

UK National Clinical Guidelines in Paediatric Dentistry

This revised Clinical Guideline in Paediatric Dentistry replaces the previously published eighth Guideline entitled 'The pulp treatment of the primary dentition' [Llewelyn, 2000]. The process of guideline production began in 1994, resulting in first publication in 1997. Each guideline has been circulated to all Consultants in Paediatric Dentistry in the UK, to the Council of the British Society of Paediatric Dentistry, and to people of related specialties recognised to have expertise in the subject. In the case of the present guideline, an internationally recognised expert on primary pulp therapy was invited to be a co-author (ABF). The final version of the guideline is produced from a combination of this input and thorough review of the published literature. The intention is to encourage improvement in clinical practice and to stimulate research and clinical audit in areas where scientific evidence is inadequate. Evidence underlying recommendations is scored according to the SIGN classification and guidelines should be read in this context. For those wishing further detail, the process of guideline production in the UK is described in the International Journal of Paediatric Dentistry 1997; 7: 267–268.

Pulp therapy for primary molars

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Introduction

Management of the grossly carious primary molar is a common but sometimes challenging aspect of dental care for young children. Regrettably, the caries experience of British 5-year-olds looks unlikely to improve in the foreseeable future [Pitts *et al.*, 2005]. It is therefore essential that clinicians are both confident and competent in selecting and undertaking the most appropriate treatment for grossly carious primary molars.

In view of new insights into primary pulp biology [Rodd and Boissonade, 2001, 2002, 2005], developments in pulpal medicaments and worldwide changes in clinical practice, it was felt necessary to update the previous Clinical Guideline on pulp treatment for the primary dentition [Llewelyn, 2000]. It is hoped that this revised guideline will continue to facilitate good decision-making and evidence-based practice for young patients. However, with continued advancement and availability of bioactive pulp medicaments

additional revisions to this guideline may be indicated in future years [Goldberg, 2003].

1. Treatment planning

The first treatment decision for the young patient with one or more extensively carious primary molars is whether to retain or extract these teeth. Any treatment plan should be based on a thorough history, examination and appropriate investigations. It should also take into account the patient's social, medical and dental status.

1.1 Diagnosis

It is important to try to provisionally diagnose the likely pulpal status of the tooth concerned, as this will determine the most appropriate treatment.

1.1.1 Clinical signs and symptoms

The following symptoms and clinical signs are likely to be associated with significant pulpal inflammation and pathology:

- Any history of spontaneous severe pain, particularly at night
- Reported pain on biting
- The necessity for analgesics

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- The clinical extent of the caries, notably the presence of marginal ridge breakdown
- The presence of any intra-oral swelling or sinus
- A history of intra-oral or facial swelling

1.1.2 Special investigations

- Gentle finger pressure may determine whether the tooth is mobile or tender
- Pulpal sensibility testing is not appropriate for primary molars
- Radiographs are usually mandatory as these provide further important information about the extent of the caries, the proximity of large restorations to a pulp horn, presence of any periradicular pathology, degree of pathological or physiological root resorption, and presence of a successor

1.2 Indications for tooth retention

1.2.1 Medical factors

- Patients 'at risk' from an extraction (e.g. bleeding disorders, hereditary angio-oedema)
- Patients 'at risk' if a general anaesthetic is required for tooth removal (e.g. some cardiac conditions, cystic fibrosis, muscular dystrophies)

1.2.2 Dental factors

- Minimal number of extensively carious primary molars likely to require pulp therapy (<3)
- Hypodontia of the permanent dentition
- Where prevention of mesial migration of first permanent molars is desirable

1.2.3 Social factors

- A regular attender, with good compliance and positive parental attitudes

1.3 Indications for tooth removal

1.3.1 Medical factors

- Patients 'at risk' from residual infection (e.g. immunocompromised, susceptibility to infective endocarditis)

1.3.2 Dental factors

- Tooth unrestorable after pulp therapy
- Extensive internal root resorption
- Large number of carious teeth with likely pulpal involvement (>3)
- Tooth close to exfoliation (>2/3 root resorption)
- Contralateral tooth already lost (in the case of a first primary molar, and if indicated orthodontically)
- Extensive pathology or acute facial swelling necessitating emergency admission

1.3.3 Social factors

- An irregular attender, with poor compliance and unfavourable parental attitudes.

2. Treatment options

2.1 Indirect pulp treatment

This approach has gained increased worldwide popularity in recent years.

2.1.1 Rationale

- To arrest the carious process and provide conditions conducive to the formation of reactionary dentine beneath the stained dentine and remineralisation of remaining carious dentine
- To promote pulpal healing and preserve/maintain the vitality of pulp tissue

2.1.2 Indications

- Tooth with a deep carious lesion
- No signs or symptoms indicative of pulpal pathosis

2.1.3 Procedure

- Local anaesthetic
- Good isolation with rubber dam
- Removal of all caries at the enamel-dentine junction
- Judicious removal of soft deep carious dentine (using hand excavators or a slowly rotating large round steel bur) lying directly over the pulp region with care to avoid a pulpal exposure
- Placement of appropriate lining material such as a reinforced glass ionomer cement, a hard-setting calcium hydroxide or zinc oxide eugenol.
- Definitive restoration to achieve optimum external coronal seal (ideally an adhesive restoration or preformed crown)

2.1.4 Clinical outcome

- >90% clinical success (absence of symptoms or pathology) at 3 years follow up

2.1.5 Level of evidence (Grade B)

Evidence has been obtained from a number of well-designed retrospective descriptive studies.

2.2 Direct pulp capping

This approach has limited application and is generally not recommended for primary molars.

2.2.1 Rationale

- To encourage the formation of a dentine bridge at the point of pulpal exposure with preservation of pulpal health and vitality

2.2.2 Indications

- Asymptomatic tooth
- Small traumatic (non-carious) pulpal exposure
- An exposure in older child (1–2 years prior to normal exfoliation of the tooth). In these cases treatment failure would not imply the need for a space maintainer following extraction, as it would in younger children

2.2.3 Procedure

- Local anaesthetic
- Optimum isolation with rubber dam
- Gentle application of cotton pledget soaked in water/saline to stem any pulpal haemorrhage
- Application of hard-setting calcium hydroxide paste or mineral trioxide aggregate (MTA)
- Definitive restoration to achieve optimum external coronal seal (ideally an adhesive restoration or preformed metal crown)

2.2.4 Clinical outcome

- Prognosis is reported to be generally poor.

2.2.5 Level of evidence (Grade C)

No studies of good quality are available thus recommendations are based on clinical experience and expert opinion.

2.3 Pulpotomy

A pulpotomy entails the removal of the coronal pulp and maintenance of the radicular pulp. There are three main approaches to this technique: i) preserving the radicular pulp in a healthy state; ii) rendering the radicular pulp inert, or iii) encouraging tissue regeneration and healing at the site of radicular pulp amputation.

2.3.1 Rationale

- To remove the coronal pulp, which has been clinically diagnosed as irreversibly inflamed, leaving behind a possibly healthy or reversibly inflamed radicular pulp

2.3.2 Indications

- Asymptomatic tooth or only transient pain (see explanatory notes 1.1.1)
- A carious or mechanical exposure of vital coronal pulp tissue

2.3.3 Procedure

- Local anaesthetic
- Good isolation with rubber dam
- Removal of caries

- Complete removal of roof of pulp chamber preferably with a non-end cutting bur
- Removal of coronal pulpal tissue with sharp sterile excavator or large round bur in a slow handpiece
- Attain initial radicular pulpal haemostasis by gentle application of sterile cotton pledget moistened with saline (haemostasis should be achieved within four minutes)
- Selection of medicament for direct application to radicular pulp stumps to include any of the following:

- 1) 15.5% ferric sulphate solution (AstringentTM, Ultradent Products Inc., Salt Lake City, UT) burnished on pulp stumps with microbrush for 15 seconds to achieve haemostasis, followed by thorough rinsing and drying
 - 2) 20% (1:5 dilution) Buckley's formocresol solution applied to radicular pulp on a cotton pledget for five minutes to achieve superficial tissue fixation
 - 3) MTA paste applied over radicular pulp with proprietary carrier
 - 4) Well-condensed layer of pure calcium hydroxide powder applied directly over radicular pulp
- [N.B. In cases of uncontrollable pulpal haemorrhage, an alternative approach may need to be considered such as root canal treatment or extraction]

- Application of a lining (if appropriate) such as reinforced glass ionomer or zinc oxide eugenol cement
- Definitive restoration to achieve optimum external coronal seal (ideally an adhesive restoration of preformed metal crown)

2.3.4 Clinical outcome

The available evidence suggests that the formocresol pulpotomy, the ferric sulphate pulpotomy, electrocautery or pulpectomy are equally successful techniques. More recent studies are also reporting good success rates with the use of MTA (grey and white formulations) in pulpotomised primary molars. Long-term success rates for the use of calcium hydroxide in primary molar pulpotomy appear to be lower than for other approaches.

2.3.5 Level of evidence (Grades A and B)

Evidence is available from meta-analysis; randomised controlled trials and other well conducted clinical studies.

2.4 Desensitising pulp therapy

2.4.1 Rationale

- To reduce pulpal inflammation and/or symptoms in order to facilitate subsequent pulpotomy or pulpectomy procedure

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2.4.2 Indications

- Carious pulpal exposure but no signs/symptoms of loss of vitality
- Non-compliant child who may require inhalation sedation for further treatment
- Hyperalgesic pulp (adequate analgesia not achieved)

2.4.3 Procedure

- Local anaesthetic
- Good isolation with rubber dam
- Removal of caries
- Place a small pledget of cotton wool loaded with steroidal antibiotic paste (Ledermix™) directly over exposure site (tooth is usually too sensitive to remove entire roof of pulp chamber)
- Place a well-sealed temporary dressing (IRM - without undue pressure) over the cotton pledget
- Recall after 7–14 days and proceed with a pulpotomy or pulpectomy technique (depending on clinical findings)

2.4.4 Clinical outcome

- The effectiveness of Ledermix paste as a desensitising medicament for cariously exposed primary molars has not been widely reported in the literature. However, its anti-inflammatory and analgesic properties have been well documented in permanent teeth of adults
- The success rate for the use of Ledermix™ as a pulpotomy agent in primary teeth is not well documented

2.4.5 Level of evidence (Grade C)

No studies of good quality are available thus recommendations are reserved for cases where good anaesthesia can not be achieved or there is initial poor patient compliance.

2.5 Pulpectomy

It is acknowledged that primary molar radicular morphology, inherent physiological root resorption and the close proximity of the permanent successor tooth are complicating factors in the pulpectomy procedure. However, primary molar pulpectomy is achievable with practice and appropriate patient selection.

2.5.1 Rationale

- To remove irreversibly inflamed or necrotic radicular pulp tissue and gently clean the root canal system
- To obturate the root canals with a filling material that will resorb at the same rate as the primary tooth and be eliminated rapidly if accidentally extruded through the apex

2.5.2 Indications

- Tooth diagnosed as having irreversible pulpitis on basis of reported symptoms and /or clinical findings (e.g. profuse haemorrhage following pulpotomy procedure)
- Non-vital radicular pulp with/without associated infection
- Good patient compliance

2.5.3 Procedure

A one- or two-stage pulpectomy may be undertaken depending on whether the radicular pulp is irreversibly inflamed or non-vital (with/without an associated periradicular pathosis). If infection is present, and the presence of an exudates does not allow drying of the canal, consideration should be given to the two-stage pulpectomy technique, where the root canals may be dressed with an antimicrobial agent for 7–10 days and subsequently obturated at the second visit.

- Pre-operative radiograph showing all roots and their apices
- Local anaesthetic (to enable use of rubber dam clamp)
- Rubber dam mandatory
- Removal of caries
- Removal of roof of pulp chamber preferably with non-end cutting bur
- Removal of any remains of coronal pulp tissue with sharp sterile excavator or large bur in slow handpiece
- Note whether radicular pulp is bleeding (one-stage procedure) or necrotic (usually requiring two-stage procedure)
- Identify root canals
- Irrigate with normal saline (0.9%), Chlorhexidine solution (0.4%) or sodium hypochlorite solution (0.1%)
- Estimate working lengths of root canals keeping 2 mm short of the radiographic apex
- Insert small files (no greater than size 30) into canals and file canal walls lightly and gently
- Irrigate the root canals
- Dry canals with pre-measured paper points, keeping 2 mm from root apices
- If infection present (canal exudate and/or associated sinus) dress root canals with non-setting calcium hydroxide and temporise (two-stage procedure). Consider prescribing a systemic antimicrobial
- If canals can be dried with paper points, obturate root canals by injecting or packing a resorbable paste e.g. slow-setting pure zinc oxide eugenol, non-setting calcium hydroxide paste or calcium hydroxide and iodoform paste (Vitapex™ or Endoflas™)

- Definitive restoration to achieve optimum external coronal seal (ideally a preformed crown)

2.5.4 Clinical outcome

- 86% clinical success at 36 months follow up (lower success rates found at longer follow-up times)

2.5.5 Level of evidence (Grade B)

Evidence is available from randomised controlled trials and other well conducted clinical studies.

2.6 Review

Regular clinical and radiographic review following any primary molar pulp therapy is mandatory.

Explanatory notes

1. Treatment planning

1.1 Diagnosis

1.1.1 Clinical signs and symptoms

It is important to take a good history of the presenting symptoms. This will aid assessment of the likely pulpal status of the tooth concerned and will therefore help determine the most appropriate treatment [Fuks, 2000]. Although correlation between symptoms and pulpal status is known to be quite poor [Guthrie *et al.*, 1965], Seltzer and Bender [1984] found that a high percentage of teeth with spontaneous pain demonstrated irreversible pulpitis. A pulpotomy procedure is therefore not indicated for any tooth with unprovoked continuous pain. However, care should be taken not to misinterpret a throbbing pain, simulating an irreversible pulp condition, with that associated with an inflamed dental papilla owing to food impaction. These symptoms generally disappear following restorative treatment [Fuks, 2005]. Conversely, the absence of pain does not indicate a pulp free from widespread inflammation or necrosis.

In teeth with carious breakdown of more than half of the buccolingual intercusp distance, there are likely to be some inflammatory changes within the pulp horn region [Duggal *et al.*, 2002]. In such teeth, some form of conservative pulpal therapy, possibly indirect pulp treatment, is thus usually indicated.

1.2 Indications for tooth retention

1.2.3 Dental factors

Retention of second primary molars is usually advisable to prevent or minimise mesial drift of first permanent molars. This may be of benefit in reducing subsequent premolar crowding and/or avoiding the establishment of undesirable buccal relationships.

1.3 Indications for tooth removal

1.3.3 Dental factors

In cases where a first primary molar has already been lost, extraction (rather than pulp treatment) of the contralateral first primary molar is usually recommended (unless the dentition is very spaced) to avoid subsequent centre line shift [Rock, 2002].

2. Treatment options

Once the decision has been made to retain the tooth, the clinician needs to select the most appropriate treatment option. A fundamental consideration is whether the pulp is likely to be vital or non-vital. A good history followed by a careful clinical examination and appropriate radiograph will frequently help in reaching a correct diagnosis and selecting the most appropriate treatment. However, on some occasions, once treatment has commenced, further empirical clinical findings, such as the presence of uncontrollable pulpal haemorrhage from the amputated radicular pulp stumps, may also aid treatment selection.

2.1 Indirect pulp treatment

2.1.3 Procedure

Some authors have recommended that indirect pulp treatment be undertaken as a two-stage procedure [Vij *et al.*, 2004]. Initial caries removal is achieved without the use of local anaesthetic and a reinforced zinc oxide eugenol or glass ionomer cement restoration is placed for a 1–3 month period, prior to further caries removal under local anaesthetic [Falster *et al.*, 2002]. No precise method has been developed to determine how much caries to remove; it is reliant on good clinical judgement. This approach may have merit in young anxious patients but it is of paramount importance that the temporary restoration is not subject to microleakage. Conversely, other investigators have reported a higher success rate when indirect pulp treatment is performed as a single visit procedure [Farooq *et al.*, 2000].

There is insufficient evidence to support the use of any one specific lining material for indirect pulp treatment [Ehrenreich, 1968]. However, newer research appears to be directed towards the use of glass ionomer cements [Massara *et al.*, 2002].

2.1.4 Clinical outcome

Several studies have reported success rates (an absence of symptoms or pathology) of over 90% at 3 years follow-up [Farooq *et al.*, 2000; Falster *et al.*, 2002; Al-Zayer *et al.*, 2003; Vij *et al.*, 2004]. It would appear that success is greater in second primary molars than first primary molars [Al-Zayer *et al.*, 2003].

The success of the technique appears to be highly dependent on achieving a good external coronal seal, which will effectively cut off the nutritional supply for any remaining dentinal bacteria and will prevent further bacterial microleakage. It has been shown that failure is 7.7 times more likely in a tooth restored with an amalgam than one restored with a performed metal crown [Al-Zayer *et al.*, 2003]. Adhesive restorations have also been shown to provide optimum protection from marginal leakage in pulpotomised primary molars [Guelmann *et al.*, 2004]. It is therefore strongly recommended that adhesive restorations or preformed crowns are employed following any primary molar pulp therapy procedure.

2.2 Direct pulp capping

2.2.4 Clinical outcome

Although some clinical success has historically been reported for direct pulp capping of primary teeth [Hargreaves, 1969], the technique is not normally advocated for carious primary molars [American Academy of Pediatric Dentistry, 2004]. No long-term outcome data are available but prognosis is reported to be generally poor, with some studies reporting a high incidence of internal resorption [Starkey, 1963; Kopel, 1992]. Interestingly, a recent case report described the use of MTA (ProRoot, Dentsply) in a cariously exposed primary molar and reported clinical success at 18 months follow up [Bodem *et al.*, 2004]. However, further studies will be required before such a technique is universally recommended.

2.3 Pulpotomy

2.3.3 Procedure

- Formocresol

A key factor to prompt revision of the existing Clinical Guidelines was the perceived need to re-evaluate the use of formocresol. The dental profession has always expressed some reservations about the use of formocresol, or more specifically formaldehyde, in primary molar pulp treatment [Waterhouse, 1995]. In a recent survey of 184 British paediatric dentistry specialists, 54% expressed concern about the safety of formocresol [Hunter and Hunter, 2003]. In June 2004, a press release from the International Agency of Research on Cancer (IARC) stated that there was now considered to be 'sufficient evidence that formaldehyde causes nasopharyngeal cancer in humans' [IARC, 2004]. Studies linking formocresol with nasopharyngeal cancer in both humans and animals are based on chronic exposure to formaldehyde at very high doses [Swen-

burg *et al.*, 1980]. There is also strong, but as yet inconclusive, evidence of a causal relationship between formaldehyde exposure and leukaemia [IARC, 2004; Collins and Lineker, 2004].

Occupational formaldehyde exposure occurs in numerous industrial settings but strict regulations are in place to monitor and reduce worker exposure [National Institute for Occupational Safety and Health, 1981]. The actual amount of formaldehyde vapour exposure (ppm) to a child undergoing a formocresol pulpotomy is unknown. More importantly, the degree and potential effect of accumulative formaldehyde exposure to dental professionals is also unknown.

There appears to be conflicting opinion amongst British paediatric dentists as to the justification for continued use of formocresol. It is, however, anticipated that the availability of formocresol will become increasingly problematic and may actually drive a change in clinical practice. It is the intention of this Guideline to highlight current concerns regarding formaldehyde and to suggest that routine use of the formocresol pulpotomy may be imprudent given the availability of effective alternatives (ferric sulphate and MTA) [Srinivasan *et al.*, 2006]. As in all areas of clinical practice, careful consideration should be given to the perceived benefits of any intervention versus the potential risks.

- Ferric sulphate

Ferric sulphate promotes pulpal haemostasis through a chemical reaction with blood. It has been proposed as a pulpotomy agent on the basis that it controls pulpal bleeding and forms a 'protective' metal-protein clot over the underlying vital radicular pulp. A zinc oxide eugenol base is then usually applied over the radicular pulpal tissue. However, a number of authors have speculated that the eugenol may in fact promote internal resorption when placed in contact with vital tissue following a ferric sulphate pulpotomy [Smith *et al.*, 2000; Casas *et al.*, 2003]. This possible complication warrants further investigation.

- Mineral trioxide aggregate

Mineral trioxide aggregate has been used successfully in adult endodontic procedures since the early 1990s [Lee *et al.*, 1993]. The constituents include: tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferrite, calcium sulphate and bismuth oxide. The material has excellent bioactive properties and essentially stimulates cytokine release from pulpal fibroblasts, which in turn stimulates hard tissue formation. It is mixed with sterile water to a sandy consistency, which is gently packed against the

radicular pulp stumps. The material is hydrophilic and takes up to four hours to set completely.

- Other pulpotomy procedures

Although not commonly used by British paediatric dentists, electrosurgery has been well described as a non-pharmacological haemostatic pulpotomy approach for carious primary molars. The procedure carbonises and denatures superficial pulp tissue producing a layer of coagulative necrosis with healthy radicular pulp beneath it. Success rates are reported to be similar to those achieved with a formocresol pulpotomy [Dean *et al.*, 2002; Rivera *et al.*, 2003]. However, the electrosurgical technique will not eliminate inflammation within pulp tissue and success is therefore reliant upon the initial inflammatory status of the radicular pulp. To date there has been limited research on the use of lasers in human primary molar pulpotomy.

2.3.4 Clinical outcome

A recent systematic review of pulp therapy for primary molars [Nadin *et al.*, 2003] identified three randomised controlled clinical trials where the follow up period had been at least 12 months. From the findings of these studies, it was concluded that the formocresol pulpotomy, the ferric sulphate pulpotomy, electrocautery or pulpectomy were equally successful techniques [Ibricevic *et al.*, 2000; Dean *et al.*, 2002; Casas *et al.*, 2003, 2004]. A recent meta-analysis of formocresol versus ferric sulphate primary molar pulpotomies found both approaches to have a similar rate of clinical and radiographic success [Loh *et al.*, 2004].

The clinical and radiographic success of ferric sulphate pulpotomies is generally reported as being > 90% at 2 years [Fuks *et al.*, 1997; Smith *et al.*, 2000; Casas *et al.*, 2003]. More recent studies are reporting very good success rates with the use of MTA in pulpotomised primary molars. The use of grey and white formulation MTA has been found to be 100% and 90% respectively at a 12-month follow up period [Agamy *et al.*, 2004]. Holan and co-workers [2005] achieved a 97% clinical and radiographic success rate for MTA pulpotomies as compared to an 83% success rate for formocresol pulpotomies.

Long-term success rates for the use of calcium hydroxide in vital primary molar pulpotomy appear to be lower than for other approaches. The main reported complication is internal root resorption, which is attributed to the presence of an extra-vascular blood clot [Schroder, 1971]. However some studies have reported favourable outcomes in over 80% of cases [Heilig *et al.*, 1984; Gruythuisen and Weerheijm, 1997].

It should be appreciated that, although studies report high levels of clinical success following pulpotomy procedures, radiographic findings often indicate some pathological changes, which most commonly include calcific metamorphosis and internal resorption [Smith *et al.*, 2000]. Casas and colleagues [2003] noted that 55% of their ferric sulphate-treated molars showed some radiographic evidence of internal resorption and 71% demonstrated pulp canal obliteration. Papagiannoulis [2002] reported that the internal resorption, present in some ferric sulphate treated teeth, did not progress or even remineralise. Thus these changes are not considered potentially damaging to the underlying successor tooth, and as such, are not an indication of treatment failure.

2.4 Desensitising pulp therapy

2.4.3 Procedure

Historically, this two-stage technique used paraformaldehyde paste to fix and devitalise hypersensitive coronal pulp tissue. However, in view of increasing concerns about the use of formaldehyde, an alternative approach, using LedermixTM paste, is recommended [Waterhouse, 2004]. LedermixTM is a readily available paste containing triamcinalone acetonide (steroid) and demeclocycline (antimicrobial). It is used widely in adult endodontic procedures and has been shown to reduce pulpal inflammation and pain [Langeland *et al.*, 1977; Sazak *et al.*, 1996; Ehrmann *et al.*, 2003].

2.4.4 Clinical outcome

There have been no histological or clinical studies reporting the success of LedermixTM as a desensitising medicament in primary pulp therapy. Interestingly, its use as a pulpotomy agent has been described with a reported success rate of 79% [Hansen, 1971].

2.5 Pulpectomy

2.5.3 Clinical procedure

Slow setting pure zinc oxide eugenol paste has traditionally been the material of choice as a primary molar root filling material. However, concerns have been expressed regarding the slow removal of zinc oxide eugenol by the body (if extruded though the root apex) and the differential rate of resorption between this material and the tooth itself [Fuks, 2000]. Recently investigators have found that VitapexTM (a mixture of calcium hydroxide and iodoform paste) has a superior success rate to that of zinc oxide eugenol (100% versus 78.5% at 16 months) and is removed more readily if extruded through an apex [Mortazavi and Mesbahi, 2004].

Some clinicians have advocated the use of chemotherapeutic agents in infected primary molar teeth as a simpler option to pulpectomy [Ballesio *et al.*, 2002; Takushige *et al.*, 2004]. However, the medicaments used in these studies are not yet commercially available. Traditionally, British paediatric dentists have employed beechwood creosote to 'disinfect' non-vital primary molars in a two-stage 'non-vital pulpotomy' procedure, but this medicament is highly toxic [Duggal *et al.*, 2005], not easily obtained and success rates are poor [Hobson, 1970]. In the light of the knowledge today, it would not be biologically acceptable to leave necrotic tissue in a root canal. Similarly, formocresol has also been in primary molars with irreversibly inflamed or necrotic radicular pulp tissue. In view of increasing concerns about formocresol, this approach is now also outmoded.

2.5.4 Clinical outcome

In a recent study, Casas [2004] reported an 86% success rate for pulpectomised primary molars, filled with zinc oxide eugenol, at 36 months follow up. The same study reported that pulpectomised primary molars showed significantly greater survival rates than those subject to a pulpotomy. Excellent success rates have also been reported where KRI paste or a calcium hydroxide and iodoform preparation has been employed [Nishino *et al.*, 1980; Fuks *et al.*, 2002]. It should also be noted that higher failure rates are generally reported where canals are overfilled as compared to underfilled [Holan and Fuks, 1993].

2.6 Review

Whilst the clinical success of many primary tooth pulp treatments is reportedly high, studies often demonstrate a much lower proportion of teeth with radiographic signs of complete healing. It should also be noted that radicular cyst development is a well-recognised sequelae [Savage *et al.*, 1986; Takiguchi *et al.*, 2001]. Hence, regular clinical and radiographic review following any primary molar pulp therapy is strongly recommended.

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