THE EFFECT OF DENTINE-BONDING AGENTS ON THE MICROLEAKAGE OF PROVISIONAL CROWNS

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A Mini-thesis submitted in partial fulfilment of the requirements for the degree of Magister Chirurgiae Dentium (MChD) in the Department of Restorative Dentistry, Faculty of Oral Health Sciences and WHO Oral Health Collaborating Centre, University of the Western Cape.

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KEYWORDS

Provisional crowns

Microleakage

Dentine-bonding agent

Self-etching adhesive

Total-etch systems

Dentinal tubules

Smear layer

ABSTRACT

Introduction: The use of provisional acrylic crowns is common practice with prosthodontic treatment. Provisional crowns are prone to marginal leakage and poor retention due to weak interim cements.

Aim: The aim of the study is to assess the effect of the application of two different dentine-bonding agents on the microleakage of provisional crowns.

Methodology: Thirty recently extracted caries-free wisdom teeth were divided into three groups of ten teeth each. Crown preparations were carried out for thirty full-coverage provisional crowns on caries-free wisdom teeth by means of a stationary handpiece secured in a clamp. Provisional crowns were constructed by means of an indirect laboratory technique. In group A (control group), the crowns were cemented with TempBond NE (Kerr) on unsealed tooth preparations. In group B (test group 1), the tooth preparations were sealed with Prime & Bond NT (DENTSPLY) dentine adhesive and cemented with TempBond NE. In group C (test group 2), the tooth preparations were sealed with Xeno III (DENTSPLY) self-etching dentine adhesive prior to provisional cementation with TempBond NE of the crowns. All specimens were thermocycled in methylene blue for 500 cycles between $5^0$and 55^0 C with a dwell time of 30 seconds. Five bucco-lingual sections of approximately 500 micrometers thickness of each tooth were examined microscopically and the dye penetration along the tooth-crown interface and the amount of dentinal tubule infiltration was scored according to an accepted scale.

The extent of dye penetration was assessed by one observer. Each score was recorded on proforma's provided and subjected to a statistical analysis. Data analysis was performed by a qualified statistician using non-parametric data analysis. A p-value<0.05 was considered to be statistically significant.

Results: Neither Prime & Bond NT nor Xeno III prevented marginal microleakage of the provisional crowns when compared with the unsealed control group. Specimens sealed with Xeno III showed a statistically significant difference (p-value<0.05) with regard to the extent of dentinal tubule infiltration when compared to the unsealed control group.

Conclusion: Prime & Bond NT and Xeno III do not prevent marginal microleakage nor do they prevent dentinal tubule infiltration of provisional crowns.

DECLARATION

I declare that "The Effect of Dentine-Bonding Agents on the Microleakage of Provisional Crowns" is my own work, that it has not been submitted before for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

Name:

Signed:

Date:

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I would like to thank Professor GAVM Geerts for her ongoing support in the execution of this project.

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DEDICATION

This project is dedicated to my family and colleagues who supported me through the course of this degree.

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CHAPTER 1

LITERATURE REVIEW

INTRODUCTION

The provision of a full-coverage artificial crown involves the removal of the overlying enamel and superficial layers of the dentine of the tooth. The need to provide sufficient reduction of tooth structure for an adequate thickness of the restorative material results in the exposure of countless dentinal tubules. Once the enamel is removed, the peripheral seal of the dentine and pulp is effectively removed. Dentine is a porous, innervated tooth substance through which bacterial products and fluids may pass towards the pulp (Goldman, Laosonthorn and White1992).

Prosthodontic practice demands the placement of a provisional crown after tooth preparation. Provisional crowns are usually manufactured from an acrylic or composite resin. Provisional crowns provide an interim seal to protect the prepared dental tissues from the detrimental effects of exposure to the oral environment. Provisional restorations are also used to assess alterations in the tooth shape, anterior guidance, occlusal plane and the aesthetic zone. In addition, they allow for the evaluation of questionable teeth and the performance of periodontal, endodontic, orthodontic and implant treatment (Wassell, St George, Ingledew and Steele 2002).

The penetration of fluids, molecules, bacteria and their products between the margins of a restoration and the prepared enamel and dentine of a tooth is known as microleakage. Microleakage is a well-documented process, which has attracted much research in the dental literature. Ultimately, it is probably the cause of failure of many crowns, bridges and restorations due to the presence of oral bacteria and bacterial products that set up pathological processes beneath the restorations. The definition of microleakage has undergone an inevitable evolution as researchers have increased their understanding of the biochemistry of the different tooth substances - enamel, dentine and pulp - and their interaction with various restorative materials (Kidd 1976; Bergenholtz, Cox, Loesche and Syed 1982; Pashley and Pashley 1991).

MICROLEAKAGE

DEFINITION

Kidd (1976) defined microleakage as the "clinically undetectable passage of bacteria, ions, molecules and fluids between the prepared cavity margins and the applied restorative material". Pashley and Pashley (1991) described microleakage as a phenomenon which presented with two features. These authors stated that firstly, degradation of the marginal seal allowed hydrodynamic fluid movement through patent dentinal tubules which resulted in a hypersensitivity to osmotic and thermal stimuli. And secondly, pathological conditions like caries and pulpal lesions were caused by the infiltration of bacteria and bacterial products through the degraded marginal gap.

MICROLEAKAGE TESTING PROCEDURES

Raskin, D'Hoore, Gonthier, Degrange, and Dejou (2001) reported that the literature contained conflicting results about in vitro microleakage studies. In a review of 144 studies, they reported that tremendous experimental inconsistency prevented meta-analysis of these results and they advised caution in the interpretation of research findings. Other reports have examined microleakage-testing procedures. According to Yap, Ho, and Wong (1998) dye penetration methods are the most popular of the in vitro microleakage tests. Gale, Darvell, and Cheung (1994) stated that microleakage was a three-dimensional phenomenon and that single–section studies underestimated the full extent of the leakage. Gwinnett, Tay, Pang, and Wei (1995) reviewed the three traditional methods of testing for microleakage along restorative interfaces and discussed the merits of each technique in relation to different restorative procedures. They concluded that the clearing protocol was less useful than the multi-surface protocol in detecting microleakage in full-coverage restorations. They also believed that a single longitudinal section along the midline of a restoration underestimated the three-dimensional nature of microleakage.

Baldissara, Comin, Martone, and Scotti (1998) studied the microleakage of four different provisional cements and compared these to zinc-phosphate and cavity base compound. In their study, 30 provisional crowns were constructed using the direct technique on extracted human premolars. These specimens were then thermocycled and dyed after which they were sectioned and analyzed. They reported that microleakage usually occurred at the cement-dentine interface. The authors suggested that the inherent weakness of provisional cements was the likely cause for this site of leakage. Furthermore, they reported that microleakage was greater in provisional cements than with the zinc-phosphate cement tested.

Various studies have reported on the microleakage of class V restorations. Conflicting results are probably due to experimental inconsistency and material properties. The effects of storage time, smear layer, cavity design, and thermocycling procedure all seem to affect the amount of microleakage (Crim and Mattingly 1981; Crim and Garcia-Godoy 1987; Mixson, Eick, Moore and Tira 1992; Chan and Swift 1994).

PROVISIONAL CROWNS

MARGINAL ACCURACY

The marginal accuracy of provisional crowns is due to a combination of factors that include material properties, fabrication techniques and dynamic loading factors. Any marginal gap combined with an inherently weak provisional cement will provide an ideal site for microleakage to occur. However, comparisons between published studies are difficult due to the lack of standardization of testing procedures, the difference between materials tested and the mechanisms of assessing marginal gap size or microleakage. Conflicting results have been reported as to which material or technique showed the best marginal fit (Crispin, Watson, and Caputo 1980; Robinson and Hovijitra 1982; Tjan, Tjan, and Grant 1987; Koumjian and Holmes 1990; Moulding, Loney and Ritsco 1994).

Other studies have examined the effect of water temperature on the fit and strength of provisional crown materials. Ogawa, Aizawa, Matsuya, Hasegawa and Koyano (1999) recommended final polymerization of provisional crowns at 30ºC to accelerate curing. A water temperature above 30°C was found to compromise the fit of these crowns. Ogawa, Tanaka and Koyano (2000) studied the effect of water temperature on the strength of self-curing provisional resins. They found that the flexural strength of the resin tested was increased two-fold when allowed to polymerise in water at 60 to 80 ^{0}C.

Mitchell, Pintado and Douglas (2001) commented that inaccurate margins accumulated plaque near the gingival margins, which caused gingival inflammation.

PROVISIONAL CEMENTATION

The cementation of provisional crowns is usually accomplished with zinc-oxide eugenol cements since they are easily removed from teeth and crowns, have a relatively low cost, and have sedative and antibacterial properties for the pulp. Zinc-oxide eugenol cements have been shown to affect the polymerization of some acrylic and composite resins and may leave residues, which adversely affect the curing of definitive resin-based luting agents. Consequently, the use of non-eugenol provisional cements like TempBond NE (Kerr Italia S.p.A, Salerno, Italy) has been recommended for the provisional cementation of treatment restorations (Rosenstiel and Gegauff 1988).

THERMOCYCLING AND OCCLUSAL LOADING

The effect of thermocycling and occlusal loading on the marginal accuracy of provisional crowns has been examined in many studies. Combined thermocycling and occlusal loading has been recommended as a testing procedure in an attempt to mimic the clinical situation. The effect of these testing procedures on the changes in the axial contours of provisional crowns has also been observed. Material properties such as crazing and glass transition probably account for these observed changes (Blum, Weiner and Berendsen 1991; Hung, Weiner, Dastane and Vaidyanathan 1993; Zwetchkenbaum, Weiner, Dastane and Vaidyanathan 1995; Dubois, Kyriakis, Weiner and Vaidyanathan 1999; Ehrenberg and Weiner 2000).

DENTINE-BONDING AGENTS

Current dentine-bonding agents can be divided into two main groups based on their interaction with the smear layer. Self-etching adhesives do not remove the smear layer and condition the enamel and dentine with a non-rinsing solution of acidic monomers in an aqueous solution. The rationale behind the self-etching systems is that etching, demineralization and penetration of the adhesive into the exposed enamel and dentine is accomplished in a single procedure (Strydom 2004; 2005).

Dentine adhesives which use a 30-40% phosphoric acid to pre-etch the dentine and enamel are known as total-etch adhesive systems. These systems remove the smear layer and open the dentinal tubules prior to the application of the dentine adhesive. Hydrophilic resin monomers of the bonding agent infiltrate the denatured collagen network of the superficial dentine to form a zone of resin tags interspersed with collagen fibrils. This 1.2 - 2.2μm intermediate zone of resin and dentine is known as the hybrid layer. Apart from its crucial role in creating a micromechanical bond of adhesive resin to tooth, the hybrid layer also acts to seal off the dentinal tubules from the oral environment (Pashley, Michelich and Kehl 2003).

SMEAR LAYER

The production of a smear layer during restorative procedures produces a smear plug of organic debris within the dentinal tubule orifice, which acts as a protective diffusion barrier (figure 1). Removal of the smear layer through acidic etching increased the dentine permeability, which could be disadvantageous under certain conditions (Pashley *et al* 2003).

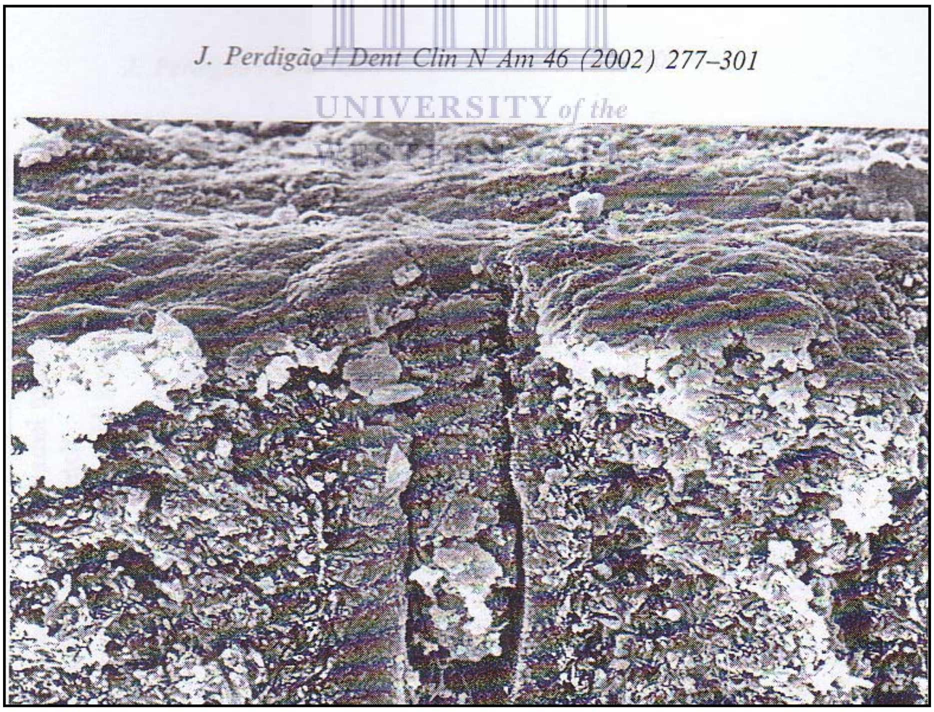


Figure 1: Smear layer formation after dentine preparation. Perdigão J. Dent Clin N Am (2002).

Factors that affected the bond strength of dentine-bonding agents include moisture sensitivity, incompatibility with restorative materials, blood, saliva, and eugenol-based provisional cements. Caries detectors and haemostatic agents were also implicated in the degradation of the bond strengths of many adhesives (Perdigão 2002).

Prime & Bond NT.

Prime & Bond NT (DENTSPLY DeTrey, Konstanz, Germany) is a total-etch dentine-adhesive system. Prime & Bond NT is a dual-cure one-bottle bond with acetone as solvent (Prime & Bond NT Technical Manual 1998; Perdigão, Baratieri and Lopes 1999). According to Perdigão *et al* (1999) Prime & Bond NT is an improvement on Prime & Bond 2.1 (DENTSPLY DeTrey, Konstanz, Germany) because nanofiller particles, a cross-linking agent and a smaller resin molecule have been added. The manufacturers claim that it has increased marginal integrity and is suitable for etched and unetched dentine and enamel amongst other features (Prime & Bond NT Technical Manual 1998). In a comparative study between unsealed provisional crowns and a group sealed with Prime & Bond NT using the total-etch technique no significant differences were found and it was concluded that the dentine-bonding agent used did not seal the dentinal tubules any more than the smear layer (Elgalaid, Youngson, McHugh, Hall, Creanor, Foye 2004).

Xeno III.

Xeno III (DENTSPLY DeTrey, Konstanz, Germany) is a light-cured, self-etching adhesive, with a water/ethanol solvent with exceptionally high bond strengths to enamel and dentine. Xeno III self-etching adhesives do not remove the smear layer and condition the enamel and dentine with a non-rinsing solution of acidic monomers in an aqueous solution. The rationale behind the self-etching systems is that etching, demineralization and penetration of the adhesive into the exposed enamel and dentine is accomplished in a single procedure (Strydom 2004). Gregoire, Guignes and Millas (2005) studied the effect of self-etching adhesives on dentine permeability using a fluid flow experimental technique. In this study, dentine disks were sealed with different self-etching systems and subjected to hydraulic conductance tests. They found that Xeno III produced the greatest reduction in fluid flow across the dentine. They also cautioned that different self-etching adhesives produced varying amounts of reduction in dentine permeability. An extensive review of self-etching adhesives listed (1) a simplified application and (2) reduced postoperative sensitivity among the advantages since smear plugs are not removed as with total-etch systems (Strydom 2004, 2005).

Sorenson, Dixit, White and Avera (1991) conducted an in vitro study to measure the microleakage of dentine-bonding agents and glass-ionomer cements using flat dentine disks. They concluded that the materials tested reduced but did not prevent microleakage from occurring.

DENTINE PERMEABILITY

Pashley, Pashley, Carvalho and Tay (2002) conducted an extensive review of dentine permeability and its implications for restorative dentistry. Among the factors affecting dentine permeability were dentine thickness, natural regional variations in permeability, restoration of the external and internal dentine seal and problems associated with dentine sealing. Richardson, Tao and Pashley (1991) studied the effects of crown preparation on dentine permeability using a pressurized fluid filtration method after removal of the smear layer. The following conclusions were drawn from this study: (1) the dentine permeability was highest on the mesial surface followed by the buccal, distal, occlusal and lingual surfaces; (2) smear layer formation by means of a diamond bur or the use of potassium oxalate were equally effective in decreasing dentinal permeability and (3) that decreasing dentine thickness caused significant increases in dentine permeability.

DENTINE HYPERSENSITIVITY

Numerous authors have reviewed the aetiologies, symptoms and theories of pain production in dentine. The three main theories about dentine hypersensitivity are the odontoblastic–receptor theory, the direct nerve-ending and hydrodynamic theory. The most widely accepted is still the hydrodynamic theory of intratubular fluid movement affecting the pulpal nerves. In this theory, pain is produced by displacement of tubular fluid in the direction of the dentine–enamel junction. Calcifications and tubule sclerosis are natural pulpal defence mechanisms from irritating stimuli (Dowell and Addy 1983; Krauser 1986).

Factors which influence dentine hypersensitivity after crown preparation depend on preparation technique, remaining thickness of dentine, smear layer, microleakage of provisional cement, length of time between preparation and final luting and type of cement used (Nahon, Dentkos, Nelson, Gardner and Rillman 2001).

Although microleakage has enjoyed much support in the literature with regard to the leakage of direct amalgam and composite resin restorations, endodontic posts, inlays, onlays, permanent crowns and veneers, not much literature exists on the effect of sealing of abutment preparations on the leakage of provisional crowns.

CHAPTER 2

MATERIALS AND METHODS

AIMS AND OBJECTIVES

The aim of the study was to evaluate the effect of the sealing of crown preparations by means of two different dentine-bonding agents on the in vitro marginal microleakage and the amount of dentine tubule infiltration of provisional crowns.

The objectives of the study were: -

1. To compare microleakage in a prepared tooth specimen sealed with (a) Prime & Bond NT and (b) with Xeno III and restored with a provisional crown to the control group.
2. To compare the dentine tubule infiltration of the 2 study groups with a control group.

NULL HYPOTHESIS

There is no statistically significant difference between unsealed provisional crowns cemented with TempBond NE and those sealed with Prime & Bond NT or Xeno III and cemented with TempBond NE.

Thirty recently extracted human caries-free wisdom teeth were collected for the study from teeth obtained in the Maxillo-Facial and Oral Surgery Department of the Oral Health Centre of the University of the Western Cape at Tygerberg Hospital.

For the study sample, teeth were included if they were caries-free and restoration-free wisdom teeth. Teeth were excluded if they had caries, fractures, restorations, artificial crowns, endodontic treatment, apicoectomies or surgical damage.

The teeth were collected and stored in a solution of saline and 1% thymol crystals for a period of no longer than 3 months at a temperature of 4ºC prior to use in the experiment. The teeth were cleaned of any remaining soft tissue, residual deposits of plaque and calculus by means of hand scalers and polishing pumice. The roots of the teeth were notched to provide additional retention in the acrylic resin blocks. The teeth were then mounted in self-curing acrylic resin (Excel Special Tray material, Wright Health Group Ltd, Dundee, U.K.) that was contained within commercially available conduit piping cut into 2cm high sections. The teeth were mounted so that the full circumference of the CEJ was visible above the acrylic resin block and that the long axis of the tooth was parallel to the long axis of the conduit piping (figure 2).

Figure 2: Representative test specimen of tooth mounted in acrylic conduit piping.

The test specimens were labelled alphanumerically and were randomly divided into 3 groups of 10 teeth each.

The specimens were mounted onto a surveyor table so that the long axis of the test specimen was parallel to the long axis of a tapered diamond bur (FG 199G018, Horico, Berlin, Germany). Crown preparations were carried out on each tooth by means of a high-speed dental turbine clamped onto an adjustable laboratory clamp. Circumferential shoulder preparations were carried out by manually rotating the specimen against the bur in the stationary handpiece. The preparations were carried out so that the entire circumference of the shoulder preparation was located above the cemento-enamel junction. The depth cut of the shoulder preparation was determined by the width of the bur at its tip. A flat occlusal reduction was carried out by means of a grinding lathe (Metaserv Universal Polisher, Betchworth, Surrey, England) so that the vertical height of the axial wall measured 4mm. A new round-end tapered diamond bur was used for each tooth specimen (figure 3).

Figure 3: Representative mounted specimen prior to tooth preparation.

After crown preparation, elastomeric impressions were made of each preparation using Aquasil Ultra vinyl polysiloxane impression material (DENTSPLY Caulk, Milford, De, USA. figure 4). A single–stage putty-wash technique was used to make the impressions by using a 2cm high section of conduit piping which acted as a special tray. The conduit piping was sealed on one end by means of a wax base (figure 4). The impression material was allowed to set for a period of at least 3 minutes according to the manufacturer's instructions (Jones, Cook and Moon 1996; Nahon *et al* 2001). After setting of the impression material, the impressions were cast with Die Stone (Type IV Lot No. 0407114, Heraeus Kulzer, USA) by a qualified dental technician using commercially available die stone (figure 5).

Figure 4: Polyvinyl siloxane impressions in conduit piping trays.

Provisional crowns were fabricated for each tooth preparation using an indirect method of construction (Moulding *et al* 1994). Following setting of the dies a single layer of heated base plate wax (Base plate wax toughened No.4, Associated Dental Products, Purton Swindon, England) was manually adapted over the dies.

Figure 5: Labelled specimen die prior to flasking.

After waxing-up, the dies were invested in dental flasks using standard investment procedures (figure 6). After a lost-wax technique was employed the moulds were packed with a provisional acrylic resin (Integrity Provisional Crown Material; DENTSPLY Caulk Milford, DE, USA) using standard laboratory procedures according to manufacturer's instructions.

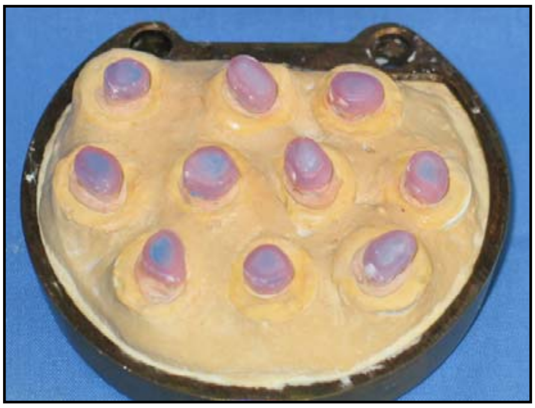


Figure 6: Waxed-up dies at investment.

The invested crowns were allowed to autopolymerize in a dental flask under pressure for 10 minutes using a laboratory clamp. After setting of the resin, the crowns were divested and a reline procedure was carried out on each tooth preparation. Finishing of the provisional crowns was accomplished by gross trimming with acrylic burs, polishing discs of decreasing coarseness and finally polishing with pumice and whiting until a clinically acceptable result was obtained for marginal fit.

In group A (Control group), the provisional crowns were cemented with TempBond NE cement mixed according to manufacturer's recommendations (Paul and Scharer 1997; Lepe *et al* 1999).

Each provisional crown was seated with a 5 kg load applied for a period of 5 minutes/crown by means of a loading device. Crowns were cemented at room temperature and were then cleaned of excess cement by light polishing with pumice. The specimens were then sealed with a clear varnish on all surfaces of the test sample except around the margin of the crown to prevent possible contamination of specimen through the apex of the tooth (figure 7).

In group B (Test group 1), a single layer of dentine-bonding agent (Prime & Bond NT) was applied to each tooth preparation according to manufacturer's recommendations for crown preparations and cured for 10 seconds. Each provisional crown was cemented according to the procedure described.

In group C (Test group 2), a self-etching adhesive (Xeno III) was applied for 20 seconds to each preparation. After application of the adhesive, a light air pressure was used for at least 2 seconds to spread the adhesive. The adhesive was then cured for 10 seconds according to the manufacturer's instructions after which the provisional crowns were cemented as above.

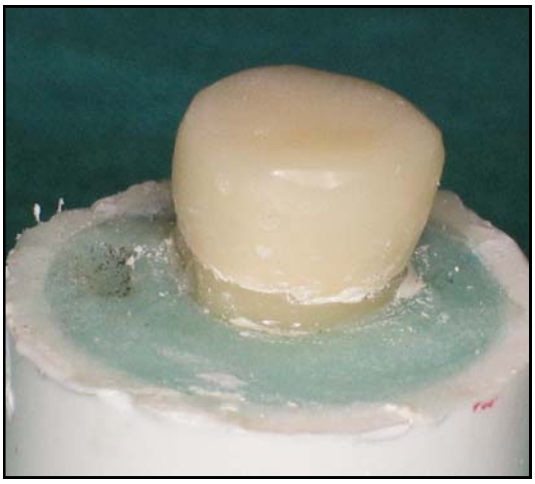
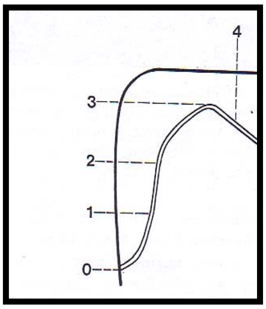


Figure 7: Test specimen sealed with clear waterproof varnish and cemented provisional crown.

Curing of the dentine-bonding agents was in accordance with the manufacturer's instruction using a dental curing light (Optilux 400-model no: VCL401 Demetron Research Corporation, Danbury, CT, USA).

Thermocycling of the specimens was carried out in 1% basic methylene blue, pH 7.2 for 500 cycles between 5^0C and 55^0C with a dwell time of 30 seconds (Crim and Mattingly 1981). Specimens were rinsed with water and lightly pumiced to remove any superficial dye. After thermocycling each test specimen was embedded into a clear acrylic resin matrix block prior to sectioning with a microtome (Struers minitom, Struers, Copenhagen, Denmark). Five sections of 500 micrometers thickness were made bucco-lingually with a blade thickness of 350 micrometers (Gwinnett *et al* 1995). All sections from a particular tooth were mounted under a glass slide and observed by one observer under a microscope (Wild Heerbrugg WildM2OEB) at 100 X magnification. The extent of dye penetration along the restoration-cement interface was measured on the buccal and lingual or palatal surfaces according to the scale below. The extent of dentinal tubule infiltration was measured according to the scale below.

Marginal leakage scale used (adapted from Tjan *et al* 1992).



0 – No microleakage.

1 – Microleakage to one third of axial wall.

2 - Microleakage to two thirds of axial wall.

3 - Microleakage along full length of axial wall.

4 - Microleakage over occlusal surface.

Dentinal tubule penetration scale used:

The amount of dye infiltration into dentine tubules of each section was evaluated on a visual scale. The extent of dye penetration was scored according to the following scale.

0 - No tubule infiltration.

1 - 1-33% tubule infiltration.

2 - 33-67% infiltration.

3 - More than 67% infiltration.

RECORDING AND ANALYSIS OF DATA

Each score was recorded on proforma's (addendum 1) and subjected to statistical analysis. Due to the ordinal nature of the data, it is presented as proportions and frequencies. Data capture was performed on an Excel Spreadsheet. Data analysis was performed by a qualified statistician using non-parametric data analysis techniques. Appropriate statistical tests were used in accordance with sample size and data set characteristics in order to generate the most appropriate results. P-values less than 0.05 (p-value<0.05) were considered to be statistically significant. The statistical software programme used was SPSS Version 13.

The results are discussed in the context of available literature pertaining to this subject.

CHAPTER 3

RESULTS

Due to small sample sizes certain data groups were “collapsed” so that Fisher’s exact test could be conducted to determine any statistical significance. This statistical test is more appropriate than the Pearson-chi test when sample numbers are small or values tend to zero.

A p-value of less than 0.05 ($p<0.05$) was considered to be statistically significant. All results are rounded to the nearest whole number.

MARGINAL MICROLEAKAGE MEASURED ON THE BUCCAL SURFACES

	Group 1	Group 2	Group 3	Total
	Unsealed Control Group	Prime & Bond NT Group	Xeno III Group	
Axial	n=o **0%**	n=5 **10.0%**	n=15 **30.0%**	n=20 13.3%
Occlusal	n=50 **100.0%**	n=45 **90.0%**	n=35 **70.0%**	n=130 86.7
Total	n=50 100%	n=50 100%	n=50 100%	n=150 100%

Table 1: Collective comparison of buccal surface of all groups.

* Group 1 vs. 2 - Fisher's exact test. p-value = 0.056. (Addendum 4)

*Group 1 vs. 3 - Fisher's exact test. p-value < 0.0001. (Addendum 5)

In the unsealed control group, 100% of specimens showed maximum microleakage along the buccal walls of the specimens while 90% of Prime & Bond NT specimens (test group 2) and 70% of Xeno III specimens (test group 3) showed microleakage to the same extent. When the extent of microleakage along the walls of all the test specimens is reported then 87% of buccal walls had microleakage onto the occlusal surface (score 4: figure 10). No statistically significant difference was found between the extent of microleakage along the buccal walls between the control group and the Prime & Bond NT group (p-value = 0.056). A highly significant difference was found between the control group and the Xeno III group with regard to microleakage along the buccal wall (p-value<0.0001). Figures 8, 9, 10 represent marginal microleakage of scores 1, 3 and 4 respectively. Addendum 3 shows the uncollapsed statistical data of the buccal group.

MARGINAL MICROLEAKAGE MEASURED ON THE LINGUAL SURFACES

	Group 1	Group 2	Group 3	Total
	Unsealed Control Group	Prime & Bond NT Group	Xeno III Group	
Axial	n=2 **4.0%**	n=6 **12.0%**	n=16 **32.0%**	n=24 16.0%
Occlusal	n=48 **96.0%**	n=44 **88.0%**	n=34 **68.0%**	n=126 84.0%
Total	n=50 100.0%	n=50 100.0%	n=50 100.0%	n=150 100.0%

Table 2: Collective comparison of all lingual surfaces.

*Group 1 vs. 2 - Fisher's exact test. p-value = 0.269. (Addendum 7)

*Group 1 vs. 3 -Fisher's exact test. p-value < 0.0001. (Addendum 8)

In the unsealed control group, 96% of unsealed specimens leaked maximally onto the occlusal surface (score 4: figure 10) while 88% of Prime & Bond NT and 68% of Xeno III specimens leaked onto the occlusal surface of preparations. Collectively, 84% of lingual surfaces had leakage onto the occlusal surface (score 4: figure 10). No statistically significant difference was found between the control group and the Prime & Bond NT group with regard to microleakage along the lingual walls (p-value = 0.269). A highly significant difference was found between the unsealed control group and the Xeno III group (p-value < 0.0001). Addendum 6 shows the uncollapsed statistical data of the lingual group.

PHOTOGRAPHIC REPRESENTATION OF MARGINAL MICROLEAKAGE OF TEST SPECIMENS

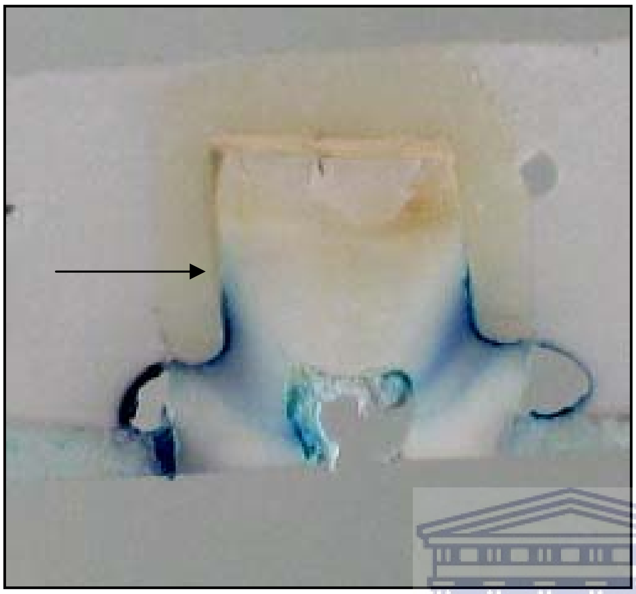


Figure 8: Section showing microleakage along one-third of dentine-cement interface. Score 1.

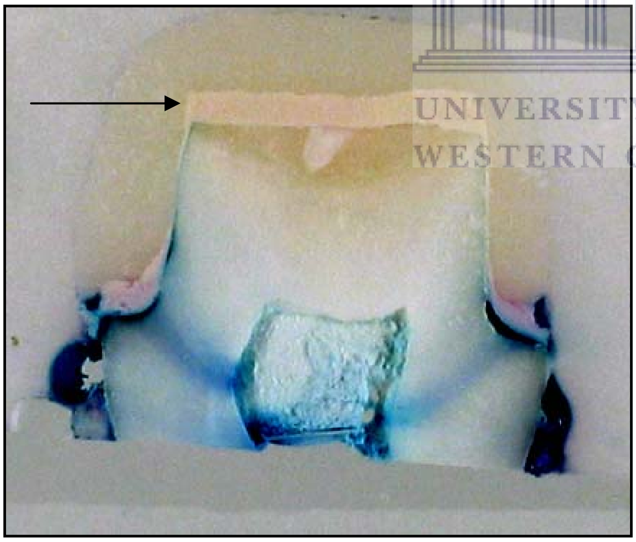


Figure 9: Section showing microleakage of dye along dentine-cement interface along full length of axial wall. Score 3.

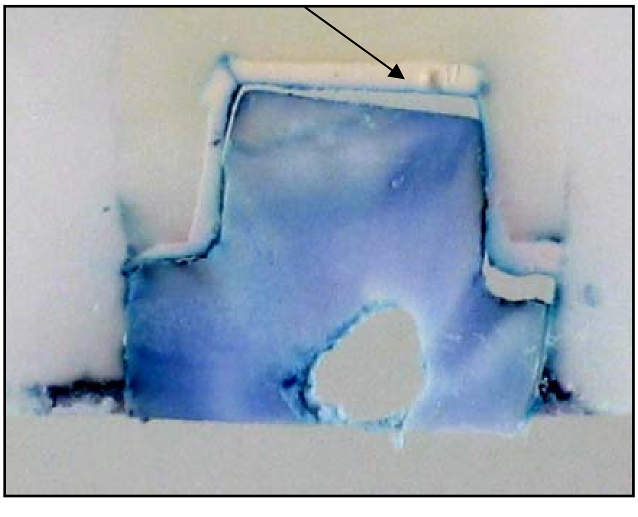


Figure 10: Section showing microleakage of dye along dentine-cement interface onto occlusal surface. Score 4.

DENTINE INFILTRATION - OVERALL COMPARISON

	Group 1	Group 2	Group 3	Total
Dentine Infiltration	Unsealed Control Group	Prime&Bond NT Group	Xeno III Group	
<33% Score 1	n=13 **26.0%**	n=20 **40.0%**	n=27 **54.0%**	n=60 40.0%
33-67% Score 2	n=29 **58.0%**	n=23 **46.0%**	n=19 **38.0%**	n=71 47.3%
>67% score 3	n=8 **16.0%**	n=7 **14.0**	n=4 **8.0%**	n=19 12.7%
Total	n=50 100.0%	n=50 100.0%	n=50 100.0%	n=150 100.0%

Table3: Collective comparison of dentinal tubule infiltration.

*Group 1 vs. 2 – Pearson Chi-Square p-value = 0.326. (Addendum 9)

*Group 1 vs. 3 - Pearson Chi-Square p-value = 0.016. (Addendum 9)

When the extent of dentine tubule penetration was collectively compared irrespective of the group then 47% of specimens showed microleakage into 33-67% of dentine tubules (figure 12). 40% of specimens had dentine tubule microleakage of less than 33% (figure 11) while 13% (figure 13) showed dentine tubule infiltration of greater than 67%. In the control group and Prime & Bond NT most of the leakage occurred in the 33-67% range while most leakage occurred in the 0-33% range in the Xeno III group.

When this parameter was evaluated, no statistically significant difference was found between the unsealed control group and the group sealed with Prime & Bond NT (p-value = 0. 326). However, a statistically significant difference was found between the unsealed control group and the Xeno III group (p-value = 0.016).

PHOTOGRAPHIC REPRESENTATION OF DIFFERENT AMOUNTS OF DENTINAL TUBULE INFILTRATION

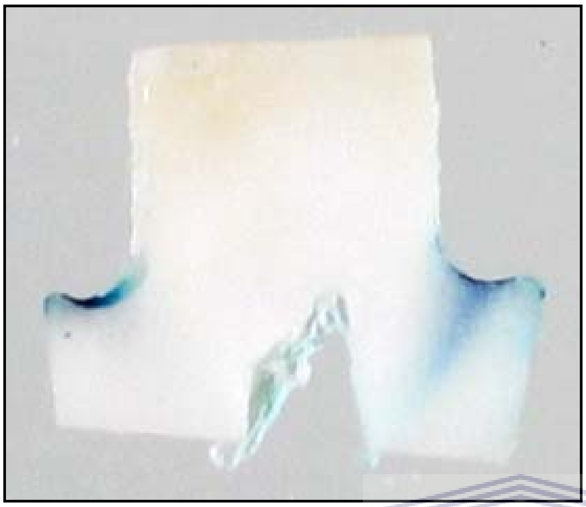


Figure 11: Section representing score 1 for dentinal tubule infiltration.

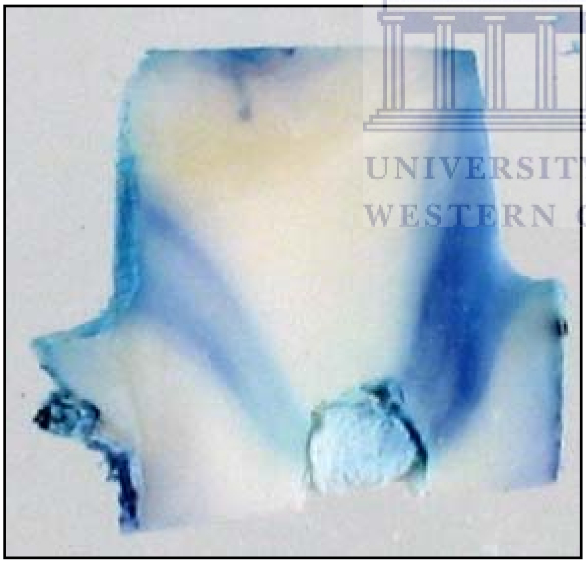


Figure 12: Section representing score 2 for dentinal tubule infiltration.

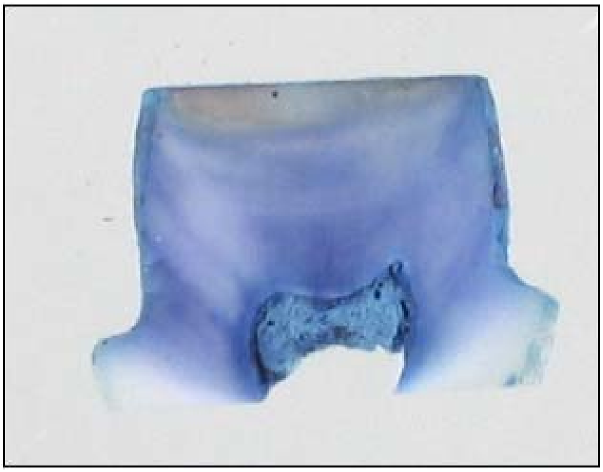


Figure 13: Section representing complete dentinal tubule infiltration. Score 3.

CHAPTER 4

DISCUSSION

Provisional restorations often debond due to weak provisional cements exposing the prepared dentine to the oral environment. If dentine-bonding agents effectively prevent microleakage it would seem wise to reseal the dentine after every additional tooth preparation until such time that the definitive restorations are luted. In this study, dentine-bonding agents are used as interim sealants for the prepared abutments and not for the purposes of definitive luting of artificial crowns.

Certain unforeseen problems were encountered during the study which may have affected the results. Firstly, the provision of a consistently standardized shoulder preparation by manually rotating the test specimens against the dental bur proved to be difficult. Secondly, the natural curvature of the cemento-enamel junction meant that a small number of specimens had occlusal reductions which were sometimes within enamel and dentine. Thirdly, by manually adapting the base-plate wax to the dies provisional crowns of varying thickness were obtained. Fourthly, the size of the marginal gaps was not measured after cementation of the provisional crowns. The effect of these variables on the extent of marginal microleakage and dentine tubule infiltration is unclear since no literature pertaining to these parameters with regard to provisional restorations could be found.

The only variable as far as the materials used was the use of two different dentine-bonding agents i.e. Prime & Bond NT and Xeno III. In doing so, it was hoped that a more stringent comparison could be made between the effect of the dentine-bonding agents used and the extent of the microleakage. A multiple-section protocol was used since a more accurate assessment could be made of the overall extent of the microleakage as recommended by Gale *et al* (1994) and Gwinnett *et al* (1995). These authors suggested that single longitudinal sections through the midline of a restoration underestimated the amount and three-dimensional extent of dye penetration. Only the buccal and lingual surfaces were inspected in this study. Whether a study design inspecting mesial and distal surfaces as well would have yielded markedly differing results is uncertain. It was felt that sectioning each tooth into quarters i.e. mesio-distally and bucco-lingually would have provided sections which would have been too thick to evaluate with light microscopy. The thickness of sections in this study (about 500 micrometres) yielded sections which provided enough strength and durability for ease of analysis. Thinner sections (about 350 micrometres) proved to be too fragile for routine assessment.

Nahon *et al* (2001) studied the effect of different impression materials on the integrity of a dentine-bonding agent by means of dentine permeability tests using a total-etch technique. They concluded that (1) the making of an impression with any of the materials used should have no effect on the dentine hybrid layer, (2) the application of a dentine-bonding agent significantly reduced dentine permeability and (3) the use of primer only and primer–adhesive produced no significant difference in the dentine permeability. They recommended that an additional application of the dentine-bonding agent before the cementation of the definitive restoration was unnecessary due to the potential for pooling of the adhesive at the margins of the preparation which may promote microleakage and affect the fit of the definitive restoration. The effect of the impression materials used on the hybridized dentine fell outside the scope of this study.

Within this study, an indirect technique of fabrication was employed since this technique is believed to offer the best marginal fit. However, the literature seems to be inconclusive as to which technique of fabrication or material provides the best results. The marginal accuracy of provisional crowns is due to a combination of factors that include material properties, fabrication techniques, dynamic loading factors and changes in axial contours during in vitro studies and intraoral situations (Crispin *et al* 1980; Robinson and Hovijitra 1982; Tjan *et al* 1987; Koumjian and Holmes 1990; Moulding *et al* 1994). Blum *et al* (1991) concluded that PMMA crowns exhibited marginal degradation from thermocycling and that this marginal breakdown promoted microleakage. They also found that the type of finish line did not affect the marginal fit.

The phenomenon of microleakage is a clinical reality in operative dentistry and its effects on and implications for the integrity of prepared enamel dentine and pulp has attracted much attention over the past few decades in the dental literature. In vitro microleakage tests are considered to be stricter than in vivo tests for a number of reasons such as (1) easier dispersion of dye than oral microorganisms or their byproducts; (2) deposition of organic material which has the potential to calcify at the marginal gap and may influence the marginal seal; and (3) positive pulpal pressure in dentinal tubules in vital teeth which may affect molecular penetration. Consequently, it is suggested that test materials should respond better in the clinical situation (Pashley 1990; Jacobs and Windeler 1991). On the other hand, provisional crown fabrication, dentine bonding and cementation protocols were conducted under “ideal circumstances” which are not feasible within the clinical situation.

A combined thermocycling and occlusal loading protocol has been recommended as the most suitable testing procedure for provisional crowns since it mimics the masticatory cycle (Blum et al 1991; Hung et al 1993; Zwetchkenbaum et al 1995; Dubois et al 1999; Ehrenberg and Weiner 2000). However, a lack of appropriate testing equipment prevented the use of this recommended protocol and only a thermocycling technique was applied. Consequently, caution is advised when comparing the results of this study with results from other studies that used a combined thermocycling and loading protocol as well.

A dye infiltration method was used in this study since these are the most accepted in vitro microleakage tests. Other techniques include bacteriological and electrochemical tests and scanning electron microscopy tests (Yap *et al* 1998).

One of the most important differences between in vitro microleakage tests and in vivo tests is the absence of a natural positive pulpal pressure within the dentinal tubules. Dentinal fluid is under approximately 15cm H_2O pressure (Pashley *et al* 2002). Whether this constant pressure has any bearing on the immediate bonding of dentine adhesives to living dentine is unclear in the literature. It has been speculated that this outward flow of dentinal fluid may influence the infiltration of dentine-bonding adhesive monomers into the smear layer, demineralized collagen network and dentinal tubules and negatively affect the formation of the hybrid layer. However, the use of vasoconstrictive local anaesthetic solutions effectively reduces this pulpal pressure (Pashley *et al* 2002; Perdigão 2002).

This study seems to confirm the findings of Elgalaid *et al* (2004) who found no difference between dentinal tubule sealing between unsealed crowns and provisional crowns sealed with Prime & Bond NT.

In this study, the key objective was to determine the effect of two different dentine-bonding agents (Prime & Bond NT and Xeno III) on the microleakage along the axial walls of the test specimens. The use of a single layer of Prime & Bond NT or Xeno III according to the manufacturer's instructions did not display any statistically significant difference as far as microleakage along the walls of the dentine when compared to the unsealed test group. Almost all test specimens showed maximal leakage onto the occlusal surface with the site of leakage between the cement-dentine interfaces. This finding is in agreement with Baldissara *et al* (1998) who cited the inherent weakness of provisional cements as the likely reason. They also suggested that the marginal seal in the provisional phase might be the most important factor for the long-term success of fixed crowns and bridges.

Dentine permeability studies have shown varying results. These conflicting findings are probably due to a number of variables, which include study design, varying methodologies and materials tested. Traditional dentine permeability test are based on a fluid filtration model using dentine disks and a simulated pulpal pressure. Gregoire *et al* (2005) found that total-etch systems including Prime & Bond NT provided a greater reduction in dentine permeability than the self-etching systems they tested. The results of this study conflict with these previous findings.

Dentine-bonding agents are technique-sensitive and dentine adhesion is subject to many variables such as dentine thickness, regional variations in permeability, restoration of the external and internal dentine seal, pulpal pressure and problems associated with dentine sealing (Pashley *et al* 2002). Factors that affect the bond strength include moisture sensitivity, incompatibility with restorative materials, blood, saliva and eugenol-based provisional cements. Caries detectors and haemostatic agents are also implicated in the degradation of the bond strengths of many adhesives (Perdigão 2002). All of these factors were not eliminated in this study and this study did not contribute any new knowledge in this regard. The effect of the cement on the quality of the adhesive bond and subsequent leakage and dye penetration also fell outside the scope of this study.

Sorenson *et al* (1991) conducted an in vitro study to measure the microleakage of dentine-bonding agents and glass-ionomer cements using a fluid filtration technique with flat dentine disks. They concluded that the materials tested reduced but did not prevent microleakage from occurring. While the aspect of bond strength of dentine-bonding agents fell outside the scope of this study, the findings of this study are in agreement with the previous authors who reported that dentine–bonding agents reduced but did not prevent microleakage from occurring.

In this study, a single layer of each bonding agent was applied according to manufacturer's instructions. A number of studies have evaluated changing the dentine-bonding procedures to enhance the sealing ability and the bond strengths of various dentine-bonding agents. These departures from the manufacturers' recommended procedures include variations on the pre-etching technique and the application of multiple layers of the dentine-bonding agent. Many studies have favoured the application of multiple layers of particular dentine-binding agents as well as the use of an acid pre-etch even with self-etching adhesives. While these changes to the recommend procedures may enhance certain properties of a particular dentine-bonding agent, they may be detrimental to the fit of artificial crowns (Strydom 2004, 2005). These variations in the application technique fell outside the declared objectives of this study and can be researched in follow-up studies.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The results of this study should be treated with caution due to the small sample size and the material and technique variables. Subtle variations in the application technique may yield vastly different results.

Within the limitations of the study the following conclusions can be drawn.

1. All artificial provisional crowns leaked to the maximum extent along the walls of the preparations irrespective of whether the crown preparations were treated with a dentine-bonding agent or not.
2. The application of a single layer of Prime & Bond NT or a single layer of Xeno III to the prepared enamel and dentine of the teeth reduced but did not completely prevent microleakage.
3. No statistically significant difference was found between the amounts of dentinal tubule infiltration in the unsealed tooth specimens when compared with specimens which were sealed with a single layer of Prime & Bond NT.
4. Specimens that were sealed with a single layer of Xeno III showed statistically significant less amounts of dentinal tubule infiltration than the unsealed tooth specimens.

The application of these two dentine-bonding agents did not prevent microleakage of provisional crowns. Prime & Bond NT and Xeno III reduced but did not completely prevent dentinal tubule infiltration of the dye tracers used. In light of the above findings, the application of a single layer of Prime & Bond NT to provisional crowns preparations appears to be of no significant benefit when compared to crowns cemented with the provisional cement TempBond NE. However, based on the limitations of this study the application of a single layer of Xeno III self-etching adhesive may be of some benefit as a dentine sealant for provisional crown preparations as an interim measure prior to final crowns preparations and luting of the final crowns. Further research is needed to evaluate the effectiveness of dentine-bonding agents as a prophylactic sealant for exposed dentinal tubules. It is recommended that the variation in the application of the self-etching adhesives be researched in order to find a recipe to further enhance the sealing ability for provisional restorations.

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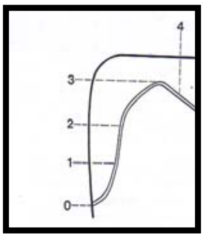

ADDENDUM 1
RECORD SHEET

Tooth	Section	Buccal	Lingual	Dentine
1	1			
	2			
	3			
	4			
	5			
2	1			
	2			
	3			
	4			
	5			
3	1			
	2			
	3			
	4			
	5			
4	1			
	2			
	3			
	4			
	5			
5	1			
	2			
	3			
	4			
	5			
6	1			
	2			
	3			
	4			
	5			
7	1			
	2			
	3			
	4			
	5			
8	1			
	2			
	3			
	4			
	5			
9	1			
	2			
	3			
	4			
	5			
10	1			
	2			
	3			

ADDENDUM 2

PRODUCT LIST

Product	Lot number	Manufacturer
Integrity Crown and Bridge material	0508111	DENTSPLY Caulk
Tapered diamond burs FG 199g018	66548	Horico, Berlin
Aquasil Soft Putty/Regular Set Impression material	0510001884	DENTSPLY DeTrey
Aquasil Ultra LV impression material	0505261	DENTSPLY
Xeno III self-etching dentine adhesive	050500 1099	DENTSPLY
Prime & Bond NT	0505000695	DENTSPLY DeTrey

ADDENDUM 3

BUCCAL GROUP UNCOLLAPSED STATISTICAL DATA

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Buccal * Group	150	100.0%	0	.0%	150	100.0%
Lingual * Group	150	100.0%	0	.0%	150	100.0%
Dentine * Group	150	100.0%	0	.0%	150	100.0%

Buccal * Group

Crosstab

			Group			Total
			1	2	3	
Buccal	67% axial	Count	0	5	12	17
		% within Group	.0%	10.0%	24.0%	11.3%
	Full axial	Count	0	0	3	3
		% within Group	.0%	.0%	6.0%	2.0%
	Occlusal	Count	50	45	35	130
		% within Group	100.0%	90.0%	70.0%	86.7%
Total		Count	50	50	50	150
		% within Group	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21.516[a]	4	.000
Likelihood Ratio	26.104	4	.000
Linear-by-Linear Association	17.555	1	.000
N of Valid Cases	150		

a. 3 cells (33.3%) have expected count less than 5. The minimum expected count is 1.00.

Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.125	.026	4.082	.000
		Buccal Dependent	.000	.000	.[c]	.[c]
		Group Dependent	.150	.036	4.082	.000
	Goodman and Kruskal tau	Buccal Dependent	.111	.039		.000[d]
		Group Dependent	.072	.019		.000[d]
	Uncertainty Coefficient	Symmetric	.112	.026	3.767	.000[e]
		Buccal Dependent	.194	.036	3.767	.000[e]
		Group Dependent	.079	.021	3.767	.000[e]

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Cannot be computed because the asymptotic standard error equals zero.

d. Based on chi-square approximation

e. Likelihood ratio chi-square probability.

ADDENDUM 4

BUCCAL GROUP 1 VS. GROUP 2 "COLLAPSED DATA"

CHI-SQUARE TESTS

	Value	df	Asymp. Sig. (2 sided)	Exact sig. (2-sided)	Exact Sig. (1 sided)
Pearson Chi-Square	5.263^{b}	1	0.022		
Fisher's Exact test				0.056	0.028

a. Computed only for a 2x2 table.

b.2 cells (50%) have expected count less than 5. The minimum expected count is 2.50.

ADDENDUM 5

BUCCAL GROUP 1 VS. GROUP 3 "COLLAPSED DATA"

CHI-SQUARE TESTS

	Value	df	Asymp. Sig. (2 sided)	Exact sig. (2-sided)	Exact Sig. (1 sided)
Pearson Chi-Square	17.647[b]	1	0.000		
Fisher's Exact test				0.000	0.000

a. Computed only for a 2x2 table.

b.0 cells (.0%) have expected count less than 5. The minimum expected count is 7.50.

ADDENDUM 6

LINGUAL GROUP UNCOLLAPSED STATISTICAL DATA

Lingual * Group

Crosstab

			Group 1	Group 2	Group 3	Total
Lingual	33% axial	Count	1	1	0	2
		% within Group	2.0%	2.0%	.0%	1.3%
	67% axial	Count	0	5	11	16
		% within Group	.0%	10.0%	22.0%	10.7%
	Full axial	Count	1	0	5	6
		% within Group	2.0%	.0%	10.0%	4.0%
	Occlusal	Count	48	44	34	126
		% within Group	96.0%	88.0%	68.0%	84.0%
Total		Count	50	50	50	150
		% within Group	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21.851[a]	6	.001
Likelihood Ratio	27.223	6	.000
Linear-by-Linear Association	10.496	1	.001
N of Valid Cases	150		

a. 6 cells (50.0%) have expected count less than 5. The minimum expected count is .67.

Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.121	.028	3.810	.000
		Lingual Dependent	.000	.000	.[c]	.[c]
		Group Dependent	.150	.038	3.810	.000
	Goodman and Kruskal tau	Lingual Dependent	.085	.035		.000[d]
		Group Dependent	.073	.021		.001[d]
	Uncertainty Coefficient	Symmetric	.109	.025	3.925	.000[e]
		Lingual Dependent	.159	.032	3.925	.000[e]
		Group Dependent	.083	.021	3.925	.000[e]

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Cannot be computed because the asymptotic standard error equals zero.

d. Based on chi-square approximation

e. Likelihood ratio chi-square probability.

ADDENDUM 7

LINGUAL GROUP 1 VS. GROUP 2 "COLLAPSED DATA"

CHI-SQUARE TESTS

	Value	df	Asymp. Sig. (2 sided)	Exact sig. (2-sided)	Exact Sig. (1 sided)
Pearson Chi-Square	2.174b	1	0.140		
Fisher's Exact test				0.269	0.134

a. Computed only for a 2x2 table.

b.2 cells (50%) have expected count less than 5. The minimum expected count is 4.00.

ADDENDUM 8

LINGUAL GROUP 1 VS. GROUP 3 "COLLAPSED DATA"

CHI-SQUARE TESTS

	Value	df	Asymp. Sig. (2 sided)	Exact sig. (2-sided)	Exact Sig. (1 sided)
Pearson Chi-Square	13.279[b]	1	0.000		
Fisher's Exact test				0.000	0.000

a. Computed only for a 2x2 table.

b.0 cells (.0%) have expected count less than 5. The minimum expected count is 9.00.

ADDENDUM 9

DENTINE GROUP UNCOLLAPSED STATISTICAL DATA

Dentine * Group

Crosstab

			Group			Total
			1	2	3	
Dentine	< 33%	Count	13	20	27	60
		% within Group	26.0%	40.0%	54.0%	40.0%
	33-67%	Count	29	23	19	71
		% within Group	58.0%	46.0%	38.0%	47.3%
	> 67%	Count	8	7	4	19
		% within Group	16.0%	14.0%	8.0%	12.7%
Total		Count	50	50	50	150
		% within Group	100.0%	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.409[a]	4	.078
Likelihood Ratio	8.595	4	.072
Linear-by-Linear Association	7.121	1	.008
N of Valid Cases	150		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.33.

Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.123	.063	1.881	.060
		Dentine Dependent	.101	.081	1.185	.236
		Group Dependent	.140	.059	2.251	.024
	Goodman and Kruskal tau	Dentine Dependent	.035	.024		.034[c]
		Group Dependent	.028	.019		.079[c]
	Uncertainty Coefficient	Symmetric	.028	.018	1.500	.072[d]
		Dentine Dependent	.029	.019	1.500	.072[d]
		Group Dependent	.026	.017	1.500	.072[d]

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on chi-square approximation

d. Likelihood ratio chi-square probability.