UNIVERSITI TEKNOLOGI MARA

THE EFFECTS OF REPEATED ETCHING CYCLES ON ENAMEL LOSS, RELATIVE ATTENUATION COEFFICIENT, SURFACE ROUGHNESS AND ESTHETICS OUTCOMES OF RESIN INFILTRATION ON DEMINERALIZED ENAMEL – AN *IN VITRO* STUDY

DAYANG FADZLINA BINTI ABANG IBRAHIM

Dissertation submitted in partial fulfillment
of the requirements for the degree of
Dr in Paediatric Dentistry

Faculty of Dentistry

July 2023

ABSTRACT

Introduction: Resin infiltration is used to mask enamel opacities and the recommended etching cycles are three. However, anecdotal evidence suggests that favorable esthetics outcomes can be obtained by increasing the etching cycles. **Objectives:** The purpose of this study was (i) to determine the incremental and total enamel loss when enamel surfaces are exposed to multiple etching cycles using 15% HCl, (ii) to assess the relative attenuation coefficient after various etching cycles and resin infiltration treatment, (iii) to compare changes of surface roughness between the various etching cycle groups at multiple treatment stages and (iv) to compare the esthetics outcomes of various etching cycle groups at multiple treatment stages. **Methodology:** On the buccal surface of ninety healthy premolars, an artificial demineralization was created. The teeth were separated into nine groups (n=10), with each group undergoing one additional etching cycle up to a total of nine cycles. Each group underwent seven stages of evaluation that include at baseline, after demineralization, after etching, after resin 1 treatment, after resin 2 treatment, post resin 7 days and post resin 28 days. The teeth were scanned using optical coherence tomography (OCT) and enamel loss was quantified using a custom written MATLAB program. Resin infiltration was performed twice, first for 3 minutes (Resin 1) and again for 1 minute (Resin 2). All teeth were examined for baseline surface roughness using a profilometer (Ambios XP-200) before being treated to a pH cycling regime for 7 and 28 days. Esthetics changes was assessed using a Minolca spectrophotometer. Data were analyzed with one-way ANOVA and two-way ANOVA. **Result:** There was no significant difference in incremental enamel loss between each group with a mean depth of 6.801 ± 0.606%. However, there is a significant total enamel loss of more than 33% found at seven etching cycles and above. A two-way ANOVA revealed that there was a statistically significant interaction between the effects of the relative attenuation coefficient on the different stages and various etching groups, $F(24, 216) = 2.184$, $p = 0.006$. There was a significant interaction between the different stages and various groups of etching cycles on surface roughness, $F(48, 126) = 3.48$, $p < 0.001$.There was also a significant interaction between the different stages and various groups of etching cycles on color changes, ($F(4, 126) = 1.177$, $p = 0.045$). The esthetics outcome of the two applications of resin infiltration is comparable to the baseline (sound tooth) and found to significantly mask the demineralized lesions at 4 etching cycles and beyond. **Conclusion**: Repeated etching for the purpose of resin infiltration is acceptable and capable of improving esthetic outcomes. However, this study recommends that etching should not be repeated more than seven cycles to prevent excessive enamel loss. After eight rounds of etching, resin infiltration penetration nearly matched that of healthy enamel. The results showed that demineralized lesions treated with resin infiltration showed low surface roughness comparable to sound enamel, indicating the treatment efficacy of resin infiltration for demineralized enamel lesions. This study revealed that resin infiltration produced favorable esthetics results after more than 5 etching cycles. The esthetic outcome and surface roughness remain unchanged for up to 28 days.

Keywords: Resin infiltration; attenuation coefficient; surface roughness, esthetics, optical coherence tomography

ACKNOWLEDGEMENT

First and above all, I praise Allah s.w.t, the Almighty for providing me this opportunity and granting me the capability, dedication and good health in completing this thesis.

I want to start by sincerely thanking my main and dearest supervisor Associate Prof. Dr. Annapurny A/P Venkiteswaran for her direction, support, and vast knowledge, without which I would not have been able to complete this thesis. She additionally supports my statistical analysis.

I am grateful to Dr Noren Nor Hasmun for her brilliant idea about the research topic and introduce me to optical coherence tomography and resin infiltration materials as well as for endless support and sharing of knowledge in this study.

I would also like to thank my co-supervisor Associate Prof. Ir. Dr Liew Yih Miin for her arduous efforts in designing the MATLAB algorithm for my data analysis and for guiding me to use optical coherence tomography. I am indebted to her for supervising me on the experimental part of the research.

Thank you so much, Puan Najibah, for all the help and direction you've given me in statistical analysis. My thanks and appreciations also go to the research Science Officer, Biomaterials Research Laboratory University Malaya, Mdm. Helen Ng Lee Ching for her relentless assistance and guidance in using the profilometer and spectrophotometer. Many thanks to all of my colleague's Postgraduate Programmes, and all others who may have, directly or indirectly supported the research.

I would like to express my deepest appreciation towards my family, especially to my handsome husband, Heyrodden bin Haji Hamji and my son Haidar Humaidi who have been very supportive and understanding in this tough time. To my beloved parent, Abang Ibrahim and , thank you for the endless support and prays.

TABLE OF CONTENT

	Page
CONFIRMATION BY PANEL OF EXAMINERS	**iii**
AUTHOR'S DECLARATION	**iv**
ABSTRACT	**v**
ACKNOWLEDGEMENT	**vi**
Table of CONTENT	**ii**
LIST OF TABLES	**vi**
LIST OF FIGURES	**viii**
LIST OF SYMBOLS	**xii**
LIST OF ABBREVIATIONS	**xiii**
LIST OF NOMENCLATURE	**xiv**
CHAPTER ONE INTRODUCTION	**1**
1.1 Research Background	1
1.2 Problem Statement	4
1.3 Objectives	5
1.4 Significance of Study	5
1.5 Hypothesis of the Study	6
CHAPTER TWO LITERATURE REVIEW	**7**
2.1 Introduction	7
2.2 Enamel Tooth Structures and Caries Pathophysiology	7
2.2.1 Enamel Composition, Formation And Structure	7
2.2.2 Caries Formation and Histological Features	12
2.2.3 Demineralization	14
2.2.4 Remineralization	15
2.3 Refractive Index of Tooth	16
2.4 Diagnostic Methods Of Using OCT	16
2.4.1 OCT: Working Principal And Image Generated	17
2.4.2 OCT in Dentistry	20
2.4.3 WSL Detection Using OCT	21

CHAPTER ONE
INTRODUCTION

1.1 Research Background

White spot lesions (WSL) are opaque white lesions on smooth tooth surfaces as a result of demineralization, are the first symptoms of early enamel lesions and may or may not progress to more severe enamel breakdown (Pitts, 2016). These lesions have intact outer enamel surfaces with a porous subsurface layer underneath and are clinically presented as white opacities (Fejerskov et al., 2003). The prevalence of WSL in orthodontic patients ranges from 25% to 46% (Eltayeb et al., 2017). WSL develops as a result of the demineralization of enamel with the dissolution of calcium, phosphate and fluoride ions and may lead to microporosities in the remaining tooth structure (Ferreira et al., 2018). This porosity leads to a visual change in enamel because of the changes in light scattering optical properties of the decalcified enamel (Prasada et al., 2018). Scattering occurs at the interfaces between two materials of different refractive indices (RI), e.g. between enamel (RI=1.62), water (RI=1.33) and air (RI=1.00) (Meng et al., 2009).

The use of fluoride and casein phosphopeptide-amorphous calcium phosphate are examples of preventive intervention strategies for treating WSL (Wang et al., 2021). Remineralization, however, is not always effective since it necessitates patient compliance and many patients discontinue the course of treatment before it is completed (Wang et al., 2021). Therefore, a different strategy for the minimally invasive treatment of demineralized enamel lesions has been developed which is resin infiltration (Paris et al., 2007). Currently, the only resin infiltration product on the market is ICON^{TM} (DMG, Hamburg, Germany) which was originally developed to arrest the progression of proximal caries lesions (Meyer-Lueckel & Paris, 2008).

Resin infiltration technique involves three steps. The first step involves the superficial demineralization of the hypermineralized pseudointact surface layer of enamel by the application of 15% hydrochloric acid (HCl) which makes enamel porous for the complete occlusion of the lesion bodies with the infiltrant (Paris et al., 2007). Ethanol was used in the second stage to get rid of any leftover water at the bottom of the lesion body and to make the resin infiltration less viscous (Paris et al., 2007). The third phase involves replacing the water and air-filled porosities with resin material and perfusing a low viscosity resin called