Current concepts in vital primary pulp therapy

A.B. FUKS

ABSTRACT: Review Recent progress in understanding the molecular and cellular changes during tooth development and how they are mimicked during tissue repair, offers the opportunity to assess the biologic validity of the various vital pulp treatments. Under this light, indirect pulp treatment can be an acceptable procedure for primary teeth with reversible pulp inflammation, provided that this diagnosis is based on a good history, a proper clinical and radiographic examination, and the tooth had been sealed with a leakage-free restoration. Several articles report the success of this technique of direct pulp capping (DPC) and calcium hydroxide has been widely used with high success rates in young permanent teeth, but the results in primary teeth are less satisfactory. Recent studies have reported successful results with direct adhesive capping of exposed pulps, while others showed pulp inflammation and unacceptable results using this technique. Thus, the traditional rationale for the use of calcium hydroxide should be maintained, and this treatment modality reserved for iatrogenic exposures in asymptomatic teeth that are expected to exfoliate within a short period of time. In younger children, iatrogenic or carious exposures should be treated by pulpotomy. Formocresol has been the most popular pulp dressing material for pulpotomized primary molars for many years but, due to its deleterious effect, the use of formocresol is decreasing considerably worldwide. Ferric sulphate has been proposed as a substitute to formocresol, and the success rates were comparable to those of formocresol. More recently, considerably better results have been obtained with MTA (Mineral Trioxide Aggregate), and statistically significant differences were reported when compared with formocresol. Internal root resorption, a finding seen both in ferric sulphate and formocresol, was not observed in the MTA treated teeth. MTA is commercially available, but its cost is very high, and cannot be kept once opened. Thus, ferric sulphate can still be a valid and inexpensive solution for pulpotomies in primary teeth.

KEYWORDS: Indirect pulp, Direct pulp capping, Pulpotomy

Introduction

The primary objective of pulp treatment is to maintain the integrity and health of the oral tissues. Although a tooth can remain functional without a vital pulp, it is desirable to attempt to maintain the vitality of the pulp [American Academy of Pediatric Dentistry Reference Manual, 2001-2002]. Thus, the objective of vital pulp therapy (indirect pulp treatment, direct pulp capping and pulpotomy) is to treat reversible pulp injury [Tziafas et al., 2000]. Recent progress in understanding the molecular and cellular changes during tooth development and how they are mimicked during tissue repair offers the opportunity to assess the biologic validity of the various vital pulp treatments. The present article reviews briefly the dentinogenesis process during tooth formation, throughout life and in response to injury. Under this light the various vital pulp treatments will be analyzed.

Dentinogenesis in healthy state. The odontoblasts are cells derived from the ecto-mesenchymal cells of the dental papilla. During the post-mitotic state the odontoblasts line the formative surface of the matrix, and start secreting primary dentine. The other cells of the pulp (in the sub-odontoblastic layer and in the pulp core), although supporting dentinogenesis, do not play a direct role in primary dentine secretion [Linde and Goldberg, 1993]. After secretion of the bulk of dentine during primary dentinogenesis, physiological secondary dentine is secreted at a much slower rate throughout the life of the tooth, leading to a slow reduction in the size of the pulp chamber [Baume,
1980]. The original post-mitotic odontoblasts, responsible for primary dentinogenesis, survive for the life of the tooth, unless subjected to injury. These cells remain in a resting stage after primary dentinogenesis, and the physiologic secondary dentine formation represents a basal level of cell activity in the resting stage [Linde and Goldberg, 1993].

**Dentinogenic response to injury.** The pulp-dentine complex responds to injury by formation of new hard tissue, mainly tertiary dentine, increasing the distance between the injury and the pulp cells and sometimes decreasing the dentine permeability [Tziafas et al., 2000]. The nature and quality of the tertiary dentine depends on its tubular structure, influencing the dentine permeability of the area. Thus, in case of a mild injury, the odontoblasts responsible for the primary odontogenesis can frequently survive the challenge, and are stimulated to secrete reactionary dentine beneath the injury site [Smith et al., 1995]. Since the original odontoblasts are responsible for this matrix secretion, there will be tubular continuity and communication with the primary dentine matrix [Mjor, 1983].

Reactionary dentine might be considered as an extension of physiological dentinogenesis. However, since it is a pathological response to injury, it should be regarded as distinct from the primary and secondary dentinogenesis.

When the injury is severe, the odontoblasts beneath the injury may die but, if suitable conditions exist in the pulp, a new generation of odontoblast-like cells may differentiate from underlying pulp cells, secreting a reparative dentine matrix. As this dentine is formed by a new generation of cells, there will be discontinuity in the tubular structure, with a subsequent reduction in permeability [Byers et al., 1999].

A critical question that arises is what are the factors responsible for triggering the stimulation of odontoblastic activity? Although much still has to be learnt of the molecular control of cells activity in general and of odontoblastic activity in particular, one family of growth factors, the TGFb superfamily, has been reported to have extensive effects on the mesenchymal cells of many connective tissues [Messagne, 1990]. During tooth development, the odontoblasts secrete TGFbs, and some of them remain sequestered into the dentine matrix. These TGFbs may be released during any process leading to tissue dissolution, such as dental caries [Tziafas et al., 2000]. Thus, dentine matrix should not be considered as an inert dental hard tissue, but rather as a potential tissue store of a cocktail of bioactive molecules (particularly growth factors) waiting to be released, if appropriate tissue conditions prevail [Tziafas, 2000].

In contrast to reactionary responses, reparative dentinogenesis represents a more complex sequence of biological processes. Migration and differentiation of pulpal progenitor cells must take place, creating a new generation of odontoblast-like cells, prior to matrix secretion. A series of stereotypic wound healing reactions will be occurring in the pulpal connective tissue, including vascular and cellular inflammatory reactions. In vitro and in vivo experiments on reparative odontogenesis demonstrate that the non-inflamed pulp constitutes an appropriate environment where competent pulp cells (potential preodontoblasts) can differentiate into new odontoblast-like cells, forming reparative dentine [Nakashima et al., 1994a; Magloire et al., 1996; O’Kane and Ferguson, 1997].

**Review of clinical strategies in vital pulp therapy.**

A variety of clinical procedures have been used traditionally in restorative dentistry, with a considerable degree of success, although somewhat empirical and not always directed to the initiation of particular tissue events. The improvement in knowledge of molecular and cellular processes in dentine and pulp allows a better understanding the traditional procedures on these tissues.

**Indirect pulp capping.** Indirect pulp treatment is recommended for teeth that have deep carious lesions approximating the pulp, but no signs or symptoms of pulp degeneration. In this procedure, the deepest layer of the remaining carious dentine is covered with a biocompatible material to prevent pulp exposure and additional trauma to the tooth. Two materials are most commonly used in indirect pulp treatment: calcium hydroxide (CH) and zinc oxide-eugenol paste (ZOE). Presently, glass ionomer cements are also recommended. Treatment of dentine with various cavity conditioning agents has shown their ability to solubilize TGFb from the matrix. It seems probable that this solubilizing effect of cavity conditioners results in the release of TGFb from the tissue, diffusing down the dentinal tubules, promoting a reactionary dentinogenic response in the underlying odontoblasts [Smith and Smith, 1998]. The rationale for indirect pulp treatment is that few viable bacteria remain in the deeper dentine layers, and after the cavity has been sealed properly they will be inactivated. Stainless steel crowns (SSC) are frequently recommended after indirect pulp treatment, particularly if the tooth has to function for several years (Fig. 1). These facts argue against a two-step procedure, in which the tooth is reentered for the
The purpose of excavating the previously carious dentine and to confirm the formation of reparative dentine. This procedure risks creating a pulp exposure and further insult to the pulp [Dumshat & Hovland, 1985]. A practical judgement would advise reentry in permanent teeth or in primary teeth that will be maintained for long periods of time, as the restorations may eventually leak and lead to a reactivation of the carious process and pulpal involvement [Camp, 1984].

The ultimate objective of this treatment is to maintain pulp vitality [Eidelman et al., 1965], by arresting the carious process, promoting dentine sclerosis (reducing permeability), stimulating the formation of tertiary dentine, and remineralizing the carious dentine. Success rates of indirect pulp treatment have been reported to be higher than 90% in primary teeth [Farooq et al., 2000; Straffon et al., 2000; Falster et al., 2002], and thus its use is recommended in patients where a preoperative diagnosis suggests no signs of pulp degeneration.

Direct pulp capping. Direct pulp capping is a procedure that is carried out when a healthy pulp has been inadvertently exposed during an operative procedure. The tooth must be asymptomatic, and the exposure site must be pinpoint in diameter and free of oral contaminants. A CH medicament is placed over the exposure site to stimulate dentine formation and thus “heal” the wound and maintain the vitality of the pulp [Levine et al., 1988]. The ability of the TGFβs and BMPs (Bone Morphogenetic Proteins) to induce reparative dentinogenesis in pulp capping situations in vivo [Rutherford et al., 1993; Rutherford et al., 1994; Nakashima, 1994c; Tziafas et al., 1998; Hu et al., 1998] provides the basis for development of a possible new generation of biomaterials. As the specificity of these growth factors to induce reparative processes is not clear, further studies are required to fully understand the kinetics of growth factor release and the sequence of growth factor-induced reparative dentinogenesis.

Direct pulp capping of a carious pulp exposure in a primary tooth is not recommended, but can be successful in immature permanent teeth. The direct pulp cap is indicated for small mechanical or traumatic exposures when conditions for a favourable response are optimal. Even in these cases the success rate in primary teeth is not particularly high. Failure
of treatment may result in internal resorption (Fig. 2) or acute dentoalveolar abscess. Kennedy and Kapala [1985] claim that the high cellular content of the primary pulp tissue may be responsible for the increased failure rate of direct pulp capping in primary teeth. These authors believe that undifferentiated mesenchymal cells may differentiate into odontoclasts, leading to internal resorption, a principal sign of failure of direct pulp capping in primary teeth.

The use of dentine bonding agents for direct pulp capping has been advocated by some investigators [Kashiwada and Takagi, 1991; Kanka, 1993]. The rationale for this is based on the belief that if an effective, permanent seal against bacterial invasion is provided, pulp healing will occur. Animal research has shown good compatibility of mechanically exposed pulps to visible-light-activated composite when bacteria are excluded [Cox et al., 1987].

Araujo et al. [1996] reported good clinical and radiographic results in cariously exposed primary teeth, one year after acid etch, capping with a bonding agent and restoring with a composite resin. In another publication, one year later, Araujo et al. [1997] examined histologically primary molars with micro-exposures that were successfully treated with a composite acid etch technique and were extracted or exfoliated. These authors observed microabscesses adjacent to the exposure site; no dentine bridge was formed in any specimen (Fig. 3). These results were confirmed by Pameijer and Stanley [1998, 1999], who concluded: “The belief that any material placed on an exposed pulp will allow bridge formation as long as the cavity is disinfected, is a fallacy”. Conversely, high success in direct pulp capping has been observed by the same group in monkeys employing a modified Bioglass formula, encouraging clinical studies [Clark et al., 1999].

Presently, direct pulp capping should still be looked upon with some reservations in primary teeth. However, this treatment could be recommended for exposed pulps in older children, one or two years prior to normal exfoliation. In these children, a failure of treatment would not imply a need for a space maintainer following extraction, as it would be the case in younger children.

Pulpotomy. The pulpotomy procedure is based on the rationale that the radicular pulp tissue is healthy or is capable of healing after surgical amputation of the affected or infected coronal pulp [Fuks and Eidelman, 1991]. The presence of any signs or symptoms of inflammation extending beyond the coronal pulp is a contraindication for a pulpotomy. Thus, a pulpotomy is contraindicated when any of the following are present: swelling (of pulpal origin), fistula, pathologic

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**Fig. 2** - Radiograph of maxillary primary incisors with mesial caries. a) Iatrogenic pulp exposure capped with Dycal. b) Extensive internal root resorption observed six months later.

**Fig. 3** - Histologic section of an exfoliated primary molar after direct capping with an acid etch and composite restoration. Notice the absence of a dentin bridge and the presence of a microabscess.
mobility, pathologic external root resorption, internal root resorption, periapical or interradicular radiolucency, pulp calcifications, or excessive bleeding from the amputated radicular stumps. Other signs, such as a history of spontaneous or nocturnal pain, tenderness to percussion or palpation, should be interpreted carefully.

The ideal dressing material for the radicular pulp should be bactericidal, be harmless to the pulp and surrounding structures, promote healing of the radicular pulp, and not interfere with the physiologic process of root resorption. A good deal of controversy surrounds the issue of pulpotomy agents and, unfortunately, the “ideal” pulp dressing material has not yet been identified. Formocresol (FC), usually as Buckley’s solution, has been the most popular pulp dressing material for pulpotomized primary molars for many years but, due to its deleterious effect, the use of formocresol is decreasing considerably worldwide.

Some biologic materials have been proposed as pulp dressings on the theory that they would promote physiologic healing of the pulpotomy wound: freeze-dried bone [Fadavi et al., 1989]; autolyzed, antigen-extracted, allogenic dentine matrix; allogenic bone morphogenetic protein [Nakashima, 1989]; enriched collagen solutions [Fuks et al., 1984]. All have led to varying levels of success in early experimental stages. Recent clinical studies have reported promising results using ferric sulphate (FS), a hemostatic agent, in pulpotomized human primary teeth [Davis and Furtado, 1991; Fei et al., 1991]. Fuks et al. [1997] reported a success rate of 93% in teeth treated with FS and 84% in those where dilute formocresol (DFC) was employed. These teeth were followed-up 6 to 35 months. Success rates comparable to those of FC were also reported by Smith et al. [2000]. The results of other FC clinical studies were presented by Papagiannoulis [2002] separately in this symposium.

More recently, considerably better results have been obtained with Mineral Trioxide Aggregate (MTA), and statistically significant differences were reported when compared with FC [Eidelman et al., 2001]. Internal root resorption, a finding seen both in FS and FC, was not observed in MTA treated teeth. MTA is commercially available as Proroot MTA (Dentsply, Paris), but its price is very high. As the material cannot be kept once the envelope is opened, its clinical use in pediatric dentistry practice becomes almost prohibitive. Thus, FS can still be considered a valid and inexpensive solution for pulpotomies in primary teeth.

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References


A.B. FUKS


