EFFECTS OF GLASS-IONOMER CEMENT LINING ON
SEALING ABILITY AND
POSTOPERATIVE TOOTH SENSITIVITY
AFTER
RESIN COMPOSITE RESTORATION
OF POSTERIOR TEETH

Danuchit Banomyong

Submitted in (total) fulfilment of the requirements of the degree of
Doctor of Philosophy

March 2009

Melbourne Dental School
Faculty of Medicine, Dentistry and Health Sciences
The University of Melbourne
ABSTRACT

Postoperative tooth sensitivity is an unpredictable complication in teeth restored with resin composite using a total-etching adhesive. Many approaches have been introduced in an attempt to solve the problem. It is believed that a restorative procedure providing a superior seal may reduce postoperative tooth sensitivity. Placing a glass-ionomer cement (GIC) lining or using a self-etching adhesive has been suggested. Nevertheless, the effectiveness of a GIC lining to improve sealing ability and reduce postoperative sensitivity is questionable due to the finding that micro-gap formation is frequently detected between a GIC liner and dentine. In this thesis, the laboratory and clinical studies investigated sealing ability and postoperative sensitivity after posterior resin composite restorations with or without a GIC lining. In addition, effects of a self-etching adhesive on these outcomes were also investigated.

Effects of dentine surface treatment on its permeability and micro-shear bond strength were investigated in the first experiment. Dentine permeability increased dramatically when the surface was etched with phosphoric acid, while it did not change significantly after conditioning with polyacrylic acid or priming with an acidic primer. When dentine was etched with phosphoric acid, the smear layer and smear plugs were completely removed and dentinal tubules were patent. In contrast, smear layer was partially removed and dentinal tubules were still partly occluded when polyacrylic acid or a self-etching primer was applied. Only the micro-shear bond strength of a two-step, total-etch adhesive was negatively affected by the presence of a positive pulpal pressure, while a two-step, self-etching adhesive and a high
powder:liquid ratio GIC were not. It was concluded that adhesion of a total-etching adhesive was strongly influenced by the increase in dentine permeability after acid etching.

In the second experiment, sealing ability of occlusal resin composite restorations using a two-step, total-etching adhesive with or without GIC lining were compared. In addition, restorations bonded with a two-step, self-etching adhesive were also investigated. Application of a GIC lining did not reduce fluid flow after restoration. Additionally, the self-etching adhesive did not reduce fluid flow compared with the total-etching adhesive. Most of the restorations leaked with methylene blue dye and fluorescent dye to a varying extent. Micro-gaps were detected to a greater extent in restorations with a GIC lining. When the self-etching adhesive was used, micro-gaps were rarely detected at the initial stage, and to a significantly lesser extent than those of the total-etching adhesive. It can be summarized that a GIC lining did not improve the sealing ability of the restoration, which might be explained by the presence of micro-gaps. In addition, using a self-etching adhesive failed to provide a superior seal to a total-etching adhesive, even initial micro-gap formation was rarely observed in the former.

Fluid flow after restoration with or without a GIC lining was investigated in carious teeth in the third experiment. In a preliminary study, dentine permeability after acid etching of caries-affected dentine was significantly lower than that of normal dentine due to the occluded dentinal tubules containing acid resistant precipitates. After restoration, fluid flow was not significantly different between restorations with or without GIC lining, whether in carious teeth or (cavity-prepared) intact teeth. Fluorescent dye could penetrate to the bonded interfaces in most
restorations. However, limited fluorescent dye penetration was occasionally observed in restored carious teeth. In summary, a GIC lining did not reduce fluid flow or improve the sealing ability of restorations in carious teeth.

A clinical trial was conducted to confirm the outcomes obtained from the findings in the laboratory. Postoperative sensitivity in posterior teeth restored with resin composite with or without GIC lining, using a total-etching adhesive and a self-etching adhesive, was investigated in young adult patients. In all treatments, postoperative sensitivity to cold/hot water or occlusal function was rarely reported. No significant difference in postoperative sensitivity to cold stimulation was found among restorative procedures with or without GIC lining, regardless of the adhesive used. In addition, no difference in postoperative sensitivity was noted between the two adhesives. Compared with no lining, the GIC liner did not reduce postoperative tooth sensitivity after posterior resin composite restorations.

In conclusion, GIC lining had no benefit in improving sealing ability or reducing postoperative sensitivity after posterior resin composite restoration placement in occlusal cavities. In addition, a self-etching adhesive did not provide a superior seal or less postoperative sensitivity than a total-etching adhesive.
DECLARATION

This thesis is the original work of the author, except where acknowledgment has been made in the text. None of the material in this thesis has been submitted for any degree. This thesis is less than 100,000 words in length exclusive of Figures, Tables, Bibliographies and Appendices.

Danuchit Banomyong

November 2008
DEDICATION

To my beloved wife who looked after our children while I was studying in Melbourne and always encourages me without any condition. To my beloved mother and to the memory of my father. Finally, to my beloved aunt who always looked after me since I was young and has found eternal peace.
ACKNOWLEDGEMENT

First of all, I would like to present my absolute gratefulness and gratitude to Professor Michael Francis Burrow for his generous support and encouraging me during my three years of study. His outstanding guidance and advice are magnificent and valuable. His sympathy and consideration to an international student like me are greatly appreciated.

I would like to express my sincere gratitude to Emeritus Professor Harold Henry Messer for giving the chance to study at the University of Melbourne. He always encourages and is very kind to his students along the way down the ‘academic’ road. Nothing can express the feeling of my appreciation and gratefulness for his outstanding support, encouragement and kindness.

I would like to present my appreciation and thankfulness to Dr. Joseph Palamara for his excellent guidance and technical assistance in conducting the laboratory studies. His remarkable encouragement and support are truly appreciated.

I would also like to show my gratefulness to Dr. Choltacha Harnirattisai, who was my overseas supervisor. His kind support whilst I was conducting the clinical trial in Thailand is much appreciated.

Truthfully, I am sincerely honoured to be their student, and they will certainly be a role model for my teaching carrier.
I am truly grateful to Dr. Siriporn Timpawat and Dr. Jeeraphat Jantarat who generously encouraged and supported me to study at the University of Melbourne.

I wish to thank my sponsor, the Royal Thai Government for the scholarship that enabled me to study overseas.

I am also grateful to all the people who helped me in this work: in particular, I would like to give my thankfulness to Mr. Ilya Zalizniak for his help in the laboratory, Dr. Simon Crawford for his support in scanning electron microscopy, Dr. Sandy Clark for her help in statistical analysis and Ms. Urai (my dental nurse) for her cheerful assistance in the clinical trial.

I wish to thank the staff of the Melbourne Dental School for their kindness and support and also my friends in the school for their friendship during my study.

Finally, I would like to give many thanks to all those people who contributed to this work, but not mentioned in this acknowledgement.
# TABLE OF CONTENTS

## CHAPTER 1 INTRODUCTION

- Problem statement  
- References  

## CHAPTER 2 LITERATURE REVIEW  

### 2.1 Pulpo-dentine complex

- 2.1.1 Normal dentine  
  - Basic structure of normal dentine  
  - Dentine response to age change and irritation  
- 2.1.2 Dental pulp  
  - Basic structure of dental pulp  
  - Pulpal response to age change and irritation  

### 2.2 Dental caries

- 2.2.1 Contributing factors  
- 2.2.2 Categories of dental caries  
- 2.2.3 Pulpo-dentine complex reaction to dental caries  

### 2.3 Caries removal

- 2.3.1 Caries detector dye  
- 2.3.2 Effect of caries removal/cavity preparation on the pulpo-dentine complex  

### 2.4 adhesion to tooth substrate

- 2.4.1 Adhesion concept  

---

ix
2.4.2 Dental adhesives

Basic composition 19
Classification 21
Bond to enamel/dentine 22

2.5 Resin composite 27

2.5.1 Basic composition and classification 27
2.5.2 Polymerization shrinkage 29

Basic knowledge 29
Effects of polymerization shrinkage stress on restorations 30
Minimizing the negative effects of polymerization shrinkage 31

2.6 Glass-ionomer cements 33

2.6.1 Composition and classification 33
2.6.2 Setting mechanism and water sensitivity 35
2.6.3 Bond to tooth structure 37
2.6.4 Glass ionomer liner/base (type III) 38

2.7 Dentine permeability & restorative dentistry 40

2.7.1 Dentine is a permeable substrate 40
Permeability of dentine affected by dental caries 41
2.7.2 Effects of dentine permeability on adhesive restorations 41
Effect of permeability on adhesion to dentine 42
2.7.3 Dentine permeability and tooth sensitivity 43

2.8 Postoperative tooth sensitivity 45

2.8.1 Mechanism of tooth sensitivity 45
2.8.2 Tooth sensitivity after resin composite restoration 46
2.8.3 How to prevent or reduce postoperative tooth sensitivity? 48

References 50
CHAPTER 3 AIMS AND OBJECTIVES 81

CHAPTER 4
EFFECT OF DENTIN CONDITIONING ON DENTIN PERMEABILITY AND MICRO-SHEAR BOND STRENGTH 85

Abstract 86

Introduction 87

Material and methods 89

Results 96

Discussion 99

References 104

CHAPTER 5
SEALING ABILITY OF OCCLUSAL RESIN COMPOSITE RESTORATION USING FOUR RESTORATIVE PROCEDURES 118

Abstract 119

Introduction 120

Material and methods 122

Results 128

Discussion 132

References 138
**LIST OF TABLES**

Table 4-1 Materials, components, batch numbers and manufacturers

Table 4-2 Fluid fluxes at baseline and after conditioning measured at a simulated pulpal pressure of 1.3 kPa

Table 4-3 Standard errors of differences between paired groups, obtained by REML analysis of variance of mixed model

Table 4-4 Fluid fluxes after conditioning with phosphoric acid at a simulated pulpal pressure of 0 and 1.3 kPa

Table 4-5 Micro-shear bond strengths of Fuji IX GP bonded to unconditioned and conditioned dentine surfaces, and of Single Bond 2 and Clearfil SE Bond at 0 and 1.3 kPa simulated intrapulpal pressures

Table 5-1 Materials, components, batch numbers and manufacturers

Table 5-2 Restorative procedures in fluid flow measurement and the related experiments

Table 5-3 Micro-gap formation at bonded interfaces observed from SEM montage images in percentages of total length of cavity walls at 24 h, 1 wk, 1 month and 6 months after restoration using the four restorative procedures
Table 5-4 Gap formation between GIC liner and resin composite observed from SEM montage images in percentage of total length of the interfaces at 24 h, 1 wk, 1 month and 6 months after restoration

Table 5-5 Internal dye leakage results in percentages of total length of cavity walls of restorations using the four restorative procedures

Table 6-1 Materials, components, batch numbers and manufacturers

Table 6-2 Cavity lengths, widths and depths of carious and intact teeth groups

Table 6-3 Baseline flow rates and changes in fluid flow rates: (1) after caries removal, (2) after acid etching and (3) during setting of the GIC in the carious group categorized by caries activity (slowly or rapidly progressing)

Table 6-4 Fluid flow rates after caries removal in carious teeth or after cavity preparation in intact teeth

Table 6-5 Fluid flow rates after acid etching in the groups without lining

Table 6-6 Fluid flow rates during setting of the GIC in the groups with lining

Table 7-1 Inclusion and exclusion criteria used for the recruitment of participants in the clinical trial

Table 7-2 Materials, components, batch numbers and manufacturers
Table 7-3 General information and cavity depth according to each treatment group.
..........................................................................................................................................................219

Table 7-4 Prevalence (percentage) and means (in VAS score) of tooth sensitivity on a daily basis at the three time-points according to the four restorative procedures.....220

Table 7-5 Prevalence (percentage) and means (in VAS score) of tooth sensitivity in response to cold stimulation at the three time-points according to the four restorative procedures. ...........................................................................................................................................221
LIST OF FIGURES

Figure 4-1 Diagrammatic representation of the testing apparatus for measuring fluid flow ................................................................. 108

Figure 4-2 Schematic of the test apparatus for preparing bonded specimens in micro-shear bond test...................................................... 109

Figure 4-3 SEM images of conditioned dentin surfaces ................................................. 110

Figure 4-4 Distribution in mode of failure at simulated intrapulpal pressures of 0 and 1.3 kPa ............................................................................................................. 112

Figure 5-1 Diagrammatic representation of the test apparatus for measuring fluid flow ................................................................................................................................. 142

Figure 5-2 Fluid fluxes after restoration, expressed as % change from baseline, of the four restorative procedures measured up to 6 months ......................................................... 143

Figure 5-3 Representative SEM images from resin replicas of sectioned teeth .......... 144

Figure 5-4 Representative bonded interfaces labelled with Rhodamine B fluorescence dye and obtained from confocal laser scanning microscope at 40X magnification . 145
Figure 6-1 The trend of fluid flow after restoration in carious and intact (non-carious) teeth, restored with or without GIC lining ................................................................. 175

Figure 6-2 SEM images at 1,000X magnification of dentin surface after caries removal using low-speed round steel burs, and dentin surface on the cavity floor of a cavity-prepared, non-carious tooth. .............................................................................. 176

Figure 6-3 SEM images of acid-etched normal dentin and caries-affected dentin at 4,000X magnification ................................................................................................. 177

Figure 6-4 SEM images at 2,000X magnification of acid-etched, caries-affected dentin subjacent to rapidly progressing and slowly progressing caries................. 178

Figure 6-5 SEM images of longitudinal sections of acid-etched normal dentin and caries-affected dentin ................................................................................................. 179

Figure 6-6 Color images obtained from light microscopy showing fluorescent dye diffused through dentinal tubules and deposited at bonded interfaces of restored carious and non-carious teeth ................................................................................................. 180

Figure 6-7 Color and grey images of bonded interfaces, simultaneously photographed from CLSM at 40X magnification................................................................. 182

Figure 7-1 Modified visual analog scale........................................................................ 215

Figure 7-2 Modified CONSORT flow diagram showing the flow of participants through each stage ................................................................................................. 216
PREFACE

Currently, the benefits of GIC-based linings for improving the sealing ability and reducing postoperative tooth sensitivity in posterior teeth restored with resin composite remain unclear. In addition, the effects of a self-etching adhesive on these same outcomes are also unclear and need to be clarified. The thesis consists of eight chapters as follows: (1) introduction; (2) literature review; (3) aims and objectives; (4-7) four chapters describing experimental/clinical studies; and (8) general conclusion and discussion. Chapters 4 to 7 are in the format of manuscripts prepared for publication. In Chapter 4, the research investigated the effects of dentine conditioning on dentine permeability and micro-shear bond strengths of resin-based adhesives and glass-ionomer cement (GIC) to dentine. In the second part (Chapter 5) the sealing ability of posterior resin composite restorations restored with or without GIC lining and using two resin-based adhesives was investigated using various methods. The fluid flow through carious teeth restored with resin composite with or without a GIC liner was investigated in Chapter 6. Chapter 7 presents the results from a clinical trial that investigated postoperative tooth sensitivity associated with posterior resin composite restoration with and without placing a GIC lining, using two resin-based adhesives (total-etching and self-etching adhesives).

The articles of Chapters 4 and 5 have been recently published in the European Journal of Oral Science. The manuscript of Chapter 6 has been submitted to the journal, while Chapter 7 is being prepared as a manuscript for submission to Operative Dentistry.
Chapters based on experimental and clinical work (Chapters 4-7) are written as separate parts, in the format of manuscripts for publication. General conclusion/discussion and appendices appear at the end of this thesis. Each chapter has a separate reference list.
Author/s:
Banomyong, D.

Title:
Effects of glass-ionomer cement lining on sealing ability and postoperative tooth sensitivity after resin composite restoration of posterior teeth

Date:
2009

Citation:

Publication Status:
In Press

Persistent Link:
http://hdl.handle.net/11343/35095

File Description:
Abstract