *A clinical guide to endodontics* was published. The first part considered the materials and methods used in endodontic therapies for permanent teeth and discussed the considerable change in the practice of endodontic surgery.

This second part focuses specifically on pulp therapy in children's dentistry.

PULP THERAPY FOR CHILDREN

Permanent teeth

Pulp therapy in paediatric dentistry may be required for both primary and permanent teeth. With regard to the latter, little has changed in treatment techniques since *A clinical guide to endodontics* was published. Several papers have been

published on the very successful outcomes when mineral trioxide aggregate (MTA) is used as a pulp capping agent in permanent teeth.^{1,2} There is an old endodontic cliché that the best root filling is a vital pulp – even more significant if vitality can be maintained in immature permanent teeth, allowing completion of root apex formation and root canal maturation. These reports may be considered together with the only other recent significant change regarding pulpal therapy of permanent teeth. In 2005, Bjorndal and Kidd³ summarised the principles of current thinking in caries management, describing the 'stepwise' removal of caries with pulp capping. Research shows that when the cavity is subsequently revisited, in the vast majority of cases caries has arrested and/or remineralisation has taken place. This may reduce the need for subsequent root canal therapy.

Endodontists have traditionally been reluctant to attempt such pulp capping techniques because anecdotally it was suggested that if treatment was not completely successful, a chronic low-grade inflammation resulted and the tooth developed what was termed 'asymptomatic irreversible pulpitis'. As a result of this, sclerosis made eventual root canal treatment more difficult, thus reducing the likelihood of a good prognosis. However, in the light of this report³ and a recent Cochrane

review concerning caries excavation,⁴ a knowledge, understanding and practice of modern methods of caries management and the associated scientific evidence is essential for comprehensive treatment of carious permanent teeth in children.

Primary teeth

While there may have been little change in the treatment of permanent teeth, there has been significant change in the approaches to vital and non-vital pulp therapy for the primary teeth. These can be divided into the following:

Vital pulp therapy

- Indirect pulp therapy (IPT) or indirect pulp capping
- Direct pulp capping
- Vital pulpotomy.

Non-vital pulp therapy

- Pulpectomy.

Vital pulp therapy aims to treat reversible pulp injuries, maintain vitality and function and preserve the primary tooth until exfoliation. Non-vital pulp therapy involves the removal of irreversibly inflamed or necrotic pulp tissue, cleaning of the root canals and obturation with a resorbable paste and aims to restore and/or maintain the health of the periradicular tissues until tooth exfoliation.

¹Senior Clinical University Teacher and Associate Specialist in Endodontics, Unit of Adult Dental Care, Glasgow Dental Hospital and School, 378 Sauchiehall Street, Glasgow, G2 3JZ; ²Clinical Senior Lecturer in Child Dental Health and Honorary Consultant in Paediatric Dentistry, The Newcastle University School of Dental Sciences, Framlington Place, Newcastle upon Tyne, NE2 4BW
Correspondence to: Dr Paula J. Waterhouse
Email: p.j.waterhouse@newcastle.ac.uk

Refereed Paper

Accepted 16 June 2008

DOI: 10.1038/sj.bdj.2009.56

©British Dental Journal 2009; 206: 133–139

Indirect pulp therapy (IPT)

Indirect pulp therapy is where a layer of discoloured carious dentine is purposely left at the floor of the cavity to prevent pulp exposure and additional trauma to the pulp. It follows the same principles as discussed previously for permanent teeth. This approach has been reported to be successful in symptom-free primary teeth with deep carious lesions when calcium hydroxide or glass ionomer lining cement was used as the indirect pulp capping material.^{5,6} Indeed, the findings of Marchi *et al.*⁶ were significant, showing the same order of success when either calcium hydroxide or glass ionomer lining cement was used as the indirect pulp capping agent. It is worth noting that success of IPT is also thought to be dependent upon securing a leakage-free definitive restoration, such as a preformed metal crown or bonded restoration.⁷ Glass ionomer cement is not durable enough to be used as a definitive restoration. Once again, if pulp vitality can be maintained, the need for any root canal treatment will be avoided.

Direct pulp capping

Direct pulp capping in the primary dentition, where an agent is placed in direct contact with exposed pulp tissue, should be reserved for non-carious, iatrogenic exposures only. Favourable results were reported when MTA was used as the direct pulp capping agent.⁸⁻¹² Such treatment must be carried out in aseptic conditions, preferably under rubber dam, to enhance the chance of success. In addition, previous studies have reported similar levels of success when calcium hydroxide was used in these situations.^{5,6}

Single-visit vital pulpotomy

The gold standard agent in vital primary molar pulpotomy procedures since the 1930s has been Buckley's formocresol solution (BFS), either in its full strength solution or a 20% (1:5) dilution.¹³

At the time *A clinical guide to endodontics* was being published, several papers were appearing in the dental literature questioning the use of this traditional pulpotomy medicament. Questions have been raised concerning the safety of BFS, in part due to its

formaldehyde content and also the finding that success rates appeared to reduce over time when compared with IPT.¹⁴ It is becoming difficult to obtain BFS because of an increasing reticence of pharmacy staff to prepare the formulation in either its full-strength or diluted form.^{15,16} Perhaps most importantly, in light of contemporary knowledge of the healing capacity of both the primary and permanent tooth pulp, it has been suggested that it is timely to re-evaluate our treatment strategies based on present scientific evidence.¹⁶⁻¹⁸

There is debate within the speciality of paediatric dentistry regarding the suitability of BFS as a pulpotomy medicament, and a survey of UK-based paediatric dentists reported that 54% of respondents expressed reservations over using formocresol.¹⁸ Formaldehyde is a volatile organic compound which is accepted as being toxic and corrosive, particularly at the point of contact. Similarly cresol, a major constituent of BFS, is a known irritant and is corrosive. Much research has been published relating to the toxicity, genotoxicity and carcinogenicity of formaldehyde in animal models.¹³ The International Agency for Research on Cancer (IARC) released a report in 2004 stating that from evidence available from large human epidemiological studies, a causal relationship between formaldehyde and nasopharyngeal carcinoma was seen but that evidence did not support a causal relationship for leukaemia.¹⁹ Subsequent to the publication of the IARC findings, the UK's Health and Safety Executive (HSE) Working Group on Action to Control Chemicals (WATCH) published their findings from a committee looking at the carcinogenicity of formaldehyde.²⁰ It is generally accepted that formaldehyde is toxic at the site of contact (for example, if sufficient amounts are inhaled, the nasal mucosa may be affected). It was also concluded that human and animal *in vivo* studies indicate that formaldehyde is a mutagen at the site of contact and has been shown to be an experimental carcinogen in rats at high levels of exposure. It was concluded that a combination of local, chronic irritation and local genotoxicity in humans would be of concern in relation to cancer.²⁰ It is important to note that the

WATCH report raised concerns relating to possible inconsistencies in some of the epidemiological studies considered during the evaluation of evidence by IARC. The IARC press release in 2004 led to a withdrawal of Buckley's formocresol and other formaldehyde or para-formaldehyde containing preparations (such as Aeslich's or Miller's devitalising pastes) from many of the specialist paediatric dental services.

The treatments using formaldehyde-containing preparations described in *A clinical guide to endodontics* are no longer recommended by all paediatric dentists. Recently published work considering the alternative interventions and materials available for pulp therapy may be useful for further reading.^{11,12} The recently published UK National Clinical Guideline on pulp therapy for primary molars still lists BFS as a pulpotomy agent in acknowledgement that it is not a banned substance and the debate over its use is far from over.¹⁶ It appears from the literature that two agents may be good alternatives to BFS, namely ferric sulphate and mineral trioxide aggregate (MTA). First, ferric sulphate appears to be as effective²²⁻²⁴ or better than formocresol as a pulpotomy agent.²⁵⁻²⁸ Similarly, MTA appears from recent studies to be clinically and radiographically more successful than BFS.²⁹⁻³⁴ A recent meta-analysis concluded that MTA was a more successful pulpotomy agent than BFS.³⁵ However, more long-term studies providing data relating to its clinical success are recommended.

TREATMENT GUIDELINES

As with all treatment, the importance of diagnosis and appropriate treatment planning remains paramount. Diagnosis of pulp status in children can be difficult and decisions relating to treatment are often made during the treatment itself. Whenever possible, the health of the pulp should be maintained. Figure 1 represents a suggested protocol for managing an extensively carious primary molar.²¹ Practitioners may find this helpful when dealing with such a tooth. The following paragraphs and descriptions of clinical techniques are a direct replacement for those published in *A clinical guide to endodontics*.

Before commencing treatment

Radiographic examination as part of thorough treatment planning for caries management is essential and should be undertaken prior to embarking upon restorative treatment. The operator must be aware of the extent of a carious lesion, as this aids decision making on pulp management and subsequent coronal restoration. The majority of the following restorative procedures will require adequate local anaesthesia. In accordance with the biological principles established throughout the text, adequate isolation will also be necessary to prevent salivary contamination. A rubber dam should be placed wherever possible, and isolation completed with cotton wool rolls and saliva ejector. Following pulp treatment (of any type), the definitive restoration should afford optimum coronal seal, which for a two or more surface lesion is a preformed metal crown.¹⁶

Indirect pulp therapy (IPT)

The aim of IPT is to maintain pulp vitality in a deep carious lesion. The tooth must be symptom-free. All carious dentine should be removed from the walls of the cavity, such that the amelo-dentinal junction is caries-free and a layer of deep softened, discoloured dentine may be left if its removal would cause a pulpal exposure. The amount of stained dentine left may be subjective and may vary between operators. A lining of either setting calcium hydroxide or glass ionomer lining cement is placed, and the tooth restored over the lining with a permanent restorative material to provide optimum coronal seal, such as a preformed metal crown. A glass ionomer restorative material is not sufficiently durable and should not be used as a means of definitive restoration. The tooth should be monitored regularly, including radiographic examination related to the child's caries risk status.

Direct pulp capping

This treatment is only recommended when a small traumatic or iatrogenic exposure occurs during cavity preparation of a vital, non-inflamed pulp. Direct pulp capping is not recommended following a carious exposure.^{7,16} Bleeding must be arrested before a calcium hydroxide

Fig. 1 A suggested protocol for the management of an extensively carious primary molar. (MH) medical history; (LA) local anaesthesia; (RA) relative analgesia; (GA) general anaesthesia; (ADJ) amelodentinal junction; (GIC) glass ionomer cement; (ZnOE) zinc oxide-eugenol cement; (PFMC) preformed metal crown; (GDP) general dental practitioner. (Reproduced with kind permission of Wiley-Blackwell Publishing²¹)

dressings is placed directly over the pulp, followed by a lining and well-sealed restoration. It has been suggested that the high cellular content of primary pulp tissue may be responsible for the failure of direct pulp capping in primary teeth.³⁶ Undifferentiated mesenchymal cells may differentiate into osteoclastic cells in response to either the caries or direct pulp capping, which leads to internal resorption. It has also been suggested that exposures on axial walls have a poor prognosis as the pulp coronal to the exposure may be deprived of its blood supply and undergo necrosis.³⁶

If the pulp of a primary tooth is exposed during caries excavation, either a pulpotomy or pulpectomy may be performed depending on the status of the radicular pulp tissue.

Pulpotomy

Pulpotomy is intended to remove the irreversibly inflamed coronal pulp tissue allowing the residual healthy or reversibly inflamed radicular tissue to maintain its health or undergo tissue repair. Following coronal pulp amputation, if haemorrhage from the radicular pulp stumps is profuse and uncontrolled,

the assumption is made that the inflammatory process has extended into the radicular pulp tissue and a different treatment should be adopted (either pulpectomy or extraction). There are three pulpotomy techniques that may be considered.

i) Vital ferric sulphate pulpotomy

The treatment is carried out using local anaesthesia and adequate isolation. Figure 2 outlines the stages of the technique. Following cavity preparation in the normal manner, deep caries is removed and if a pulp exposure is evident, the coronal pulp chamber is unroofed with a non-end cutting bur, so that there is no overhanging dentine inhibiting the complete removal of the pulp tissue. The coronal pulp tissue is removed using a sterile excavator or sterile rose head steel bur, taking care not to perforate the floor of the pulp chamber. The cavity should be irrigated with sterile saline and sterile cotton wool applied to the radicular pulp tissue to achieve haemostasis. Bleeding should stop within 2-3 minutes, indicating either a healthy or reversibly inflamed pulp. A small pledget of sterile cotton wool is dipped in a 15.5% solution of the haemostatic agent ferric sulphate and applied to the radicular pulp stumps for 15 seconds. Ferric sulphate may also be applied by 'dripping' the solution over the pulp stumps using a dento-infuser tip or pear-shaped burnisher. A second application of ferric sulphate may be necessary, but could indicate that the radicular pulp is too inflamed to heal and the tooth may be better managed with a pulpectomy or extraction. If haemorrhage has stopped completely, the chamber is dried using more cotton wool and a layer of zinc oxide-eugenol cement is applied. The tooth is restored, preferably with a preformed metal crown to provide good coronal seal.

ii) Mineral trioxide aggregate pulpotomy

Following haemostasis, MTA is mixed with sterile water to produce a 'wet sand' consistency and may be placed over the radicular pulp stumps using a small, sterile endodontic amalgam carrier or excavator. The MTA is gently condensed

Fig. 2 The stages of a single-visit ferric sulphate pulpotomy (reproduced from reference 40 with kind permission from Quintessence Publishing Co. Ltd). a) A cariously exposed primary molar. Caries removal will expose pulp tissue; b) removal of caries and good access to the pulp chamber. Bleeding has stopped within 2-3 minutes indicating an un-inflamed radicular pulp; c) a 15.5% solution of ferric sulphate applied to the pulp stumps via cotton wool pledget for 15 seconds; d) cotton wool removed and tooth restored with zinc oxide-eugenol cement over the pulp stumps followed by glass ionomer cement; e) a preformed metal crown is the definitive restoration

Fig. 3 The stages of a desensitising pulpotomy (reproduced from reference 40 with kind permission from Quintessence Publishing Co. Ltd). a) A cariously exposed primary molar. Caries removal will expose pulp tissue; b) carious exposure which is sensitive and pulp is bleeding; c) place desensitising paste on cotton wool pledget (eg Ledermix™) over exposed pulp tissue and anchor pledget with a setting calcium hydroxide lining material. Place a well-sealed temporary restoration; d) second visit, administer local anaesthesia and proceed to a ferric sulphate pulpotomy; e) a preformed metal crown is the definitive restoration

Fig. 4 The stages of a pulpectomy procedure (reproduced from reference 40 with kind permission from Quintessence Publishing Co. Ltd). a) A cariously exposed primary molar with areas of necrotic pulp (1), irreversible inflammation (2) and some residual vital tissue (3); b) identify root canals using a radiograph. Insert small files into root canals, keeping 2 mm from the radiographic apex. Lightly and gently clean walls of canal but do not shape; c) copious irrigation with hypochlorite solution. Dry canals with premeasured paper points; d) non-setting calcium hydroxide paste can be placed as an interim canal dressing if required. Ensure the pulp chamber is dry using a pledget of cotton wool. Place fresh cotton wool over the canal orifices and place a temporary intra-coronal restoration. This can be left *in situ* for 7-14 days before obturating (see text); e) obturate root canals with a slow setting paste (eg pure zinc oxide-eugenol) using a spiral paste filler or blunt end of a paper point; f) restore as for vital pulpotomy (Fig. 2)

over the pulp stumps using small pledgets of cotton wool. A layer of fast setting zinc oxide-eugenol cement is placed over the MTA and the tooth restored as mentioned previously.

iii) Desensitising pulpotomy

Sometimes a carious tooth proves too sensitive for vital pulpotomy to be performed, even with local anaesthesia, or because local anaesthesia has not been administered. Historically, paraformaldehyde devitalising agents such as Aeslich's or Miller's paste may have been used to devitalise the pulp tissue over time, but due to their formaldehyde content, some dentists may choose to avoid these agents. An alternative technique may be employed using a steroidal antibiotic paste such as Ledermix™ (Lederle Pharmaceuticals, Wolfrathausen, Germany), in a two-stage procedure. At the

first visit, cavity preparation is carried out which results in an exposure of pulp tissue. The pulp will be sensitive for one of the two reasons mentioned previously. As shown in Figure 3, the isolated cavity is irrigated with sterile saline and gently dried with sterile cotton wool pledgets. A small amount of Ledermix™ on a pledget of cotton wool is applied directly to the exposed pulp tissue. The cotton wool is sealed in the cavity using quick setting calcium hydroxide cement and a well-sealed provisional restoration placed. At the second visit one to two weeks later, if the tooth has been symptomless then local anaesthesia is administered and the dressing removed, pulpotomy undertaken and the tooth restored. If the pulp remains hyperalgesic, reapplication of Ledermix™ may be considered, however a plan should be made to progress to pulpectomy or extraction. If the

child is unable to accept treatment then consider extraction, particularly if there have been symptoms of spontaneous pain. Once again, following pulpotomy or pulpectomy an effective clinical and radiographic monitoring regime should be implemented.

Pulpectomy

Pulpectomy is indicated where the pulp is either non-vital or irreversibly inflamed, the latter indicated by radicular pulp tissue which bleeds profusely. The types of clinical scenarios where pulpectomy may be an option include patients with hypodontia, extensively carious second primary molars and carious or traumatised primary incisors where retention of such teeth is important for future occlusal development. Parental motivation and cooperation from the child are also key factors to consider. Although the technique is often considered difficult because of the complexity of the root canals in primary molars, clinical studies have shown a reasonable prognosis.^{37,38} The cavity preparation and removal of the necrotic coronal pulp is carried out as previously described. If the radicular pulp is necrotic and infection is present, a two-stage procedure is required, but if it is irreversibly inflamed and no periradicular infection is present, a one-stage technique may be undertaken (Fig. 4). The root canals should be obturated using a resorbable material such as pure zinc oxide-eugenol paste. If inflammatory root resorption is evident on radiograph the tooth should be extracted.

One stage technique

The root canals are identified and carefully instrumented to the working length estimated from a pre-operative radiograph, approximately 2 mm short of the apex. Copious irrigation with an antiseptic irrigant such as sodium hypochlorite (1%) or chlorhexidine (2%) should be used, but only very limited filling with small hand files should be performed due to the very thin root canal walls. After drying the canals with carefully measured paper points, the root canals may be filled with a resorbable obtundant such as pure zinc oxide-eugenol or a calcium hydroxide and iodoform

paste such as Vitapex³⁹ (Neo Dental Chemical Products Co, Tokyo, Japan), using a rotary paste filler or injection system, and the restoration of the tooth completed. Again, the ideal restoration following pulpectomy and obturation is a preformed metal crown.

Two stage technique

Initially, the root canals are cleaned and irrigated to remove all necrotic debris. A dressing of non-setting calcium hydroxide paste may be placed in the canals, and the orifices protected with a small pledget of damp cotton wool ensuring that no fibres protrude from the cavity, which would permit ingress of micro-organisms. The tooth may be temporarily restored with a quick setting zinc oxide-eugenol or glass ionomer cement.

At the second visit the procedures described above for the one visit technique are carried out. However, if the child's symptoms have not resolved extraction is advisable.

All the techniques discussed here are reviewed in the recent UK National Guidelines in Paediatric Dentistry and represent the best clinical practice.¹⁵

REVIEW

Following any form of endodontic treatment, regular clinical and radiographic reviews must be made of the tooth involved and its successor. If following IPT or pulpotomy, rarefaction of the bone in the furcation area is seen, pulpectomy may be considered. Following pulpectomy, if similar evidence of failure is seen clinically and/or radiographically, extraction is advisable. Radiographs should also be checked for evidence of internal resorption, which may occur particularly following inappropriate pulpotomy of a vital radicular pulp that was irreversibly inflamed.

CONCLUSION

Recently, there has been re-evaluation of the evidence base and rationale for pulp therapy in the primary dentition. Generally there is a move away from the formocresol pulpotomy, although the technique is still being taught in some UK dental schools. The move away from formocresol has been driven in

part by concerns regarding the safety of formaldehyde coupled with the reticence of pharmacy staff to compound the solution from its raw ingredients. Long-term success of formocresol pulpotomy has been questioned and there have been significant increases in our understanding of the healing capacity of the pulp and management of the deep carious lesion, supporting the use of indirect pulp therapy. Further to this, an advance in endodontic instruments and techniques allows the option of pulpectomy if appropriate, particularly for the strategically important second primary molar. The IARC statements relating to the safety of formaldehyde stimulated the profession to move forward and assess treatment strategy, and alternative agents are now gaining in popularity. The use of effective alternative materials such as ferric sulphate and MTA has been described. With a good understanding of the underlying scientific principles and with effective local anaesthesia and isolation, the procedures outlined in this paper may result in a good prognosis when providing pulp therapy for primary teeth.

- Iwamoto C E, Adachi E, Pameijer C H, Barnes D, Romberg E E, Jefferies S. Clinical and histological evaluation of white ProRoot MTA in direct pulp capping. *Am J Dent* 2006; **19**: 85-90.
- Patel R, Cohenca N. Maturogenesis of a cariously exposed immature permanent tooth using MTA for direct pulp capping: a case report. *Dent Traumatol* 2006; **22**: 328-333.
- Bjorndal L, Kidd E A M. The treatment of deep dentine caries lesions. *Dent Update* 2005; **32**: 402-404, 407-410, 413.
- Ricketts D N J, Kidd E A M, Innes N, Clarkson J. Complete or ultraconservative removal of decayed tissue in unfilled teeth. *Cochrane Database Syst Rev* 2006; **(3)**: CD003808. DOI: 10.1002/14561858.CD003808.pub2.
- Pinto A S, de Araujo F B, Franzon R *et al*. Clinical and microbiological effect of calcium hydroxide protection in indirect pulp capping in primary teeth. *Am J Dent* 2006; **19**: 382-386.
- Marchi J J, de Araujo F B, Froner A M, Straffon L H, Nor J E. Indirect pulp capping in the primary dentition: a four year follow-up study. *J Clin Pediatr Dent* 2006; **31**: 68-71.
- Srinivasan V, Patchett C L, Waterhouse P J. Is there life after Buckley's formocresol? Part I – a narrative review of alternative interventions and materials. *Int J Paediatr Dent* 2006; **16**: 117-127.
- Aeinehchi M, Dadvand S, Fayazi S, Bayat-Movahed S. Randomised controlled trial of mineral trioxide aggregate and formocresol for pulpotomy in primary molar teeth. *Int Endod J* 2007; **40**: 261-267.
- Caicedo R, Abbott P V, Alongi D J, Alarcon M Y. Clinical, radiographic and histological analysis of the effects of mineral trioxide aggregate used in direct pulp capping and pulpotomies of deciduous teeth. *Aust Dent J* 2006; **51**: 297-305.
- Witherspoon D E, Small J C, Harris G Z. Mineral trioxide aggregate pulpotomies: a case series outcomes assessment. *J Am Dent Assoc* 2006; **137**: 610-618.
- Holan G, Eidelman E, Fuks A B. Long-term evaluation of pulpotomy in primary molars using mineral trioxide aggregate or formocresol. *Pediatr Dent* 2005; **27**: 129-136.
- Agamy H A, Bakry N S, Mounir M M, Avery D R. Comparison of mineral trioxide aggregate and formocresol as pulp-capping agents in pulpotomized teeth. *Pediatr Dent* 2004; **26**: 302-309.
- Waterhouse P J. Formocresol and alternative primary molar pulpotomy medicaments. A review. *Endod Dent Traumatol* 1995; **11**: 157-162.
- Farooq N S, Coll J A, Kuwabara A, Shelton P. Success rates of formocresol pulpotomy and indirect pulp treatment in the treatment of deep dental caries in primary teeth. *Pediatr Dent* 2000; **22**: 278-286.
- Nunn J H, Smeaton I, Gilroy J. The development of formocresol as a medicament for primary molar pulpotomy procedures. *ASDC J Dent Child* 1996; **63**: 51-53.
- Rodd H D, Waterhouse P J, Fuks A B, Fayle S A, Moffat M A. UK national guidelines in paediatric dentistry. Pulp therapy for primary molars. *Int J Paediatr Dent* 2006; **16**(Suppl 1): 15-23.
- Rodd H D, Boissonade F M. Immunocytochemical investigation of immune cells within human primary and permanent tooth pulp. *Int J Paediatr Dent* 2006; **16**: 2-9.
- Hunter M L, Hunter B. Vital pulpotomy in the primary dentition: attitudes and practices of specialists in paediatric dentistry practising in the United Kingdom. *Int J Paediatr Dent* 2003; **13**: 246-250.
- International Agency for Research on Cancer. *IARC classifies formaldehyde as carcinogenic to humans*. Lyon: IARC, 2004. Press release No. 153.
- HSE ACTS Working Group on Action to Control Chemicals. *WATCH committee paper 2005/6. The carcinogenicity of formaldehyde*. London: HSE, 2005. <http://www.hse.gov.uk/aboutus/meetings/iacs/acts/watch/130105/p6.pdf> (accessed 15 January 2009).
- Patchett C L, Srinivasan V, Waterhouse P J. Is there life after Buckley's formocresol? Part II – development of a protocol for the management of extensive caries in the primary molar. *Int J Paediatr Dent* 2006; **16**: 199-206.
- Aktoren O, Gencay K. A two year clinical-radiographic follow-up of the pulpotomies in primary molars. *J Dent Res* 2000; **79**: 543 (Abstract 3193).
- Ibricicvic H, Al-Jame Q. Ferric sulfate as pulpotomy agent in primary teeth: twenty month clinical follow-up. *Pediatr Dent* 2000; **24**: 269-272.
- Markovic D, Zivojinovic V, Vucetic M. Evaluation of three pulpotomy medicaments in primary teeth. *Eur J Paediatr Dent* 2005; **6**: 133-138.
- Fei A, Udin R, Johnson R. A clinical study of ferric sulfate as a pulpotomy agent in primary teeth. *Pediatr Dent* 1991; **13**: 327-332.
- Fuks A B, Eidelman E, Cleaton-Jones P, Michaeli Y. Pulpal response to ferric sulfate, diluted formocresol and IRM in pulpotomized primary baboon teeth. *ASDC J Dent Child* 1997; **64**: 254-259.
- Pappagiannoulis L. Clinical studies on ferric sulphate as a pulpotomy medicament in primary teeth. *Eur J Paediatr Dent* 2002; **3**: 126-132.
- Huth K C, Paschos E, Hajek-Al-Khatir N *et al*. Effectiveness of 4 pulpotomy techniques – randomized controlled trial. *J Dent Res* 2005; **84**: 1144-1148.
- Cuisia Z E, Musselman R, Schneider P, Dummett C. A study of mineral trioxide aggregate pulpotomies in primary molars. *Pediatr Dent* 2001; **23**: 168 (Abstract).
- Agamy H A, Bakry N S, Mounir M M F, Avery D R. Comparison of mineral trioxide aggregate and formocresol as pulp-capping agents in pulpotomized primary teeth. *Pediatr Dent* 2004; **26**: 302-309.
- Jabbarifar S E, Khademi A A, Ghasemi D. Success rate of formocresol pulpotomy versus mineral trioxide aggregate in human primary molar tooth. *J Res Med Sci* 2004; **6**: 55-58.
- Farsi N, Alamoudi N, Balto K, Mushayt A. Success of mineral trioxide aggregate in pulpotomized primary molars. *J Clin Pediatr Dent* 2005; **29**: 307-311.

33. Holan G, Eidelman E, Fuks A B. Long-term evaluation of pulpotomy in primary molars using mineral trioxide aggregate or formocresol. *Pediatr Dent* 2005; **27**: 129-136.
34. Naik S, Hegde A M. Mineral trioxide aggregate as a pulpotomy agent in primary molars: an in vivo study. *J Indian Soc Pedod Prev Dent* 2005; **23**: 13-17.
35. Peng L, Ye L, Guo X et al. Evaluation of formocresol versus ferric sulphate primary molar pulpotomy: a systematic review and meta-analysis. *Int Endod J* 2007; **40**: 751-757.
36. Gould A, Johnstone S, Smith P. *Pulp therapy techniques for the deciduous dentition*. London: King's College London, 1999. Compact Disc.
37. Barr E S, Flaitz C M, Hicks M J. A retrospective radiographic evaluation of primary molar pulpectomies. *Pediatr Dent* 1991; **13**: 4-9.
38. Casas M J, Kenny D J, Johnston D H, Judd P J. Long-term outcomes of primary molar ferric sulfate pulpotomy and root canal therapy. *Pediatr Dent* 2004; **26**: 44-48.
39. Mortazavi M, Mesbahi M. Comparison of zinc oxide and eugenol, and Vitapex for root canal treatment of necrotic primary teeth. *Int J Paediatr Dent* 2004; **14**: 417-424.
40. Deery C, Hosey M-T, Waterhouse P J. Pulp therapy in the primary dentition. In *Paediatric cariology*. London: Quintessence Publishing Co. Ltd, 2004.