

# Pulp response in primary teeth with deep residual caries treated with silver fluoride and glass ionomer cement ('atraumatic' technique)

Theo Gotjamanos, BDS, MDS, PhD, FRACDS\*

## Abstract

Histological assessment of the dental pulps of 55 carious primary teeth was carried out 3 to 56 months after treatment by the 'atraumatic' technique involving application of 40 per cent silver fluoride to residual caries followed by restoration with glass ionomer cement. Fifty of the 55 teeth examined showed a favourable pulpal response, including presence of abundant reparative dentine and a wide odontoblast layer. Histological comparisons were made between these teeth and others not treated with silver fluoride but restored with glass ionomer cement, amalgam or zinc oxide and eugenol.

Possible mechanisms of the action of silver fluoride in arresting residual caries are discussed. The question of whether or not treatment of carious dentine with silver fluoride represents a biologically acceptable clinical procedure cannot be answered on the basis of pulpal histology alone. The very high concentration of fluoride in commercial preparations of silver fluoride raises several questions concerning its clinical safety.

**Key words:** Atraumatic technique, silver fluoride, glass ionomer cement, dental pulp response.

(Received for publication December 1994. Revised June 1995. Accepted August 1995.)

## Introduction

Since 1983, the School Dental Service in Western Australia has approached the treatment of carious primary teeth in one of two ways. In cases where carious involvement of dentine is considered to be minimal or moderate, all caries is removed until the tooth is judged clinically to be caries-free. The tooth is then restored with glass ionomer cement (GIC).

In teeth with deep lesions, the so-called 'atraumatic treatment' of primary teeth is used. This method is

based on the technique of Craig *et al.*<sup>1</sup> that does not require removal of all carious dentine, especially from areas close to the pulp. The technique is unconventional, and therefore controversial. It has not been subjected to controlled laboratory or clinical investigation. It involves the use of a modified cavity preparation without local anaesthesia, followed by the application of silver fluoride (AgF) to residual caries, and restoration with glass ionomer cement.

The 'atraumatic' approach is aimed at minimizing potential dental-associated psychological trauma to children and avoiding the resultant behavioural problems in the dental surgery often associated with local anaesthesia and conventional full cavity preparations. Minimal cavities are prepared using slowly revolving cutting instruments, thereby avoiding patient discomfort. As there is no need for complete caries removal, the risk of pulp exposure is reduced significantly. Residual caries is treated with a 40 per cent AgF solution followed by the insertion of a GIC restoration.

While clinical follow-up of approximately 400 000 cases of deep carious lesions treated by the School Dental Service in Western Australia indicates a success rate of 100 per cent when judged solely by the absence of symptoms,<sup>†</sup> detailed histological assessment of the pulpal response to treatment with AgF and GIC has not been reported previously in the literature. This paper reports on the results of such a study conducted between 1983 and 1992 involving 55 cases.

## Materials and methods

**Primary molars** (n=51) and canines (n=4) examined in this investigation were extracted for orthodontic reasons and were obtained from male and female children aged between 6 and 13 years

\*Senior Lecturer in Oral Biology and Pathology, School of Dentistry, University of Western Australia.

<sup>†</sup>Lamplough HG, Jarmyn P. Unpublished observations.

(mean 8.7 years). The teeth exhibited deep proximal carious lesions and had been restored by dental therapists employed by the School Dental Service in Western Australia. The technique entailed removal of some of the carious dentine using hand instruments and a slowly rotating round burr, application to residual caries of 40 per cent silver fluoride solution† and restoration of the cavity with GIC.§.

Prior to tooth removal, each restoration was examined for marginal and other deficiencies. Radiographs were not taken as radiography is not used routinely by the School Dental Service. Children were questioned to determine whether any sensitivity or pain had been experienced since placement of the restoration. All GIC restorations had been deemed to be satisfactory at the time of tooth extraction.

The observation period between tooth restoration and extraction varied from 3 months to 56 months (mean: 16.3 months). Extracted teeth were removed under local anaesthesia using forceps, placed in buffered formalin, and processed routinely using a double-embedding technique.

Each specimen was sectioned serially. Six micro-metre-thick sections were cut in a plane that allowed visualization of dentinal tubules extending from cavity floor to the pulp. Every tenth section was stained with haematoxylin and eosin; selected sections were stained by the Gram method for identification of bacteria.

Histological evaluation of all microscopic specimens was carried out by the author of this paper who was neither involved in the School Dental Service's restorative treatment programme nor contracted to the Health Department as a research investigator. All specimens had been submitted by the School Dental Service to the Oral Pathology section of the Dental School in The University of Western Australia. Histopathology reports on all teeth submitted by the School Dental Service were issued in the routine manner by the author.

In reviewing the histological data for the purpose of preparing this paper, assessment of pulp response to the application of AgF and GIC was based largely on the *Fédération Dentaire Internationale's Recommended Standard Practices for Biological Evaluation of Dental Materials*.<sup>2</sup> However, none of the 55 cases fell into the FDI's short (3 to 5 days) or intermediate (21 to 30 days) observation periods. While one case conformed with the FDI's long (observation) period (90±10 days), the remaining 54 cases fell into an extended observation period ranging from 6 to 56 months (mean: 16.6 months).

As well as following the histological criteria recommended by the FDI Technical Report<sup>2</sup> for

evaluating pulp response at 90±10 days after treatment, two additional criteria were used, namely, presence of a continuous and intact layer of odontoblasts, and presence of a well-defined predentine layer. The latter criterion is considered by the author to be important in evaluating pulp response as it indicates continued functional activity of odontoblasts.

For an AgF/GIC-treated tooth to be judged as exhibiting a favourable pulp response, that is, indicative of no adverse influence of residual caries and/or restorative procedures, the following ten criteria were required to be satisfied on examination of serial sections prepared from that tooth:

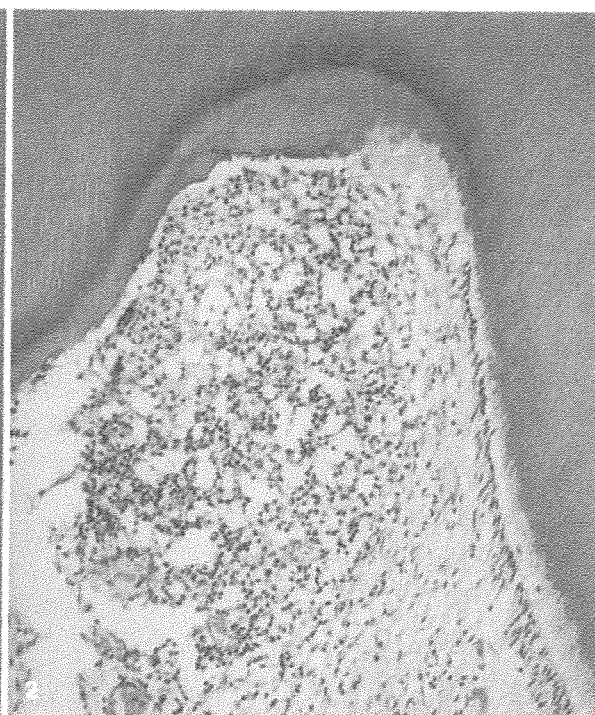
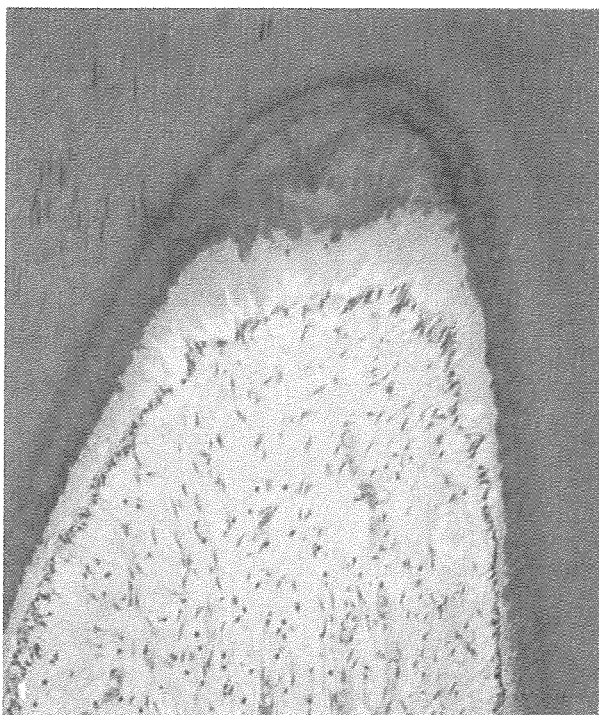
1. Presence of tubular reparative dentine in areas of the coronal pulp anatomically related to the zones of residual caries and the cavity preparation.
2. Presence of a well-defined predentine layer in the region of reparative dentine.
3. Presence of a continuous layer of odontoblasts adjacent to predentine.
4. No evidence of displaced odontoblast nuclei in the dentinal tubules.
5. No evidence of extravasated erythrocytes in the pulpal end of the carious/severed dentinal tubules.
6. No evidence of polymorphonuclear leukocytes in the odontoblastic, subodontoblastic, or central regions of the coronal pulp.
7. No evidence of ruptured capillaries within or beyond the odontoblastic layer.
8. No evidence of a brown pigment (birefringent in polarized light and indicative of circulatory disturbances) in the capillaries below the area of residual caries and cavity preparation.
9. Normal appearance and arrangement of connective tissue cells, blood vessels and nerves in the coronal pulp.
10. No evidence of focal necrosis in any part of the coronal pulp.

Haematoxylin and eosin stained sections containing reduced silver were also examined under light and confocal laser scanning microscopes. Optical sectioning was employed to determine the exact location of silver granules in the dentinal tubules, odontoblast layer and dental pulp.

Out of a total of 59 teeth treated with AgF and GIC that were submitted for microscopic examination, four showed advanced resorption and did not have sufficient remaining pulp tissue to enable a diagnosis to be made. These teeth were excluded from the study.

In addition to evaluating the pulp response in 55 carious teeth treated with AgF and GIC, a comparison was made between the pulp histology in these teeth with that observed in 23 other resorbing primary teeth that had been extracted for orthodontic reasons,

†Creighton Pharmaceuticals, Sydney, New South Wales; or Southern Dental Industries, Bayswater, Victoria.  
§Ketac-Fil. ESPE Applic System, Seefeld/Oberbay, Germany.



processed, and serially sectioned in the same manner. Eleven of these teeth had been restored with GIC; six had been restored with amalgam and/or zinc oxide and eugenol; the remaining five were non-carious and had not been subjected to any restorative intervention.

## Results

### *Resorbing, non-carious, non-restored teeth*

Non-carious teeth not subjected to any restorative intervention showed some tubular secondary dentine in the pulp horns, probably as a direct consequence of attrition of cuspal enamel and dentine. Lymphocytes and plasma cells were noted in root canal pulps near areas of root resorption, but not near the roof or lateral aspects of the coronal pulp.

### *Carious teeth restored with amalgam and/or zinc oxide and eugenol*

Although the pulps of these teeth did not exhibit any pathological changes, certain features need to be noted as they provide a basis for comparison with teeth treated with AgF and GIC, or with GIC alone.

Teeth restored with amalgam and/or zinc oxide eugenol (ZnOE) cement showed tubular reparative dentine in areas of the coronal pulp corresponding to the base of the cavity preparation. The odontoblast layer related to the reparative dentine was reduced to a width of one cell in most areas.

Although the coronal pulp did not exhibit any unusual features, lymphocytes and a few plasma cells were often seen in the root canal pulps close to

areas of active root resorption. In cases of advanced root resorption, chronic inflammatory cells could be found at the junction between the root and the coronal pulp and in the adjacent periodontal ligament region.

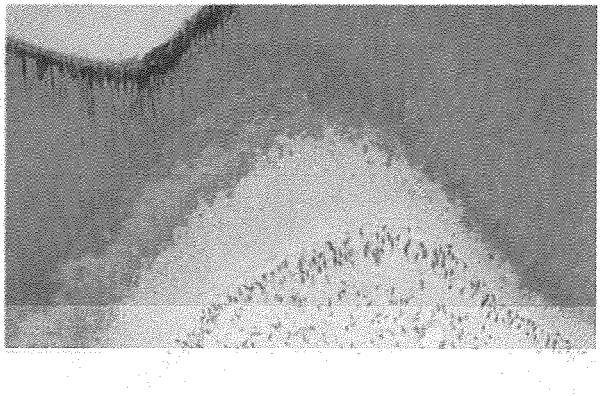
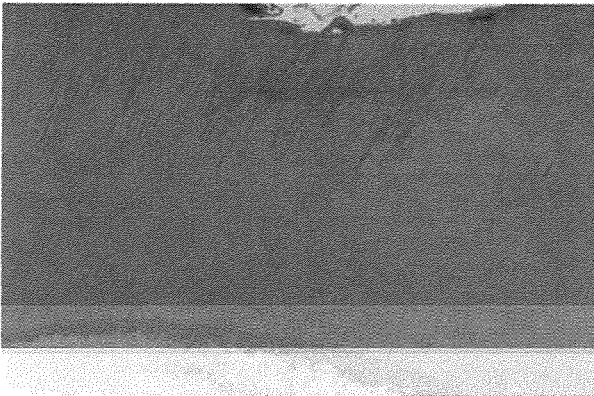
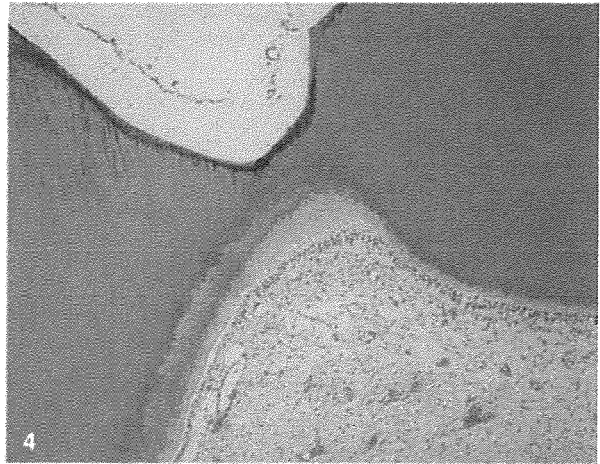
### *Teeth with relatively small carious lesions rendered 'caries-free' and restored with GIC*

There were eleven teeth in this category. Seven were judged to show a favourable pulp response; four were found to display an unfavourable response. Although all eleven teeth had been judged clinically to have had all caries removed before placement of the GIC restoration, microscopic examination of haematoxylin and eosin (H&E) stained and Gram-stained sections revealed residual caries beneath cavity preparations in 6 of the 11 teeth.

While reparative dentine was noted in 9 of the 11 teeth examined, the amount formed in each case was small (Fig. 1) and significantly less than that observed in teeth treated with AgF and restored with GIC. The pulp horn regions of coronal pulps of two teeth showed areas that were devoid of odontoblasts. Focal collections of acute and chronic inflammatory cells were noted in the adjacent areas of the pulp (Fig. 2).

### *Teeth with deep caries treated with AgF and restored with GIC*

1) Five teeth exhibited an unfavourable pulp response. Extracts from the pathology laboratory reports were as follows:



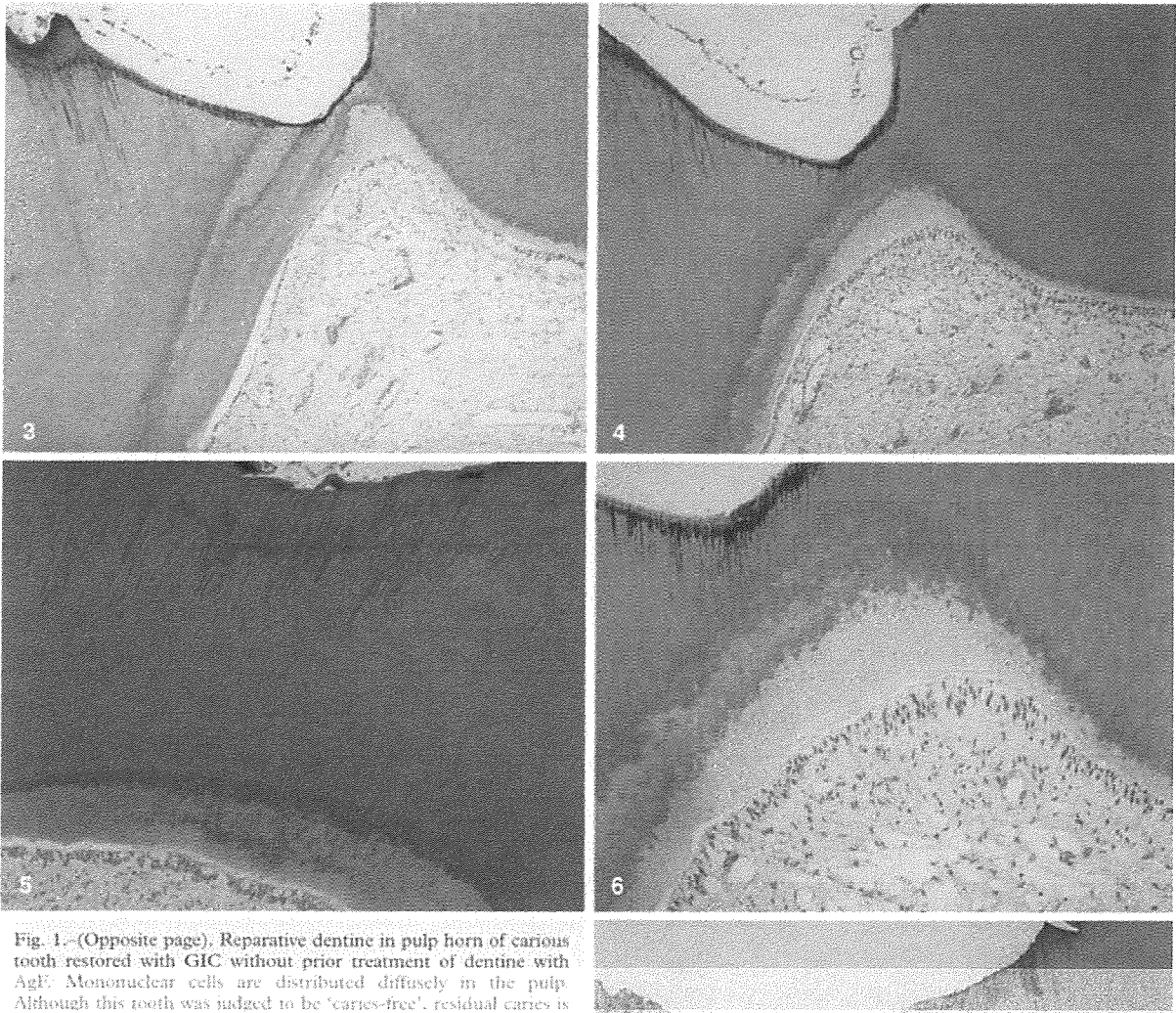
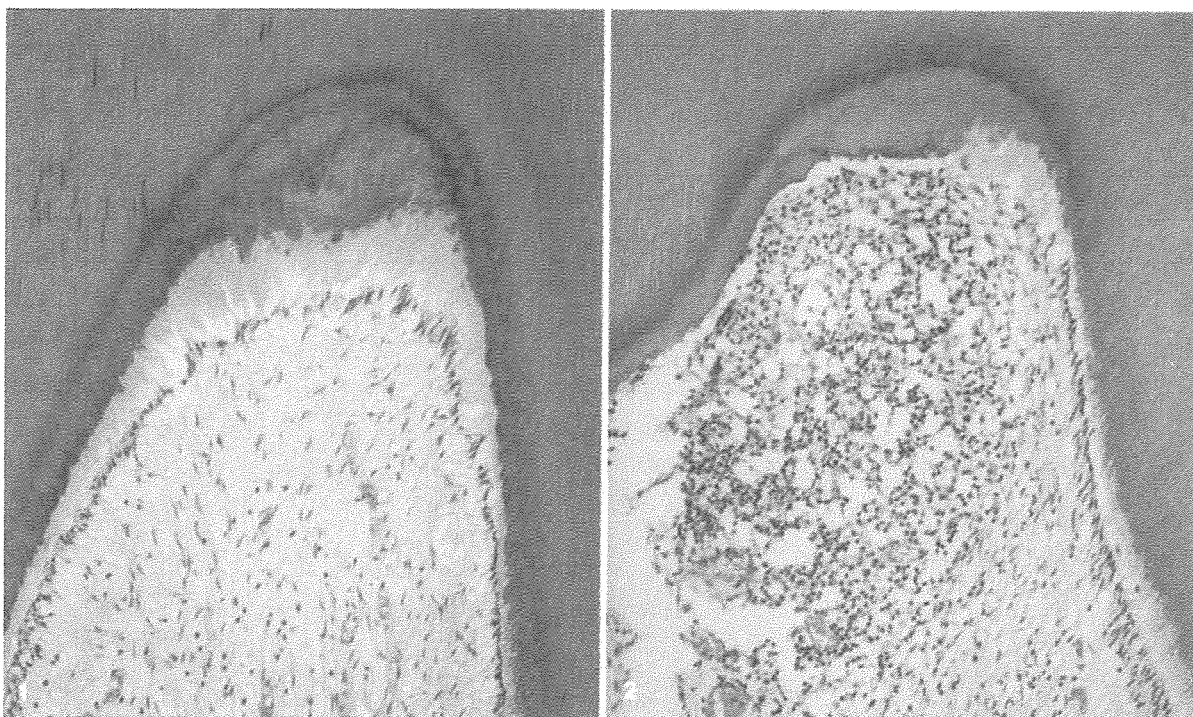


Fig. 1.-(Opposite page). Reparative dentine in pulp horn of carious tooth restored with GIC without prior treatment of dentine with AgF. Mononuclear cells are distributed diffusely in the pulp. Although this tooth was judged to be 'caries-free', residual caries is

*Fig. 1.-(Opposite page). Reparative dentine in pulp horn of carious tooth restored with GIC without prior treatment of dentine with AgF. Mononuclear cells are distributed diffusely in the pulp. Although this tooth was judged to be 'caries-free', residual caries is*



processed, and serially sectioned in the same manner. Eleven of these teeth had been restored with GIC; six had been restored with amalgam and/or zinc oxide and eugenol; the remaining five were non-carious and had not been subjected to any restorative intervention.

## Results

### *Resorbing, non-carious, non-restored teeth*

Non-carious teeth not subjected to any restorative intervention showed some tubular secondary dentine in the pulp horns, probably as a direct consequence of attrition of cuspal enamel and dentine. Lymphocytes and plasma cells were noted in root canal pulps near areas of root resorption, but not near the roof or lateral aspects of the coronal pulp.

### *Carious teeth restored with amalgam and/or zinc oxide and eugenol*

Although the pulps of these teeth did not exhibit any pathological changes, certain features need to be noted as they provide a basis for comparison with teeth treated with AgF and GIC, or with GIC alone.

Teeth restored with amalgam and/or zinc oxide eugenol (ZnOE) cement showed tubular reparative dentine in areas of the coronal pulp corresponding to the base of the cavity preparation. The odontoblast layer related to the reparative dentine was reduced to a width of one cell in most areas.

Although the coronal pulp did not exhibit any unusual features, lymphocytes and a few plasma cells were often seen in the root canal pulps close to

areas of active root resorption. In cases of advanced root resorption, chronic inflammatory cells could be found at the junction between the root and the coronal pulp and in the adjacent periodontal ligament region.

### *Teeth with relatively small carious lesions rendered 'caries-free' and restored with GIC*

There were eleven teeth in this category. Seven were judged to show a favourable pulp response; four were found to display an unfavourable response. Although all eleven teeth had been judged clinically to have had all caries removed before placement of the GIC restoration, microscopic examination of haematoxylin and eosin (H&E) stained and Gram-stained sections revealed residual caries beneath cavity preparations in 6 of the 11 teeth.

While reparative dentine was noted in 9 of the 11 teeth examined, the amount formed in each case was small (Fig. 1) and significantly less than that observed in teeth treated with AgF and restored with GIC. The pulp horn regions of coronal pulps of two teeth showed areas that were devoid of odontoblasts. Focal collections of acute and chronic inflammatory cells were noted in the adjacent areas of the pulp (Fig. 2).

### *Teeth with deep caries treated with AgF and restored with GIC*

1) Five teeth exhibited an unfavourable pulp response. Extracts from the pathology laboratory reports were as follows:

(mean 8.7 years). The teeth exhibited deep proximal carious lesions and had been restored by dental therapists employed by the School Dental Service in Western Australia. The technique entailed removal of some of the carious dentine using hand instruments and a slowly rotating round burr, application to residual caries of 40 per cent silver fluoride solution† and restoration of the cavity with GIC.§.

Prior to tooth removal, each restoration was examined for marginal and other deficiencies. Radiographs were not taken as radiography is not used routinely by the School Dental Service. Children were questioned to determine whether any sensitivity or pain had been experienced since placement of the restoration. All GIC restorations had been deemed to be satisfactory at the time of tooth extraction.

The observation period between tooth restoration and extraction varied from 3 months to 56 months (mean: 16.3 months). Extracted teeth were removed under local anaesthesia using forceps, placed in buffered formalin, and processed routinely using a double-embedding technique.

Each specimen was sectioned serially. Six micro-metre-thick sections were cut in a plane that allowed visualization of dentinal tubules extending from cavity floor to the pulp. Every tenth section was stained with haematoxylin and eosin; selected sections were stained by the Gram method for identification of bacteria.

Histological evaluation of all microscopic specimens was carried out by the author of this paper who was neither involved in the School Dental Service's restorative treatment programme nor contracted to the Health Department as a research investigator. All specimens had been submitted by the School Dental Service to the Oral Pathology section of the Dental School in The University of Western Australia. Histopathology reports on all teeth submitted by the School Dental Service were issued in the routine manner by the author.

In reviewing the histological data for the purpose of preparing this paper, assessment of pulp response to the application of AgF and GIC was based largely on the *Fédération Dentaire Internationale's Recommended Standard Practices for Biological Evaluation of Dental Materials*.<sup>2</sup> However, none of the 55 cases fell into the FDI's short (3 to 5 days) or intermediate (21 to 30 days) observation periods. While one case conformed with the FDI's long (observation) period (90±10 days), the remaining 54 cases fell into an extended observation period ranging from 6 to 56 months (mean: 16.6 months).

As well as following the histological criteria recommended by the FDI Technical Report<sup>2</sup> for

evaluating pulp response at 90±10 days after treatment, two additional criteria were used, namely, presence of a continuous and intact layer of odontoblasts, and presence of a well-defined predentine layer. The latter criterion is considered by the author to be important in evaluating pulp response as it indicates continued functional activity of odontoblasts.

For an AgF/GIC-treated tooth to be judged as exhibiting a favourable pulp response, that is, indicative of no adverse influence of residual caries and/or restorative procedures, the following ten criteria were required to be satisfied on examination of serial sections prepared from that tooth:

1. Presence of tubular reparative dentine in areas of the coronal pulp anatomically related to the zones of residual caries and the cavity preparation.
2. Presence of a well-defined predentine layer in the region of reparative dentine.
3. Presence of a continuous layer of odontoblasts adjacent to predentine.
4. No evidence of displaced odontoblast nuclei in the dentinal tubules.
5. No evidence of extravasated erythrocytes in the pulpal end of the carious/severed dentinal tubules.
6. No evidence of polymorphonuclear leukocytes in the odontoblastic, subodontoblastic, or central regions of the coronal pulp.
7. No evidence of ruptured capillaries within or beyond the odontoblastic layer.
8. No evidence of a brown pigment (birefringent in polarized light and indicative of circulatory disturbances) in the capillaries below the area of residual caries and cavity preparation.
9. Normal appearance and arrangement of connective tissue cells, blood vessels and nerves in the coronal pulp.
10. No evidence of focal necrosis in any part of the coronal pulp.

Haematoxylin and eosin stained sections containing reduced silver were also examined under light and confocal laser scanning microscopes. Optical sectioning was employed to determine the exact location of silver granules in the dentinal tubules, odontoblast layer and dental pulp.

Out of a total of 59 teeth treated with AgF and GIC that were submitted for microscopic examination, four showed advanced resorption and did not have sufficient remaining pulp tissue to enable a diagnosis to be made. These teeth were excluded from the study.

In addition to evaluating the pulp response in 55 carious teeth treated with AgF and GIC, a comparison was made between the pulp histology in these teeth with that observed in 23 other resorbing primary teeth that had been extracted for orthodontic reasons,

†Creighton Pharmaceuticals, Sydney, New South Wales; or Southern Dental Industries, Bayswater, Victoria.

§Ketac-Fil. ESPE Applic System, Seefeld/Oberbay, Germany.