A CLINICAL STUDY OF THE PROTECTIVE EFFECTS OF THE APPLICATION OF FISSURE SEALANT PRIOR TO THE DIRECT BONDING OF ORTHODONTIC BRACKETS

BY

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DECLARATION

I, DAYALAN SUNDRUM, DECLARE THAT "A CLINICAL STUDY OF THE PROTECTIVE EFFECTS OF THE APPLICATION OF FISSURE SEALANT PRIOR TO THE DIRECT BONDING OF ORTHODONTIC BRACKETS" IS MY OWN WORK AND THAT ALL THE SOURCES I HAVE QUOTED HAVE BEEN INDICATED AND ACKNOWLEDGED BY MEANS OF REFERENCES.

Signed: ....

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DEDICATION

This thesis is dedicated to the Orthodontic Department of the University of the Western Cape and to Prof. Jairam Reddy who spurred me on.

ABSTRACT

Orthodontic treatment sometimes has the unfortunate sequela of white spots forming around the margins of the brackets. These white spots or demineralized areas are of concern to the orthodontist, as they may present an aesthetic problem which might require costly restorative work later. Also at debanding the orthodontist is often faced with the time consuming and arduous task of removing residual composite from the tooth surface.

The purpose of this study was to establish whether a fissure sealant used with or without a fluoride containing mouthrinse would prevent white spot formation around orthodontic brackets and whether, coincidently, the use of the fissure sealant moved the fracture site closer to the enamel/resin interface, thereby leaving a clean enamel surface at debonding, saving the orthodontist chairside time.

One hundred patients undergoing orthodontic treatment at the Dental Faculty of University of the Western Cape were chosen for this study. The patients were given basic oral hygiene instruction, scaling and polishing and instructed to brush with a fluoride containing dentrifice. The mouth of each patient was divided

into four quadrants, with fissure sealant (Delton clear unfilled resin) being applied to two alternate quadrants. The sample was divided into two groups, one of which rinsed with a fluoride containing mouthrinse.

There was a significant difference in white spot formation when comparing fissure sealed and non-fissure sealed surfaces. Of the group which rinsed with fluoride mouthrinse, 86% had no white spots or demineralization. Also, the results of this study have shown unequivocally that the prior use of fissure sealant moved the fracture site closer to the enamel/resin interface, thereby leaving little or no residual composite on the enamel surface at debanding.

OPSOMMING

Ortodontiese behandeling het soms die nadelige gevolg dat wit vlekke vorm om die rante van die aanhegtings. Hierdie wit vlekke, of gedemineraliseerde areas, is vir die ortodontis van belang aangesien dit 'n estetiese probleem bied wat later duur herstelwerk mag benodig. Tydens bandverwydering word die ortodontis dikwels gekonfronteer deur die tydrowende en moeisame taak om aanpaksel van die tandoppervlak te verwyder.

Die doel van hierdie studie was om vas te stel of 'n fissuurverseëlaar aangewend met of sonder 'n fluoried, bevattende mondspoelmiddel, die vorming van wit vlekke rondom ortodontiese aanhegtings kan voorkom en of die fissurverseëlaar die area van die breuk nader beweeg aan die emalje/hars tussenvlak ten einde 'n skoon emalje oppervlak agter te laat met verwydering van die aanhegtings om sodoende die ortodontis tyd te bespaar.

Een honderd pasiente wat ortodontiese behandeling ontvang aan die Tandheelkunde Fakulteit van die Universiteit van Wes-Kaapland is gekies vir hierdie studie. Die pasiënte is voorsien van basiese mondhigiëne instruksie, skalering en polering en is versoek om te borsel met 'n tandepasta wat fluoried

bevat. Die mond van elke pasiënt is verdeel in vier kwadrante en fissuurverseëlaar (Delton deurskynende ongevulde hars) aangewend aan twee alternatiewe kwadrante. Die studiegroep is gehalveer; een groep het gespoel met 'n mondspoelmiddel wat fluoried bevat en die ander nie.

Daarbenewens was daar 'n aansienlike verskil rakende die vorming van wit vlekke tydens 'n vergelyking tussen fisuurverseëlde- en nie-fissuurverseëlde oppervlaktes. Van die groep wat met fluoriedspoelmiddel gespoel het, het 86% geen wit vlekke of demineralisering getoon nie. Die resultate van hierdie studie het onomwonde bewys dat die fissuurverseëlaar die breuk area nader beweeg aan die emalje/hars tussenvlak en terselfdertyd weinig of geen aanpaksel laat op die emalje oppervlak na verwydering van die tandbande.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

When orthodontic bands were the only means of fixing brackets to the teeth, demineralization was found to occur both beneath and around these bands. Numerous researchers have done work in trying to protect the enamel surface by incorporating fluoride powder into the band cementing agents. With the advent of commercially available fluoride containing cements this problem of decalcification was partially overcome. The presence of bands and welded brackets made cleaning difficult and as a result, plaque accumulated around and beneath the bands which therefore predisposed the teeth to demineralization and gingival inflammation.

With the advent of direct bonded techniques, a much smaller area of the tooth surface was now covered by the bracket. However, the problem of plaque retention still remained. Weitman and Eames (1975) showed that plaque covered the surface of resin restorations within 24 hours of placement and concluded that the resin surface predisposed to rapid attachment and growth of oral microorganisms. Histologic studies by Waerhaug (1975) confirmed the presence of both supragingival and subgingival plaque on acrylic and other restorations. It has been reported by Gwinnett and Ceen (1979) that plaque accumulated in association with resin-bonded orthodontic brackets and on some of the resins used to bond them.

The introduction of small resin-bonded brackets has been heralded as offering a more physiologic approach to orthodontic therapy than the earlier circumferential banding of teeth (Gwinnett and Ceen ,1979). Whilst gingival irritation and white spot lesions of demineralization were commonly found in association with banding procedures, such pathoses were now also being observed in association with the direct and indirect bonded procedures. Plaque has been shown to be the etiologic factor in the development of white spot lesions (Gwinnett and Ceen, 1979) and it was essential therefore that steps be taken to prevent plaque accumulation at vulnerable tooth sites. However, as this was often not practically possible, it made clinical sense that attempts be made to protect and strengthen the enamel surface from the damaging effects of plaque accumulation.

Bracket configuration, the presence of wires, elastics, springs and other auxiliaries all predisposed to plaque accumulation as a result of interference with the patients ability to keep some portions of the teeth and brackets clean (Zachrisson, 1975; Gwinnett and Ceen, 1979; Mizrahi, 1982). The sites around the attachments were therefore susceptible to demineralization.

The decalcification that occurred around these orthodontic brackets not only led to increased susceptibility to caries, but also left unsightly, chalky white areas in the enamel (Lee et al, 1974; Lehman et al, 1981; Artun and Brobakken 1986).

At the debanding stage, the orthodontist is faced with a further problem of residual composite on the enamel surface after bracket removal. The removal of this composite had to be accomplished with care to prevent damage to the enamel surfaces (Gwinnett and Gorelick, 1977). This was also a time consuming and arduous task.

In the light of the above, the aims and objectives of this study were;

1) To determine whether the prior use of a fissure sealant, in association with a fluoride mouthrinse, would reduce the prevalence of common white spot lesions during orthodontic treatment.

2) To evaluate the fracture site and to quantify the amount of residual composite left on the tooth surface when debonding these brackets using a standard method of debonding.

3) To assess clinically the effect of the fissure sealant on the bonding properties of the adhesive.

REVIEW OF LITERATURE

DEMINERALIZATION AND ORTHODONTIC BRACKETS

In its early stages, caries appears as dull white stripes or larger greyish-white spots (Darling, 1958; Fehr, et al 1970; Gorelich et al, 1982; Artun and Thylstrup, 1986). Studies have shown that the white spots are caused by changes in the optical properties of the enamel due to subsurface demineralization (Darling, 1958; Fehr et al, 1970). According to Artun and Thylstrup (1986), these white spot lesions become scars, which represent an esthetic problem, particularly if they are extensive.

Several studies have shown the association between full banded orthodontic treatment and enamel demineralization (Ingervall, 1962; Zachrisson and Zachrisson, 1971; Wisth and Nord, 1977; Hollender and Ronnerman, 1978; Lundstrom and Hamp, 1980; Mizrahi, 1983; Glatz and Featherstone, 1987).

An almost linear correlation between plaque accumulation and the development of caries has been found in orthodontic patients (Zachrisson and Zachrisson, 1971). Therefore, failure to properly manage plaque removal during orthodontic treatment may lead to an increased number of new lesions.

Artun and Brobakken (1986), found these white spot lesions to be more prevalent in the gingival areas. The teeth most affected were the lateral incisors in the maxilla and the canines and premolars in the mandible. Their data supported those of other studies (Zachrisson and Zachrisson, 1971; Ingervall, 1982; Gorelick et al, 1982) and they suggested that the small tooth surface areas between bracket and gingiva on these teeth were more susceptible to plaque retention. The presence of closing loops and elastomeric chains in the lateral incisor and canine areas, made the vestibular surfaces in these areas difficult to clean. In addition the mesiogingival concavity often seen on the maxillary lateral incisor might facilitate voids between bracket base and tooth surface, which in time might cause plaque retention and caries (Artun and Brobakken, 1986).

According to Mizrahi (1983) there was a significant increase in the prevalence of enamel opacities on the vestibular and lingual surfaces of the dentition, following orthodontic treatment. The increase was greater on the cervical and middle thirds of the crowns. Among individual teeth, there was a statistically significant increase in the prevalence and severity of enamel opacities on the maxillary and mandibular first molars, the maxillary lateral incisors, and the mandibular lateral incisors and canines.

Artun and Thylstrup (1986), in a clinical and scanning electron microscopic study of the surface changes of incipient caries lesions after debanding, found heavy accumulations of dental plaque in all areas corresponding to the white, demineralized zone. The appearance of the lesions at the time of debanding changed from chalky white to a more diffuse opacity, particularly in the peripheral parts of the lesion.

These white spots or lesions that developed largely on the facial surfaces of both anterior and posterior teeth represent an unaesthetic side effect of orthodontic treatment, which may counteract the otherwise beneficial results (Ogaard et al, 1988 a and b).

The affected area was found to be slightly softer than the surrounding sound enamel. The white appearance is caused by an optical phenomenon due to subsurface demineralization and is seen to increase in whiteness when air dried (O'Reilly and Featherstone, 1987). Various experimental techniques like microradiography, polarized light microscopy, microhardness and electron microscopy have been used to explore the characteristics of carious enamel. From these experiments, two initial stages of enamel demineralization have been observed. The first stage is that which is characterized by preferential removal of interprismatic substance, the mineral loss being most pronounced at the enamel surface. This is followed by the formation of the subsurface lesion where the dissolution occurred mainly in the deeper part of the enamel; a porous but mineral rich layer still covered the body of the lesion, which was found to be low in minerals.

O,Reilly and Featherstone (1987), demonstrated conclusively in an in vivo study that a measurable and significant amount of demineralization, as quantified by microhardness testing, occurred immediately adjacent to orthodontic appliances within one month after bonded appliance placement. This demineralization was as a result of plaque activity and not due to the initial acid etching process before bonding. Up to 15% mineral loss was routinely seen. The mineral loss was localized to an area 50-70 microns from the periphery of the bracket base and did not extend along the whole buccal surface. Whilst the rapidity of the demineralization was striking, the authors emphasized, however, that this demineralization was as yet not clinically visible. This suggested therefore that considerable mineral loss could occur without being observed by the the clinician. These observations would seem to support the scanning electron microscopic work of Diedrich (1981) who reported that even though bonded teeth apparently had a normal enamel translucency, there was a physical lack of mineral in the bonded ie. treated areas.

THE USE OF FLUORIDE SUPPLEMENTS DURING ORTHODONTIC TREATMENT

From the literature it would appear that there is general agreement that the development of white spots seems to be related to the retention of plaque on the gingival side of the brackets or bands, the degree of oral hygiene efficiency and the inherent resistance of the individual. Studies by Hirschfield (1978) and Shannon (1980, 1981) have documented the beneficial effect of preventive fluoride programmes during multibanded orthodontic treatment.

Fluoride therapy has been shown to reduce enamel solubility, to control plaque activity through blocking bacterial enzyme systems, and also to assist in the process of enamel remineralization (Geiger et al, 1988). Recent studies by Ogaard (1989) showed that free fluoride in mouthrinse was very effective in preventing demineralization. Therefore as a caries preventative measure, fluoride provided an unequivocal benefit to the dental health of the patient. The importance of the use of a sustained fluoride program to replenish the lost ions is well established since fluoride is continually being depleted from enamel during ionic exchanges with plaque.

It is known that incorporation of fluoride ions into enamel structure as fluorapatite ($Ca_5(PO_4)_3 F$) would result in the remineralization of small decalcified or carious lesions and also reduce the formation of new lesions (Larsen et al, 1976; Silverstone, 1982; Mellberg and Mallon,1984). In addition the regular usage of topical applications of various neutral and acidulated sodium fluoride formulations would reduce the incidence of new carious lesions in normal enamel (Shannon, 1981).

An almost linear correlation between plaque accumulation and development of caries has been found in orthodontic patients (Zachrisson and Zachrisson, 1971). Therefore failure to manage plaque removal properly during orthodontic treatment may lead to an increase in white spot lesions. Frequent use of fluoride may reduce the progression rate of early carious lesions (Hirce et al, 1980; Fejerskov et al, 1981). A preventative programme which served to reduce the caries risk or to eliminate white spot formation during orthodontic treatment should include the use of topical fluoride, particularly if the patient resides in a nonfluoridated area (Harvey and Powell, 1981; Zachrisson, 1975; Shannon, 1981).

Since the early 1940's hundreds of clinical studies have been conducted to evaluate the effectiveness of different methods of fluoride administration with topical and/or systemic effects (Fischer et al, 1954; Howell et al, 1955; Brudevold, 1959). The delivery systems of fluoride to the enamel during orthodontic treatment include pastes, solutions, gels, mouthrinses, tablets, cements, sealants and coatings.

Several studies have shown that individual oral hygiene education and instruction in conjunction with fluoride mouth rinses may reduce the development of decalcification during orthodontic treatment with fixed appliances (Wisth and Nord, 1977; Zachrisson, 1977; Lundstrom and Hamp, 1980; Dyer and Shannon 1982; Geiger et al, 1988).

Lehman et al (1981) have shown that topical fluoride treatment produced a more acid resistant outer layer. Driessens, (1973) and Shannon (1980) supported the observation that increased fluoride mass in enamel played an important role in decreased enamel solubility.

Several investigators have advocated the application of topical fluoride before etching (Zachrisson, 1975; Byrant et al, 1985; Kaswiner, 1981; Harvey and

Powell, 1981) concluded that applying topical fluoride agents seven days before bonding will not reduce bond strength.

Lehman et al (1981) have recommended that fluoride be used only immediately after bonding so as to gain maximum rehardening of the etched enamel without interfering with bonding.

The caries inhibition effect of fluoride tablets may be the result of daily topical influence on erupted teeth, followed after swallowing by a systemic effect on developing tooth structures. Studies indicate that caries prevention from the use of chewable tablets is obtained mainly in teeth exposed to the administered fluoride preeruptively or shortly after eruption (Parkins, 1972, cited by Kajander et al, 1987).

Zachrisson (1975) recommended the use of acidulated phosphate fluoride (APF) gel at recementation appointments, daily rinses with dilute sodium fluoride (NaF) and APF solutions throughout the treatment and the regular use of a fluoride dentrifice. Harvey and Powell (1981) designed a structured fluoride program before, during and after the removal of orthodontic appliances, which included the use of 2% neutral NaF or APF solution, 10% SnF dentrifice, 0.05% NaF solution 5% MFP dentrifice and NaF containing dentrifice at specified times. Orthodontists could take advantage of topical fluoride benefits for their patients and these included fluoride supplements, dentrifices, mouthrinses and topical agents (Saloum and Sondhi, 1987). Kajander et al, (1987) have recommended the use of an acidified topical NaF rather than neutral NaF, to incorporate maximum fluoride into the exposed etched enamel periphery surrounding banded orthodontic brackets and other resin procedures.

Geiger et al (1988) reported on the effects of a preventative fluoride programme in reducing the incidence and severity of white spots during orthodontic treatment. In addition to receiving professional fluoride treatment by means of fluoride gel application, these patients were also required to rinse with a 0.05% sodium fluoride solution, after having brushed with a fluoridated toothpaste.

When compared with earlier studies (Stratemann and Shannon, 1974; Magness et al, 1979; Gorelick et al, 1982) this study by Geiger et al (1988) showed a 30% reduction in the number of patients who presented with white spots. They concluded that decalcification of labial surfaces of teeth during orthodontic therapy could be significantly reduced by the consistent use of 0.05% NaF rinse during treatment. Despite their efforts to educate patients and parents, poor compliance with a preventative fluoride rinse programme occurred in 50% of patients. The one time topical application of acidulated phosphate fluoride gel immediately after banding appeared to be of little benefit in reducing the incidence of white spots. Daily administration of topical fluoride and the use of fluoridated toothpaste was one method of providing the continuous reservoir of fluoride ions necessary for enamel protection against white spot formation (Geiger et al, 1988).

On the basis of extensive data, Stokey (1985), cited by Saloum and Sondhi 1987, showed that dentrifices containing NaF were currently the most effective in helping to prevent early demineralization.

Studies by Ogaard et al (1988 a + b) have shown that daily mouthrinses with a neutral 0.2% sodium fluoride solution retarded lesion development significantly. This fluoride applied as a mouthrinse has a marked cariostatic effect on the poorly accessible locations underneath orthodontic bands and surrounding orthodontic brackets. Ogaard et al (1988 a + b) also found an even more pronounced caries protection effect was obtained with a single topical application of a fluoride solution having a very low pH. The rationale for using this agent was that a low pH favoured calcium fluoride (CaF) formation probably due to an increase in available calcium ions from the existing plaque. The low pH fluoride solution produced twice as much calcium fluoride as did a neutral 2.0% NaF solution. The calcium fluoride appeared to be bound more firmly to the enamel surface since the rate of dissolution in alkali was much slower. This also may account for the better clinical effect of this fluoride solution. The calcium fluoride deposit may as such form an acid-resistant protection against cariogenic challenges and serve as a significant reservoir of fluoride for release in the inhibition of demineralization (Ten Cate and Duijsters, 1983; Ogaard, 1989).

Remineralization means the redeposition of mineral after loss during caries attack. In vitro, it has been shown that apatite minerals can be redeposited in the lesion during remineralization (Ogaard et al, 1988 a + b). Fluoride has been shown to increase the remineralization speed, although complete in vivo repair was inhibited by precipitation of fluoride in the surface layer (Ogaard et al, 1988 a + b). It has been shown that the surface softened lesion (the early lesion) remineralized faster and more completely than the subsurface lesion and that the efficiency of remineralization was better in nonfluoridated control groups than in fluoride rinsing groups (Gelhard, 1982, cited by Ogaard et al, 1988).

The remineralizing capacity of saliva in the absence of concentrated fluoride agents was relatively fast. The visible white spots on the facial surfaces of teeth that have developed during orthodontic treatment, should therefore not be treated with concentrated fluoride agents since this procedure would arrest the remineralization process and hence prevent complete repair (Ogaard et al, 1988 a + b).

White spot lesions i.e. visible incipient enamel caries have also been shown to disappear once the brackets have been removed (Darling, 1958; Fehr et al, 1970; Artun and Thylstrup, 1986). It has been postulated that this might be due to the deposition of minerals in the demineralized enamel or possibly due to abrasion of the surface layer. However, in vivo indications are that remineralization of carious white spots is reduced (Ogaard, 1988 a + b). The problem seems to be that rapid remineralization of the surface layer and the formation of fluoride precipitates on the surface, restricted the passage of ions to deeper layers of the lesion (Silverstone, 1977; 1982). The main reason for gradual regression of carious white spots at the clinical level may be the result of surface abrasion (Artun and Thylstrup 1986; 1989).

USE OF FISSURE SEALANT / OR SEALANT SUPPLEMENTS

Since 1970 when Buonocore first published the clinical significance of fissure sealants, numerous other studies have confirmed that sealants effectively prevented occlusal caries (Buonocore, 1970; Rock, 1974; Horowitz et al, 1977; Simonsen , 1980; Mertz-Fairhurst,1984). A fissure is fully protected as long as it is completely sealed. Indeed , not a single report has shown that caries developed in pits and fissures under an intact sealant. Mertz-Fairhurst (1984) reported that sealants had a tremendous advantage over other restorative materials because they were noninvasive and the tooth, therefore, remained intact. Also they were the most effective and long lasting preventive agents that we could provide our patients within the dental office.

In 1952 Meyers in a clinical test, coated teeth with copal varnish while Lee (1965), analyzed the possibilities of using epoxy resins as a protective coating against demineralization (cited by Lee et al, 1973).

As early as 1973, Lee, Orlowshi and Kobashigawa began looking at utilizing effective surface coating solutions that could prevent demineralization in the orthodontic patient. The rationale was that decalcification could be avoided or minimized by using a protective coating prior to the placement of the orthodontic bands and later removed on completion of the orthodontic treatment (Lee et al, 1973).

In 1979 a new composite, Enamelite, was developed and clinically tested as a coating material for discoloured enamel. The consistency was suitable for applying with a brush-on technique and it had a low film thickness that allowed it to blend smoothly into undetectable margins. This material was shown to have high wear resistance and also showed good retentive properties.

Further research by the Lee Pharmaceutical company resulted in the marketing of a modified formulation (Protecto) which incorporated additional characteristics which made it more suitable for orthodontic applications. This new material was composed of two parts being in the form of a medium viscosity suspension of solid microfibrous structured filler in diacrylate-type resin. This material could be applied either prior to installation or after installation of bands. This coating, however, may be readily removed by applying a peeling force.

It has been reported by Lee et al (1973), that the use of this polymeric adhesive coating as an effective orthodontic prophylaxis could eliminate the problem of decalcification. The mechanisms of retention have not been clearly elucidated, but the increased adhesion was due in part to mechanical interlocking of the etched enamel surface with the cured resin. Protecto was further tested by Tillery et al (1976), and it was found to provide more protection against decalcification of teeth under loose orthodontic bands than did either acidulated phosphate fluoride or stannous fluoride.

In 1979 Younis et al tested the efficacy of materials such as Copalite, Portrait Veneer, Nuva seal and Protecto against enamel decalcification. Nuva-seal and Protecto gave significant protection against decalcification over a period of 14 weeks. However, Nuva-seal proved to be significantly better than Protecto for the time period of twenty one weeks used in their study.

In 1979, Hughes et al tested various other materials and found that the ultra-violet-light-activated bis GMA resin (Portrait Veneer) provided more protection against in vitro decalcification of teeth under loose orthodontic bands than did any other product.

Investigations in 1978 by Zachrisson, however, indicated that definite inadequacies were found with polymerization in thin films of conventional sealants mainly because of oxygen inhibition upon polymerization.

Zachrisson et al (1979) tested the effects of five different sealants on the smooth buccal surfaces of premolar teeth. The purpose of their study was to assess the polymerization of some conventional and some new sealants in thin films, on smooth tooth surfaces. This study demonstrated the inadequacy of some conventional sealants to polymerize in a thin film on smooth tooth surfaces. The main reasons probably were non- polymerization (due to oxygen inhibition) and flow (viscosity of sealant). Saga sealant which has acetone added, was able to polymerize in thin films, due to a "blanket" of acetone vapour preventing the ingress of oxygen.

The problem of wear and or loss of unfilled resins with time must also be considered. Gwinnett and Ceen (1979), showed that ultra-violet-polymerized sealant (Nuva-seal) showed signs of rapid wear and loss.

Recent studies by Hicks and Silverstone (1982) have shown that enamel surfaces became less soluble to acid dissolution after bonding procedures even if the overlying resin mass (sealant) was lost. They suggested that resin tags remaining in the etched enamel may hinder acid dissolution of the surface in some manner. This concept was in agreement with results from previous work (Silverstone, 1974; 1977) which demonstrated conclusively that resin tags increased the ability of enamel to resist acid dissolution. Tag-like extensions extending into the enamel surface up to about 25 microns were observed by Buonocore, Matsui and Gwinnett (1968) and this was also confirmed by Sharp and Grenoble (1971), cited by Lee et al, 1973.

Croll (1987) described a method of using visible light polymerized resin bonded sealants to restore incipient carious lesions, areas of enamel decalcification, and enamel craze fractures on smooth dental surfaces. He increased the wear resistance of the smooth surface sealant by blending the resin sealant with densely filled resin. Croll used Delton fissure sealant (visible light cured) which blended unobtrusively into the surrounding tooth structure when bonding procedures were performed. In addition visible light cured clear sealant did not turn yellow or brown in the mouth as time passed. Such colour stability existed because the aromatic tertiary amine accelerator commonly found in auto-polymerizing resins was not included in photopolymerizing resin formulations.

RECENT TRENDS IN USING FLUORIDE RELEASING CEMENTS AND RESINS

Because conventional bands continue to be used in clinical orthodontics, new dental cements have come onto the market in an attempt to prevent acid demineralization. One such cement is the glass ionomer cement. This cement developed by Wilson and Kent (1972) has the adhesive properties of the polycarboxylate cement, with the hardness and insolubility of the silicate cements (Hotz et al, 1977; Duperon and Jedrychowski, 1980).

Mizrahi (1988) has stated that the use of the glass ionomer cement contributed to a significant decrease in bond failure rate. According to Norris et al (1986) and Retief et al (1984), the glass ionomer protected the tooth from decalcification under and around the orthodontic band significantly better than zinc phosphate cements, because of the slow release of fluoride from the cement.

Recently Sonis and Snell (1989) showed that a visible light activated, fluoride releasing bonding system was capable of adequately retaining brackets while aiding in the prevention of decalcification around bonded appliances. It has been shown that the fluoride released in this method will be site specific to those areas most susceptible to demineralization, namely adjacent to the brackets.

Their study made use of the recently introduced fluoride releasing composite, Fluor Ever which has the fluoride not bound but rather encapsulated within the composite. The fluoride is released by a diffusion/dissolution mechanism over a prolonged period to the adjacent enamel which resulted in a high enamel concentration of fluoride. It is available as a light cured composite which will allow ample working time, such that flash material around the bracket could readily be removed. The material also has an added advantage of fluorescing under ultra-violet light, thereby allowing easy recognition of residual composite after debonding. In vitro studies of this material demonstrated a "burst effect" of fluoride release within the first several hours after placement of this composite (Temm et al 1987) cited by Sonis and Snell 1989. This material has also been shown to maintain a slow, sustained rate of fluoride release, which is considered effective in initiating remineralization of incipient carious lesions.

A more recent development has been the incorporation of fluoride in the bonding resin (Underwood et al 1987). This fluoride releasing resin has anticariogenic properties and was developed by Rawls and Zimmerman (1983). The fluoride releasing resin is unique in that the fluoride ion is incorporated as a mobile ion charge in an anion - exchanging resin. Rather than supplying fluoride to the oral environment by material dissolution, the fluoride is given up in exchange for other anions and the structural integrity of the resin is maintained. Long term low-level fluoride release is therefore possible without reduction in necessary physical characteristics.

Underwood <u>et al</u> (1987), showed that the use of the fluoride exchanging adhesive resulted in 93% reduction of occurrence of dark zones compared with the control adhesive, indicating a reduction of early demineralization. Translucent zone progression to dark zone was reduced. This fluoride exchanging resin holds promise as a clinically useful orthodontic adhesive.

Research has also shown that fluoride could be slowly released from the sealant, allowing the fluoride to penetrate the enamel. As much as 3500 ppm may be deposited at 10µm depth in the enamel. This resin sealant is expected to protect the enamel from caries attack even after detachment of the sealant (Tanaka <u>et al</u>, 1987).

DEBONDING AND ASSOCIATED PROBLEMS

Since the introduction of the acid etch technique and its application to the bonding of brackets for orthodontic purposes, the literature has been replete with studies on the shear bond strength of the adhesive composites used, the amount of composite remaining at debonding and the removal of this residual composite.

Gwinnett and Gorelick (1977) suggested the use of a ligature cutter at the enamel/adhesive interface and a peel force to remove the adhesive. Remants could be removed by means of a green rubber wheel or with hand instruments. It has been said that the hand instrument could be used with considerably less force and, therefore, would cause fewer and shallower scratches on the enamel surface.

Zachrisson and Artun (1979) found that scratches still remained on the tooth surface when using a rubber wheel. They recommended the use of a low speed tungsten carbide bur since it produced the finest scratch pattern.

Pus and Way (1980) showed that enamel loss ranged from 26.1 to 31.8 microns for unfilled resin and from 29.5 microns to 41.2 microns for filled resin, depending on the instrument used for prophylaxis and debonding.

Various authors have shown that bracket removal at the debonding stage can have harmful effects on the enamel surface (Burapavong et al, 1978; Zachrisson et al, 1980; Pus and Way, 1980; Jones, 1980; Rouleau et al, 1982; Bennett et al, 1984). These studies have shown fracture or gouging of the enamel or enamel tears at debonding. Bennett et al (1984) recommended the use of a squeeze technique to effectively peel the bracket away and later having the residual composite removed by using a 12 bladed carbide finishing bur and polishing disks.

Artun and Bergland (1984) compared the effects of gently squeezing the wings of the bracket to those of gently squeezing the edges of the base with a bracket removal plier. The amount of residual composite was measured using the Adhesive Remnant Index (ARI) developed by them in a pilot study.

A recent study by O'Brien, Watts and Read (1988) has suggested that the amount of residual debris following removal of the bonded bracket was not related to the shear bond strength at the separate interfaces (i.e. at the adhesive enamel and adhesive bracket base interface) but was governed by factors caused by bracket base design and properties of the adhesive used. They found that the combination of the mini-mono/ concise combination ie. conventional metal brackets with stainless steel mesh produced significantly more residual composite on the enamel than any other bracket base/adhesive.

Knoll et al (1986) have shown in an in vitro study that orthodontic brackets have higher bond strengths when bonded to anterior teeth. This was in agreement with the clinical observation that brackets bonded to posterior teeth fail more frequently (Zachrisson, 1977). This could possibly be attributed to greater masticatory forces produced in the posterior region or due to the nonuniformity of resin thickness between enamel and bracket base for curved posterior teeth.

Gwinnett and Gorelick (1977) found that posterior teeth tended to have a composite/enamel break whereas anterior teeth displayed more composite/bracket breaks.

Oliver (1988), compared three different methods of bracket removal with the amount of residual adhesive remaining. He found that the peeling effect by squeezing the wings of an edgewise bracket and the lift-off debracketing instrument (LODI) left very little residual adhesive. He also found that there was a highly significant difference between heavily filled composite (70% filled particles) and a small diluted variant (56% filled particles). The adhesive qualities were altered, shifting the weakest link in the debonding chain from the composite/enamel interface for the former to the composite/bracket interface for the latter.

The bond between enamel and the orthodontic bracket is unique in dentistry in that it is intended to be temporary. The bond is required to remain intact for up to two years, withstanding both orthodontic forces and the forces of occlusion. The bond must then be broken at debonding with the minimum amount of trauma to the tooth and patient.

All current methods of debonding are mechanical apart from the thermal debracketing instrument. Ideally one would require that all the adhesive remained on the bracket and that it could be removed easily from the tooth without fracture of enamel or adhesive. With metal brackets the major site for failure was between the adhesive and the bracket, although separation often occurred at a mixed interface with microscopic enamel fractures and retention of resin tags and a resin film on the enamel surface. There may even be damage to the enamel (Jones, 1980; Andreason and Chan, 1981; Bennett et al, 1984).

A study by Kinch et al (1989) was designed to assess the amount of adhesive remaining on the tooth at debonding, comparing etch times of 15 second and 60 seconds, together with the effect of other known influencing variables. They concluded from their study that the use of a 15 second etch time left more composite on the enamel at elective debonding than a 60 second etch time. They reported too that the quantity of composite remaining on the tooth was related to the tooth position within the arch, bracket type used and method of debonding.

SEALANTS

The autopolymerizing sealant, Delton (J.J. Dental Product) has repeatedly demonstrated good retention when used as a pit and fissure sealant (Buonocore, 1970; Going et al, 1976; Simonsen, 1980; Mertz-Fairhurst et al, 1982; Houpt and Shey, 1983; Mertz-Fairhurst, 1984).

The majority of the sealants used in dentistry today are based on the Bis-GMA resin. These were polyurethane sealant containing inorganic fluoride compounds and polyacrylate materials. The full name for BIS-GMA is bisphenol-A-diglycidylmethacrylate. The chemistry of the BIS GMA types of sealants is essentially the same as that of the composites. The principle difference is that the BIS- GMA sealants must be made more fluid to penetrate into pits and fissures and also into etched areas produced on the enamel (Phillips et al, 1970).

The BIS-GMA sealants which polymerize by an organic accelerator are supplied as a two component system: one component contains a BIS-GMA type of resin and benzoyl peroxide as the initiator and the other component contains a similar resin with 5% organic amine accelerator. The two components are usually dispensed as viscous drops onto a suitable mixing surface and after adequate mixing they are applied onto the tooth (Graber and Swain, 1985).

The sealant coating should be thin and even, for excess sealant may induce bracket drift and unnatural enamel topography when polymerized (Brauer, 1978; Miura, 1985). Bracket placement should be started immediately after all etched surfaces are coated with sealant. The sealant surface layer may not polymerize ,in fact, the entire sealant layer may not cure when conventional autopolymerizing sealants are used. It should not be removed, however, since it will cure with the adhesive in the next step (Zachrisson et al, 1979).

A particular problem in orthodontics was that the sealant film on a facial tooth surface was so thin that oxygen inhibition of polymerization was likely to occur throughout the film with autopolymerizing sealants (Zachrisson, 1977). Non polymerization appeared to be less of a problem with the use of light polymerized sealants containing acetone.

The caries protection effect of sealant around the bracket base is uncertain but should not be ruled out completely (Gwinnett and Ceen, 1979; Ceen and Gwinnett 1981).

Ceen and Gwinnett (1981) found that light polymerized sealants protected the enamel adjacent to brackets from dissolution and subsurface lesions, whereas chemically cured sealants polymerize poorly, exhibited drift and had low resistance to abrasion.

Finally sealants may at least theoretically permit easier bracket removal and protect against enamel tear-outs at debonding, particularly when adhesives with small filler particles were used. No doubt, improved abrasion-resistant sealants with altered polymerization processes will be of great value for orthodontic purposes when they become available (Artun and Zachrisson, 1982).

MATERIALS AND METHODS

The materials and methods for the study under consideration shall be discussed under the following headings:

1 SAMPLE SIZE AND SELECTION

2 DESIGN OF THE SAMPLE

3 MATERIALS

4 CLINICAL PROCEDURE

5 EXPERIMENTAL PROCEDURE

6 MEASUREMENTS

7 STATISTICAL ANALYSES

SAMPLE SIZE AND SELECTION

The population sample used in this study was drawn from patients who presented to the Orthodontic Department for fixed appliance orthodontic treatment. No significant distribution of the sexes were observed and the patients' ages varied from 11 years to 22 years.

All patients were to receive routine orthodontic treatment for various types of malocclusion for a period of approximately 18 months to 2 years using the edgewise or the Begg technique, with standard mesh backed brackets bonded to all teeth anterior to the first molars in both jaws. The brackets were bonded using Ortho Concise (Dental Products/3M, St. Paul, Minn.) and the material was used according to the manufacturers' instruction. In all patients, care was taken to remove the excess Concise around the bracket bases to avoid unnecessary plaque retention sites.

All patients were required to follow an organized oral hygiene preventative programme including motivation and instructions in tooth brushing given by the Periodontic Department, University of Western Cape. Prior to having the brackets bonded all patients had their teeth scaled and polished. A Plaque and Gingival Index according to Loë and Sillness (1967) was carried out on the day of bonding and subsequently at 6 monthly intervals to monitor the patients oral hygiene.

At the time of the bonding, the teeth were cleaned and polished with pumice. At each subsequent visit, the patient was remotivated and instructed in oral hygiene procedures by the author and sometimes by an oral hygienist.

All patients were instructed to brush their teeth using a fluoride containing dentrifice.

DESIGN OF THE SAMPLE

Each patient was used as a control and as an experimental subject for the purposes of this study.

The mouth was considered in four quadrants (Fig.1). Fissure Sealant (Delton unfilled chemically cured - Johnson and Johnson Dental Products, Co., East Windsor, N.J.) was applied to two alternate quadrants viz.

Quadrant	A	:	Fissure Sealant
"	B	:	Non Fissure Sealant
"	C	:	Fissure Sealant
"	D	:	Non Fissure Sealant

F/S	N/F/S
A	B
D	C
N/F/S	FS

Fig 1: Showing how the patients mouth is divided into four quadrants with F/S (fissure sealant) and NFS (non-fissure sealant) applied alternatively.

For each subsequent patient the procedure for the quadrants rotated in a clockwise direction - the above array repeated after every four patients.

Fig 2. Debonding Plier.

A double bladed bracket remover.

MATERIALS

Materials used in this study include:

[1] Orthodontic edgewise metal brackets

[2] Delton-Fissure sealant, clear chemically cured unfilled resin (Johnson and Johnson Dental Products, Co., East Windsor, N.J.)

[3] Ortho-Concise bonding material (Dental Products/ 3M, St. Paul, Minn.)

[4] Nikkormat camera with 105mm lens

[5] Periodontal probe

[6] Sharp probe

[7] Debonding instrument - Double bladed bracket remover (Fig. 2)

[8] ListerFluor Mouthrinse (Warner Lambert S.A. (Pty), 241 Main Road, Retreat)

[9] Orthodontic Toothbrush (Oral B-Toothbrush. Gretkar Park, La Bel Road, Stikland, South Africa.)

Clinical Procedure

The teeth were polished with pumice using a rubber cup, air dried and then isolated using cotton wool rolls and cheek retractors. The entire buccal surface of the tooth was acid etched for 30 sec. and washed and dried properly. Fissure sealant was applied to the selected quadrants as per manufacturers' instructions, and left to cure for two minutes.

Care was taken not to allow the fissure sealant to run off the facing and pool up at the gingival margin. The rim of fissure sealant at the gingival margin which did not adhere to the enamel, was easily flicked away using a probe to give a smooth finish at the gingival margin. The brackets were then bonded onto the fissure sealed surfaces using Ortho-Concise, making sure that the excess composite was cleared around the bracket. This procedure, whereby the sealant was left to cure before the brackets were bonded, was carried out so as to create an interface between the enamel and composite. Further, the sealant was not blown with compressed air, so that uncured sealant could react with the Ortho-Concise and finally cure.

In the remaining two quadrants, the surface of each respective tooth was acid etched only on that part where the bracket was to be placed. The brackets were then bonded with Ortho Concise following the manufacturers instructions.

Throughout the duration of the treatment, notes were made of any loose brackets and the quadrant affected.

Intra-examiner and inter-examiner variability

Ten patients selected at random were examined by two operators to enable the calculation of intra-examiner and inter-examiner variability.

None of the differences were close to significance.

Experimental Procedure

At the end of treatment, debonding was carried out according to the method described by Artun and Bergland (1984), using a double-bladed debonding instrument (Fig. 2). The Adhesive Remnant Index, (ARI) described by these authors was used to determine the amount of residual composite on the enamel. Any remaining composite was then removed using the debonding instrument. The tooth surface was then dried with a stream of compressed air and a clinical examination carried out to inspect for any visual signs of decalcification (white spots). Because of the subjective nature of this assessment, any white spot formation however minute, was given a plus score. Standard photographs were also taken to compare with pre-treatment photographs and the buccal surfaces were also inspected for any white spot lesions.

MEASUREMENTS

The white spots were observed clinically i.e. they were either present or not. Even the smallest white spot discernible by the operator was given a plus score. This reading was only carried out once the tooth was air dried .

The Adhesive Remnant Index (ARI) first used by Artun and Bergland (1984) was used in this study to evaluate the amount of adhesive left on the tooth after debracketing. The criteria for this index system were as follows:

Score 0 = No adhesive left on the tooth.

Score 1 = Less than half of the adhesive left on the tooth.

Score 2 = More than half the adhesive left on the tooth.

Score 3 = All adhesive left on the tooth, with distinct impression of the bracket mesh.

STATISTICAL ANALYSES

1 The Matched Pairs t-Test was used to determine whether there was a significant difference between the means for the fissure sealed and the non fissure sealed teeth using the ARI index.

2 The Two- Sample t-Test analysis was used to determine whether there was a significant difference between the means for the upper and lower teeth and between individual teeth.

3 The Chi- Square test in strata was used to evaluate differences in the distribution between the fluoride and non fluoride groups in the incidence of white spot formation.

An Odds Ratio was also used to give a description of this relationship.

At the end of the study, 63 patients of the original number of 100 subjects were available for analysis. Of the total number (1096) teeth, half the number (548) were fissure sealed and the other half had no sealant.

The effect of fissure sealant was quite marked and highly statistically significant when comparing the ARI Scores ($p = 0$). The non-fissure sealed surfaces had much more residual composite on the enamel surface. Table I gives the mean ARI values between fissure sealed surfaces and non-fissure sealed surfaces.

	n	$\bar{x}$	SD	SIGNIFICANCE
FISSURE SEALANT	548	.71	.25	$p = 0$
NON SEALANT	548	1.40	.39	

<u>Table I</u>:
Number (n) of debonded surfaces with mean ($\bar{x}$) and standard deviation (SD) of the Adhesive Remnant Index for fissure sealed and non-fissure sealed teeth.

UPPER NON-FISSURE SEALED					
TOOTH NUMBER	1	2	3	4	5
MEAN	2.60	2.20	1.10	.67	.31
STD. DEVIATION	.82	.90	1.00	.87	.08
UPPER FISSURE SEALED					
MEAN	1.80	1.14	.36	.31	.13
STD. DEVIATION	1.03	1.16	.60	.59	.76
LOWER NON-FISSURE SEALED					
MEAN	1.90	1.80	1.17	.70	.48
STD. DEVIATION	1.10	1.00	1.10	.84	.67
LOWER FISSURE SEALED					
MEAN	1.28	.80	.25	.10	.00
STD. DEVIATION	1.00	.94	.53	.31	.00

Table II:

Mean x and standard deviation (SD) of adhesive remnant index (ARI) for each tooth - comparing upper and lower jaws for fissure sealed and non-fissure sealed surface.

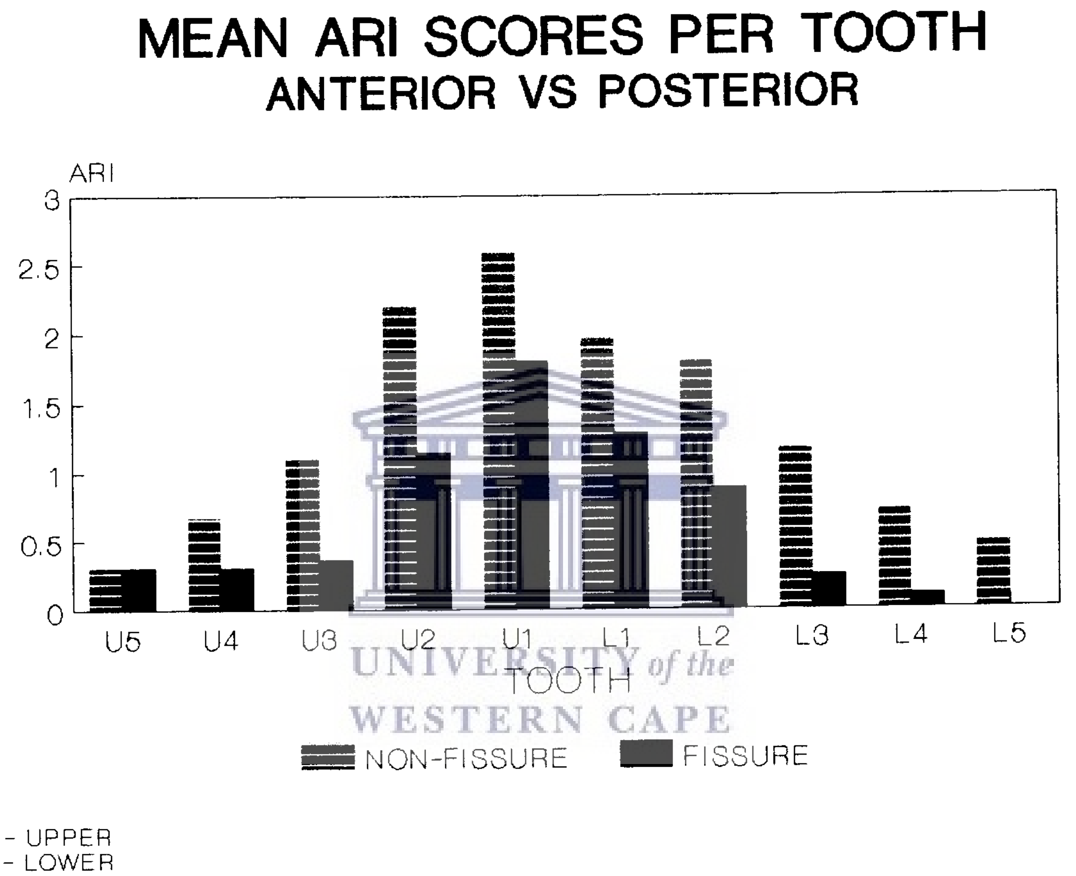

Fig 4. Mean ARI per tooth: -
comparing anterior and posterior teeth

Table II gives the mean and standard deviation of the ARI for each tooth. The data has been pooled so that tooth number 1 in the table represents all central incisors having fissure sealant, or, all having no fissue sealant.

In both maxilla and mandible a pattern was evident in which high ARI values are demonstrated for the incisors, with values progressively decreasing posteriorly along the arch (Fig. 2).

Fig. 3 shows the mean Adhesive Remnant Index (ARI) values for each Maxillary (fissure sealed and non-fissure sealed) and mandibular (sealed and non-fissure sealed) tooth.

Fig. 4 shows the mean ARI values for each tooth. There is a clearly demonstrated trend in both the maxilla and the mandible for more composite to remain on the anterior teeth. It also demonstrates the tendency for posterior teeth to have a composite/enamel break. The mean ARI scores for the posterior teeth ie. the premolars, were below one.

	n	$\bar{x}$	SD	t-test
UPPER SEALANT	63	.84	.37	p = 0
LOWER SEALANT	63	.57	.38	
UPPER NON SEALANT	63	1.52	.47	p = .02
LOWER NON SEALANT	63	1.33	.49	

Table III:

Number (n), mean ($\bar{x}$) and SD of ARI and p-value from upper and lower fissure sealed and non-fissure sealed quadrants.

Table III shows mean and standard deviation of ARI scores for upper and lower fissure sealed quadrants and upper and lower non-fissure sealed quadrants. There was a statistically significant difference between the upper and lower jaws both for the fissure sealed ($p = 0$) and non-fissure sealed surfaces ($p = 0.02$).

	FISSURE SEALANT	NON FISSURE SEALANT	TOTAL
WHITE SPOTS	0	8	8
NO WHITE SPOTS	295	287	582
TOTAL	295	295	590

Table IV

Number of fissure sealed and non- fissure sealed surfaces with white spot formation in the fluoride rinse group.

The above table looks at the comparison of white spots between the fissure sealed and non fissure sealed surfaces in the fluoride rinse group. No white spots were present in the fissure sealed group and only eight surfaces in the fissure sealed group showed demineralization. The difference was statistically significant (chi- square, p = 0.01).

	FISSURE SEALANT	NON FISSURE SEALANT	TOTAL
WHITE SPOTS	26	52	78
NO WHITE SPOTS	227	201	428
TOTAL	253	253	506

Table V:

Number of fissure sealed and non-fissure sealed surfaces with demineralization or white spot formation in the non-fluoride rinse group.

The table shows a comparison of white spot formation between fissure sealed and non- fissure sealed surfaces in the non- fluoride rinse group. As seen from the table twice as many teeth in the non- fissure sealed group had white spots. The difference was statistically significant (chi- square, p = .001)

	FLUORIDE	NON FLUORIDE	TOTAL
WHITE SPOTS	8	78	86
NO WHITE SPOTS	582	428	1010
TOTAL	590	506	1096

Table VI:

Number of teeth with white spots in the fluoride rinse and non-fluoride rinse group ignoring the fissure sealant.

Table VI gives the comparison between the fluoride rinse and non-fluoride rinse group. There were only 8 teeth in the fluoride rinse group showing white spot formation, whereas in the group which did not rinse with fluoride, there were 78 teeth affected in the sample. The difference was statistically significant (chi- square, p =0).

The Odds Ratio (OR) was also carried out which gives a description of the relationship between white spots in the fluoride rinse group and the non- fluoride group (OR = .075). This describes the chance of having white spots in the fluoride rinse group relative to the chance of having white spots in the non-fluoride group.

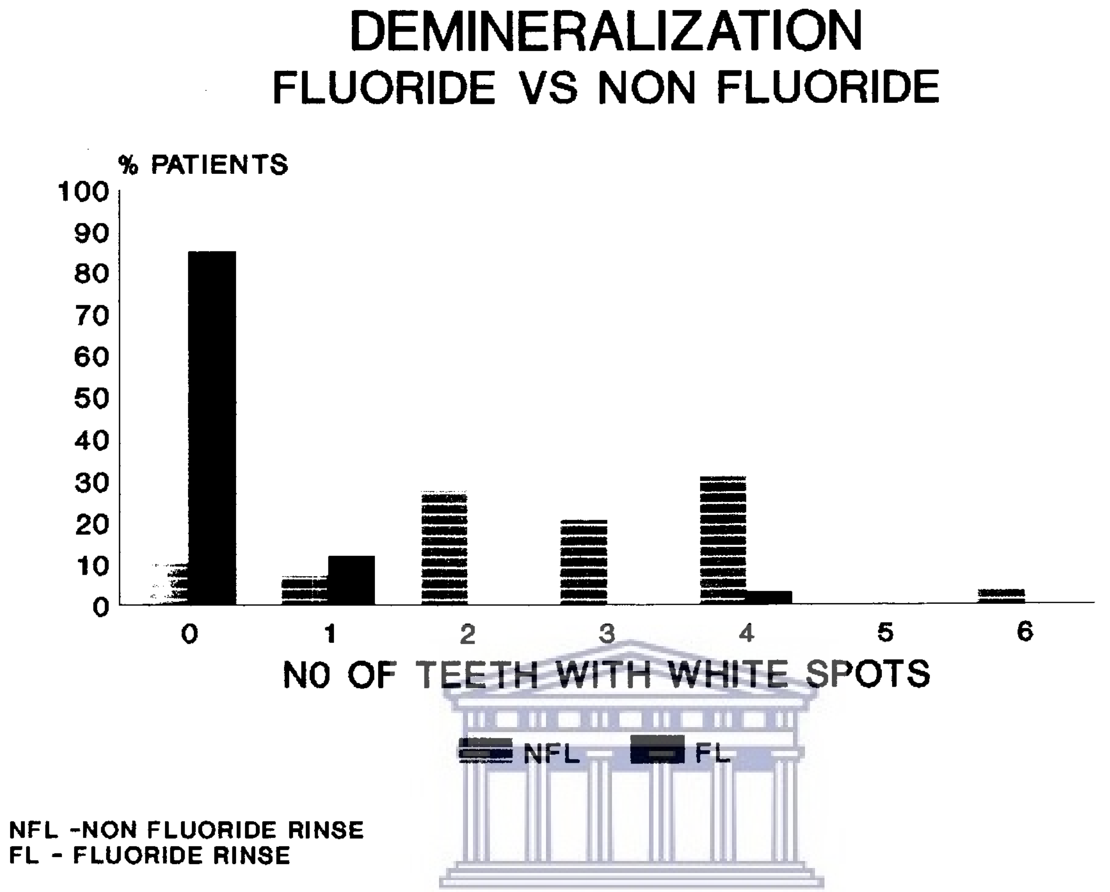

Fig 5 Fluoride and Non-Fluoride Rinse groups exhibiting white spot per tooth.

The above histogram illustrates the percentage of patients exhibiting white spot formation in the fluoride and non-fluoride groups.

It can be clearly seen that majority of the patients in the fluoride rinse group had no white spot formation while about 12% had a single white spot. Only one patient in the fluoride rinse group had four white spots in his mouth.

DISCUSSION

When using direct bonded techniques the orthodontist would like the attachments to withstand masticatory and other forces applied during the period of orthodontic treatment and on completion thereof to have an easy debonding and clean up procedure. The latter is especially important so as to avoid iatrogenic damage such as cracks, crazing, scratches, and loss of enamel that could occur during the debonding stage.

The use of fissure sealant in the present study was two fold namely, to see if the fissure sealant would afford protection around the orthodontic brackets and prevent the formation of white spot lesions and secondly to determine whether the fissure sealant would have an effect on the debonding process thereby giving a cleaner surface.

Knoll et al (1986), have shown that the weak link in the bonding chain on nonfissure sealed teeth was at the resin/bracket interface. At the time of debonding, therefore, the residual resin presents the orthodontist with the time consuming task of removal. In this study the amount of residual adhesive in the non-fissure sealant group was significantly higher than in the fissure sealant group (Table 1). This is in keeping with earlier in vitro studies showing that the fracture site between metal brackets bonded with a composite was mostly in the bracket/resin interface. (Reynolds, 1975;

Reynolds and van Fraunhofer, 1976; Gorelik, 1977; Zachrisson, 1977; Faust et al, 1978; Dickinson and Powers, 1980). This finding might be attributed to the true cohesive bond strengths of the composite being masked by the deformation of the bracket at the time of debonding (Joseph and Roussouw, 1990 a and b). This fracturing at the resin/bracket interface, therefore necessitated tedious resin removal (Gwinnett, 1988).

In a study carried out by Bryant et al (1987), the bonded test specimens failed at the bracket gauze base/resin interface or partly within the bonding resin. In no instance did failure, partial or complete, occur at the bonding resin/enamel interface. This was of clinical importance because if failure occurred partly or wholly at the resin/etched enamel surface, fracture within the enamel is a possibility (Bryant et al, 1987). It would seem therefore that the resin/bracket base interface was the weak link in the bonding system, which clearly was the more acceptable site of fracture given the problems of enamel fracture or enamel tears.

Other researchers have suggested that this fracture site was influenced by the type of adhesive material used and also the type of bracket base (O'Brien et al, 1988). They suggested that the stress concentration at the points of wire overlap that protruded from the retentive area resulted in an uneven thickness of adhesive which supposedly caused the failure at the base/adhesive interface.

Other studies have also indicated that the debonding method used had an influence on the amount of adhesive remaining on the tooth surface and also on the failure site observed (Gwinnett and Gorelick, 1977; Artun and Bergland, 1984; Bennett et al, 1984). Gwinnett and Gorelick (1977) used a shear force applied with the blades of the debonding pliers positioned at the enamel/composite interface. More often this technique produced a cohesive break with some composite remaining on the bracket and some remaining on the tooth. Artun and Bergland (1984) used a peeling effect by squeezing the mesial and distal wings of an edgewise twin bracket. They suggested that this afforded better control, while offering an easier method of debonding. Bennett et al, (1984) found the squeeze and peel method left considerable composite remaining on the enamel, whereas the debonding pliers placed at the enamel/composite interface and using a shear force removed most of the composite from the enamel.

Special instruments have been designed to remove the bracket off the tooth, by applying a shear force to the bracket. The method and instrument used in the present study was advocated by Gorelick (1977) namely

Fig 6.   Debonding instrument and method used in debonding.

by catching the mesial and distal ends of the bracket base with a double-claw bracket remover and pulling away from the tooth applying a shear force. This has been shown to provide a cohesive break, with some composite remaining on the tooth and some on the bracket (Fig 6).

In the present study no clinical signs of enamel tear or fracture was seen either in the fissure sealed or non-fissure sealed group. However, it does not preclude the fact that microscopic tears could be seen if the teeth were viewed under the microscope. If these tears are microscopic, then one can expect these surfaces to be polished smooth when the final polishing is carried out. Studies have shown that polishing removes approximately 10.7 microns of surface enamel (Fitzpatrick and Way, 1977; Pus and Way, 1980). Also, remineralization of these areas can take place with the use of fluoride supplements (Joseph and Rossouw 1990 a and b).

It is pertinent to note that in this study the fissure sealed group exhibited low ARI scores (Table 2), giving us an enamel/resin interface fracture and cleaner enamel surfaces. It could be postulated that during debonding there was a shift of the fracture site from the predominantly resin/bracket, to the resin/enamel, interface, because of the introduction of a layer of unfilled or microfilled resin between the tooth and the macrofilled Concise (Joseph and Roussouw, 1990 b). The predeliction for this fracture site was created by curing the sealant first and thereby providing an interface between the filled particles of Concise and the enamel. The brittle nature of the microfilled fissure sealant resin allowed the plane of fracture to occur through the microfilled sealant or close to it (resin/enamel fracture site) rather than the usual resin/bracket fracture site (Joseph and Roussouw, 1990 b).

The use of the fissure sealant did not, however, in any way result in a decrease of the cohesive bond strength of the adhesive material utilized in this study. The number of brackets that came loose in the fissure sealed group was no greater than that which was dislodged in the non fissure sealed group. This was in agreement with earlier in vitro studies (Lopez, 1980; Joseph, 1987). It could be argued that slippage along the resin - sealant interface or microfractures in the sealant itself may even allow the shear strength to increase over the threshold of the control group (Joseph and Roussouw, 1990 b).

Occasionally, at debonding the entire bracket will come off with all the adhesive attached ie. giving an enamel/resin fracture. This happened more frequently on premolars and canines, and rarely on central and lateral incisors. Also clinically a higher incidence of bracket failure has been observed on posterior teeth than on anterior teeth (Zachrisson, 1977; Gwinnett and Gorelick, 1977; Knoll et al, 1986).

In this study the anterior teeth, ie. the centrals and laterals, had higher ARI scores than the canines and premolars. This could be attributed to the premolars not being fully erupted at the time of bonding. The ensuing contamination which occurred when the brackets were seated against the gingival margin could have resulted in porosities which weakened the bond strength. This is in agreement with studies by Gwinnett and Gorelick (1977), who suggested that the shortness of the clinical crowns in premolars and difficulties of access in the posterior region allowed moisture contamination during bonding.

Also, the curved surface of the canines and premolars might have contributed to a non-uniformity in thickness under the bracket base, thereby resulting in irregular amounts of adhesive between bracket base and enamel. A significant variable on the posterior teeth was the non-uniformity of resin thickness beneath the brackets due to the presence of buccal grooves. It is well known that thick adhesive joints weaken bond strengths. Evans and Powers (1985), stated that as cement thickness is increased, there could be a greater amount of expansion, polymerization shrinkage, trapped volatile substances and imperfections resulting in a decreased bond strength. This might also account for some of the bond failures that were observed for posterior teeth at small force applications. Buonocore (1955) and Retief (1974) indicated that a thicker adhesive interface produced more imperfections, greater polymerization shrinkage and subsequently may deform and fracture more readily.

Knoll et al (1986) found a mean debonding force of 164,3 kg/cmm and 115.7 kg/cm for anterior and posterior brackets respectively. This further highlights the discrepancy between anterior and posterior teeth. Another postulate for this variation might be differences in enamel micro-morphology; for example different etching patterns have been reported for posterior teeth (Gailil and Wright, 1979; Arakawa et al, 1979).

In this study, it was clinically evident that lesser force was necessary when debonding posterior brackets, and patients showed no signs of pain or distress at debonding. However, more force was required to debond the anterior brackets and more residual adhesive remained on the enamel (Fig. 7). This could have resulted because of the flat "bases" of the anterior brackets. When these brackets were placed at bonding, a more uniform thickness of resin/composite resulted and more of the excess material was squeezed out, thereby expelling all air bubbles. It was likely that no porosities developed in the composite. Therefore the bond strength clinically was much higher on the anterior teeth, which was in keeping with earlier in vitro studies (Knoll, Gwinnett, and Wolff 1986; Oliver 1988).

Fissure Sealant and protection against demineralization

It has been postulated from in vitro studies that the use of sealants on the buccal surfaces of teeth, prior to the application of the orthodontic resin and bracket, might be of clinical benefit to the patient in preventing decalcification around the bracket base (Joseph and Roussouw, 1990).

For maximum effect in preventing demineralization, it would be preferable that the sealant was applied to the entire labial surface. It has been shown that the surface of the unfilled fissure sealant would wear away in a short period of time (weeks to months) leaving the enamel surface "sealed" by only resin tags. Studies by Gwinnett and Matsui (1967), Buonocore, Matsui and Gwinnett (1968), and Sharp and Grenoble (1973, cited by

Fig 7. Difference in quantities of residual adhesive on posterior (premolar and canine) and anterior (central and lateral) teeth.

Lee et al, 1973) have shown that these tag-like extensions extend into the enamel surface, even long after the topical layer, thereby giving protection for a longer period.

In this study the fissure sealant was found to confer a significant protection against decalcification (Table IV) which corroborated the work of earlier investigators (Gorelick, 1979; Silverstone, 1974; Zachrisson, 1978).

Fredrik et al (1980), have shown a deterioration of the gingival status after 3 months in orthodontically treated children. O'Reilly and Featherstone (1987), have shown that a measurable, yet clinically undetected amount of demineralization had occurred around orthodontic appliances after only one month. It is interesting to note that the increase in the amount of plaque and the concomitant gingival deterioration assessed during the early phase of active treatment, were presumably the result of impaired access to the tooth surfaces with the tooth brush, rather than the unwillingness of the children to clean the teeth properly (Fredrik et al, 1980). Several studies have shown that orthodontic appliances apart from encouraging an increase in the volume of dental plaque, also physically alter the microbial environment so that proliferation of the facultative bacterial population is increased (Dikeman, 1962; Bloom and Brown, 1964; Sakamaki and Bahn , 1968; Corbett et al, 1981; Featherstone and O'Reilly, 1987). Scanning electron microscopic studies have demonstrated that such bacterial accumulation around orthodontic bands led to a marked, localized etching of the tooth under the plaque, at the junction of the tooth and bracket after only one week (Ogaard et al, 1983; Holman et al, 1987).

Therefore if protection to the enamel surface can be enhanced in these first three months by applying a fissure sealant to the enamel surface, the benefits to the patients would be significant. In this study, the incidence of white spot formation in the fissure sealed group was very low (Tables IV and V), which would lend support to its usage. The teeth that were mainly involved were the canines and premolars. Significantly more teeth in the non fissure sealed group exhibited white spot formation (Tables IV and V). However, clinically, the white spot was no more than a crescent shaped arc on the gingival aspect of the tooth (Fig 8). It is noteworthy that the brackets on these teeth carried ball-ended hooks and other auxiliaries, which impeded cleaning.

The above finding was in agreement with other studies (Zachrisson and Zachrisson, 1971; Gorelick et al, 1982; Ogaard, 1989) which found the same trend affecting posterior teeth, while anteriorly the lateral incisors were more commonly affected than the central incisors. Ogaard (1989) found that orthodontically treated persons had significantly more teeth with white spot lesions than untreated persons.

Most of the lesions (white spots) were detected along the cervical/or gingival margin of the bracket. The more likely reason for this observation was the reduced surface area between the bracket edge and the gingival margin. Plaque retention was thus increased and plaque removal rendered more difficult to accomplish. Also in the present study, most of the teeth with white spots had brackets with ball ended hooks which extended gingivally and acted as plaque retentive areas (Fig. 9) These hooks also had added attachments and auxiliaries such as powerchain, E-elastics and lig-o-ring ties (Fig. 10).

From the above it is therefore evident that simple and neat mechanics should be utilized which may reduce plaque accumulation and facilitate plaque removal. This is necessary for the maintenance of a high standard of oral hygiene during orthodontic therapy.

The use of a chemically cured fissure sealant has been shown by Zachrisson et al (1979) to give inadequate protection when used in thin sections because of

Fig 8. White spot formation on the gingival aspect of the lower canine.

Fig. 10 The placement of auxiliaries, such as the elastic seen here, impedes oral hygiene procedures and leads to plaque accumulation.

non-polymerization of the sealant due to oxygen inhibition, the latter being a strong inhibitor of free radical polymerization. The inhibiting effect was based presumably on the formation of a copolymer of monomers and oxygen (Zachrisson et al, 1979). It could be expected that certain parts of this poorly polymerized surface would wear away, leaving an enamel surface "sealed" only by resin tags. However, it has also been shown from vitro studies, that this "tagged" enamel was more acid resistant than the normal enamel (Silverstone, 1977).

In the present study, there was a significant difference between the fissure sealed group and the non fissure sealed group (Tables IV and V). However, as stated above there were still demineralization areas seen on teeth that were coated with fissure sealant when no Fluoride mouthwash was used. It was found that the areas that were affected were highly plaque retentive and although the patient's oral hygiene was good, plaque was still present in these regions. It was possible therefore, that the fissure sealant did not give enough protection in these areas, as the pH was presumably very low for long periods, leading to demineralization.

Further, decalcification might also have been attributed to poor oral hygiene management by the patient. Whilst patients in this study had their oral hygiene carefully monitored, nevertheless, in a few patients, oral hygiene was still unsatisfactory. This, coupled with the plaque retentive areas (brackets with ball ended hooks) contributed to the demineralization seen on the canines and premolars (Fig. 11). Geiger et al (1988) reported that poor compliance by the patients to follow preventative protocol resulted in significantly greater incidence of white spots. A further reason could be the lack of polymerization at the gingival zone of fissure sealant, due to contamination from saliva or gingival crevicular fluid along the gingival margin.

This study has shown that the patients who rinsed with a fluoride mouthwash (ListerFluor) displayed no demineralization, although some of them presented with plaque or an unsatisfactory oral hygiene routine (Fig. 5). There was a significant difference (p=0) in the incidence of demineralization between the group that rinsed with ListerFluor and the group that did not rinse. Other studies have also shown that patients on a strict regime of fluoride rinsing, showed less white spot formation during orthodontic treatment (Shannon et al, 1977; Hirshfield, 1978; Magness et al, 1979; Shannon, 1981; Geiger et al, 1988). Geiger et al,

Fig. 11 Typical demineralization or white spot formation on the gingival aspect of the canine "ball ended" bracket in a patient who did not use a fluoride mouthrinse.

or inhibiting demineralization during caries attack. Calcium fluoride formation during topical treatment appeared therefore to be a major aspect of the cariostatic mechanism of fluoride. The study by Ogaard et al (1988 a and b), has shown that daily mouth rinsing with a neutral 0.2% NaF solution retarded lesion development significantly. The fluoride applied as a mouthrinse had a marked cariostatic effect even on the poorly accessible locations. The present study agreed with the above and demonstrated no demineralization areas present in those patients who used fluoride mouthrinse daily (ListerFluor -.02% Sodium Fluoride) and who had also had a prior application of fissure sealant (Fig. 5) Tables IV, V and VI .

The mechanisms of caries protection or demineralization prevention in susceptible areas (ball ended hooks on the canine and premolars) was explained by the fact that the solubility product of calcium fluoride in the plaque in this area was exceeded. This then gave a delayed interaction with enamel by subsequent release of fluoride from the calcium fluoride deposited in plaque. The released fluoride influenced the demineralizing and remineralizing processes of the enamel surface, resulting in a more resistant enamel underneath these ball ended hooks on the canines and premolars, and therefore no visible white spots were observed.

CONCLUSION

1. The presence of the fissure sealant appears to change the fracture site when debonding is performed. As a result little or no residual composite remains on the tooth surface.

2. Placement of the fissure sealant afforded significant protection to the enamel by reducing the incidence of white spot formation compared to the areas not covered by fissure sealant.

3. The use of a .02% NaF mouthrinse in this study offered significant reduction of demineralization, with no white spot formation occurring in those patients who had also received the fissure sealant treatment.

4. The presence of the fissure sealant did not appear to reduce the clinical bond strength of the composite.

APPENDICES

APPENDIX 1

Statistics

The following statistics were used in this study:

1. Two Sample T-Test

For the t-test comparison of two sample means the following formula was used:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\left(\frac{1}{n_1} + \frac{1}{n_2}\right) \times \frac{(n_1 - 1) S_1^2 + (n_2 - 1) S_2^2}{n_1 + n_2 - 2}}}$$

$\bar{x}$ = mean of sample one

$\bar{x}$ = mean of sample two

n_1 = number of sample one

n_2 = number of sampel two

S_1 = Standard deviation of sample one

S_2 = Standard deviation of sample two

(2) Chi-square Test in Strata to test the significance of the differences in the incidence of white spot formation between the fluoride rinse group and the non-fluoride rinse group.

$$X^2 = \frac{ad - bc\ (a + b + c + d)}{(a + b)\ (c + d)\ (a + c)\ (b + d)}$$

where a, b, c, d, are the frequencies ie. the number of teeth.

(3) ODDS RATIO (OR)

Gives a description of the relationship of white spots to fluoride rinse. It gives the chance of having white spots in fluoride group relative to the chance in the non-fluoride group.

$$\text{ODDS RATIO (OR)} = \frac{ad}{bc}$$

APPENDIX 2

ARI Scores per tooth / per patient.

Key:

NF	=	Non-fissure sealant
FS	=	Fissure sealant
U	=	Upper
L	=	Lower

NO	NFSU1	NFSU2	NFSU3	NFSU4	NFSU5	FSU1	FSU2	FSU3	FSU4	FSU5	NFSL1	NFSL2	NFSL3	NFSL4	NFSL5	FSL1	FSL2	FSL3	FSL4	FSL5
1	3	2	2	1		2	2	0	0		3	3	2	1		3	0	0	0	
2	3	1	0		0	1	3	0		0	3	0	3		0	3	2	0		0
3	3	2	0	0	0	3	3	0	0	0	0	0	0	0	2	0	0	0	0	0
4	3	0	2	2	1	1	2	1	1	0	2	2	1	1	1	1	3	1	1	0
5	3	1	2		0	2	0	3	2		2	1	0	1		0	0	0	0	
6	3	3	0	1	0	1	1	1	1	0	0	3	0	0	0	1	0	0	0	0
7	3	3	3		0	2	3	0		2	0	3	2		2	0	0	0		0
8	3	3	0	0		3	0	0	0		0	0	1	1		1	0	0	0	
9	3	3	1		0	3	2	0		0	3	2	0		0	0	2	0		0
10	3	2	1	0		1	2	0	0		3	3	0	0		3	1	0	0	
11	2	0	1	3	0	3	0	0	0	0	3		3	1	2	0		0	0	0
12	3	2	0		0	1	0	0		0	3	3	1		0	2	1	0		0
13	3	2	1	0	0	3	2	0	0	0	3	3	2	2	0	3	2	0	0	0
14	3	3	2	0	0	0	0	1	2	0	3	1	0	0	0	1	0	3	0	0
15	3	3	2		0	1	0	1		0	2	1	0		0	1	1	0		0
16	3	3	2	0	0	3	1	0	0	0	3	3	3	0	0	2	2	0	0	0
17	3	3	3	0	0	3	2	0	0	0	3	1	1	0	0	0	0	1	0	0
18	3	3	0		0	0	2	0		0	1	2	0		0	0	2	0		0
19	3	3	2		0	3	0	0		0	1	2	2	0		1	0	0	0	
20	1	2	0	0		1	2	0	0		3	1	0		0	2	1	0		0
21	3	3	1		0	2	2	0		0	3	3	1	1	0	2	0	0	1	0
22	3	3	2		1	1	0	0		0	3	3	0		1	3	1	0		0
23	3	0	0		0	2	0	0		0	2	1	2		0	1	0	0		0
24	3	3	3	0	0	2	0	1	0	0	3	3	0	1	0	3	2	0	0	0
25	3	3	1	0	1	3	3	0	0	0	3	3	0	0	1	2	1	0	0	0
26	2	2	1		0	3	0	0		0	2	1	0		0	1	0	0		0
27	3	3	1	1	0	3	3	0	0	0	3	2	2	1	0	2	3	0	0	0
28	3	3	1	0	0	3	1	1	0	0	1	2	0	2	1	1	0	1	0	0
29	3	3	3	0		2	3	0	0		2	3	0		1	1	2	0		0
30	3	1	1	1	0	3	1	0	0	0	2	2	1	0	0	2	0	0	0	0
31	3	2	0		0	2	1	0		0	3	2	0		1	2	1	0		0
32	3	3	2		0	2	0	0		0	1	3	3		0	2	2	0		0
33	2	2	0	1	0	2	0	0	0	0	2	2	0	1	0	0	0	0	0	0
34	2	2	2		1	3	0	0		0	3	3	3		0	2	1	0		0
35	2	3	0	0	0	0	0	1	0	1	3	1	0	0	1	0	1	1	0	0
36	0	2	0	1		1	0	0	1		0	1	1	1		1	0	0	0	
37	3	2	0		1	1	2	0		0	2	0	3		0	3	1	1		0
38	3	3	1		0	2	1	0		0	3	1	3		0	1	2	0		0
39	3	3	0		0	3	1	1		0	1	2	0		2	1	0	1		0
40	3	3	1	0	0	2	2	0	0	0	2	3	2	0	0	1	2	0	1	0
41	3	3	0		0	2	1	1		0	3	3	2		0	3	0	1		0
42	3	2	0		1	2	0	0		0	2	2	1		0	3	0	0		0
43	3	3	2	0		0	1	1	0		3	2	1	0		2	2	0	0	
44	2	3	1		0	1	2	1		0	3	3	0		0	2	0	0		0
45	3	3	3		1	3	3	0		0	3	2	1	0		3	2	0	0	
46	3	2	0		0	2	0	2		0	0	1	1		1	0	0	0		0
47	3	2	1	1	0	0	0	0	1	0	0	1	2	1	1	1	2	0	0	0
48	3	2	1	1	0	0	0	0	1	0	3	1	3	1	1	1	2	0	0	0
49	3	0	1	1	1	1	0	0	0	0	3	2	2	3	0	0	0	0	0	0
50	2	1	3		0	2	0	0		0	0	1	2		2	1	2	0		0
51	3	3	2		2	1	0	1		0	3	3	3		1	0	0	0		0
52	3	3	1		0	3	1	0		0	0	2	2	0		0	2	1	0	
53	3	1	2	1		3	2	1	0		2	2	0		0	2	1	0		0
54	3	1	1	3	0	3	3	1	0	0	1	3	1	0	0	0	0	1	0	0
55	3	0	3		0	0	3	1		0	2	2	1	3		3	2	1	0	
56	3	3	3		3	2	3	0		1	3	2	2	0		0	0	1	0	
57	0	3	1		2	2	0	0		1	0	3	2		1	2	1	0		0
58	0	2	0	1		3	0	0	1		0	0	0	1		0	0	0	0	
59	1	1	2	2	1	2	0	1	0	0	1	0	3	1	0	2	1	0	1	0
60	0	0	0		0	2	0	1		1	3	2	2	0		0	0	1	0	
61	3	3	0		1	3	3	0		0	3	1	1		0	0	0	0		0
62	3	3	0		0	0	2	0		0	1	0	0		1	0	2	0		0
63	3	3	1	0	0	3	1	1	0	0	1	2	0	2	1	1	0	1	0	0

Appendix 3

Mean ARI Scores:

(a) Upper and lower fissure sealed and non-fissure sealed teeth.

(b) Totals for fissure sealed and non-fissure sealed teeth.

NFU	FU	NFL	FL	TNFS	TFS
2	1	2.25	.75	2.13	.88
1	1	1.50	1.25	1.25	1.13
1	1.20	.40	0	.70	.60
1.60	1	1.40	1.20	1.50	1.10
1.50	1.75	1	0	1.25	.88
1.40	.80	.60	.20	1	.50
2.25	1.75	1.75	0	2	.88
1.50	.75	.50	.25	1	.50
1.75	1.25	1.25	.50	1.50	.88
1.50	.75	1.50	1	1.50	.88
1.20	.60	2.25	0	1.67	.33
1.25	.25	1.75	.75	1.50	.50
1.20	1	2	1	1.60	1
1.60	.60	.80	.80	1.20	.70
2	.50	.75	.50	1.38	.50
1.60	.80	1.80	.80	1.70	.80
1.80	1	1	.20	1.40	.60
1.50	.50	.75	.50	1.13	.50
2	.75	1.25	.25	1.63	.50
.75	.75	1	.75	.88	.75
1.75	1	1.60	.60	1.67	.78
2.25	.25	1.75	1	2	.63
.75	.50	1.25	.25	1	.38
1.80	.60	1.40	1	1.60	.80
1.60	1.20	1.40	.60	1.50	.90
1.25	.75	.75	.25	1	.50
1.60	1.20	1.60	1	1.60	1.10
1.40	1	1.20	.40	1.30	.70
2.25	1.25	1.50	.75	1.88	1
1.20	.80	1	.40	1.10	.60
1.25	.75	1.50	.75	1.38	.75
2	.50	1.75	1	1.88	.75
1	.40	1	0	1	.20
1.75	.75	2.25	.75	2	.75
1	.40	1	.40	1	.40
.75	.50	.75	.25	.75	.38
1.50	1	1.25	1.25	1.38	1.14
1.75	.75	1.75	.75	1.75	.75
1.50	1.25	1.25	.50	1.38	.88
1.40	.80	1.40	.80	1.40	.80
1.50	1	2	1	1.75	1
1.50	.50	1.25	.75	1.38	.63
2	.50	1.50	1	1.75	.75
1.50	1	1.50	.67	1.50	.86
2.50	1.50	1.50	1.25	2	1.38
1.25	1	.75	0	1	.50
1.40	.20	1	.60	1.20	.40
1.40	.20	1.80	.60	1.60	.40
1.20	.20	2	0	1.60	.10
1.50	.50	1.25	.75	1.38	.63
2.50	.50	2.50	0	2.50	.25
1.75	1	1	.75	1.38	.88
1.75	1.50	1	.75	1.38	1.13
1.60	1.40	1	.20	1.30	.80
1.50	1	2	1.50	1.75	1.25
3	1.50	1.75	.25	2.38	.88
1.50	.75	1.50	.75	1.50	.75
.75	1	.25	0	.50	.50
1.40	.60	1	.80	1.20	.70
0	1	1.75	.25	.88	.63
1.75	1.50	1.25	0	1.50	.75
1.50	.50	.50	.50	1	.50
1.40	1	1.20	.40	1.30	.70

Key:

NF = Non-fissure sealant
FS = Fissure sealant
TFS = Total fissure sealant
TNFS = Total non-fissure sealant

APPENDIX 4

The incidence of white spot formation in the fluoride mouthrinse and the non-fluoride mouthrinse group.

NUMBER OF WHITE SPOTS

fl	FS	NFS
yes	0	0
no	1	1
no	1	3
no	2	4
no	2	2
yes	0	0
no	0	0
yes	0	0
yes	0	0
yes	0	0
yes	0	0
no	1	2
yes	0	0
yes	0	0
yes	0	0
yes	0	0
no	0	3
yes	0	0
yes	0	0
no	0	2
no	0	2
yes	0	0
yes	0	0
no	2	2
yes	0	0
yes	0	0
no	2	2
no	3	1
no	0	2
yes	0	0
no	2	2
no	1	3
yes	0	0
no	0	1
no	0	1
no	1	2
no	0	2
yes	0	1
no	0	0
yes	0	0
yes	0	0
yes	0	0
yes	0	1
no	1	2
no	0	2
yes	0	0
yes	0	0
no	0	0
no	1	1
yes	0	0
no	1	1
no	0	1
no	1	3
yes	0	0
yes	0	0
no	0	1
yes	0	4
no	3	1
no	0	3
yes	0	0
yes	0	0
yes	0	0
no	3	1

Key:

fl = fluoride
FS = Fissure sealant
NFS = Non-fissure sealant

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