THE UNIVERSITY OF ADELAIDE

The effect of clinical polishing protocols on ceramic surface texture and wear rate of opposing enamel: A laboratory study

MICHAEL ZANINOVICH

Thesis submitted for the degree of Doctor of Clinical Dentistry (Prosthodontics)

School of Dentistry

The University of Adelaide

TABLE OF CONTENTS

TABLE OF CONTENTS II

PREFACE VIII

ABSTRACT IX

DECLARATION X

ACKNOWLEDGEMENTS XI

SECTION ONE 1

CHAPTER 1 MASTICATORY SYSTEM 2

1.1. Physical and mechanical properties of human teeth 2

1.2. Biomechanical process of mastication 4

CHAPTER 2 TOOTH WEAR 6

2.1. Historical background 6

2.2. Clinical importance of wear of teeth and dental materials 7

2.3. Wear behaviour of enamel and dentine 8

2.4. Aetiology, mechanisms and definitions of tooth wear processes 8

2.5. Attrition 9

2.6. Abrasion 12

2.7. Adhesion 16

2.8. Erosion 17

2.9. Saliva and tooth wear 20

2.10. Prevalence of tooth wear 21

2.11. Tooth wear and Quality of Life 21

CHAPTER 3 WEAR & SURFACE TEXTURE ANALYSIS 22

3.1. Methods of assessment of tooth and restorative material wear 22

3.2. Qualitative wear assessment methods 22

3.2.1. Tooth Wear Index 22

3.2.2. United States Public Health Services criteria 23

3.2.3. Clinical comparative scales 23

3.2.4. Hardness and erosive wear 24

3.3. Quantitative methods of wear analysis 24
3.3.1. Chemical analysis 25
3.3.2. Microradiography 25
3.3.3. Digital image analysis 25
3.3.4. Surface profilometry and mapping 26
3.3.4.1. Mechanical contact profilometer 26
3.3.4.2. Non-contact profilometer 27
3.3.4.2.1. Engineering principles of non contacting optical profilometer 28
3.3.5. Scanning Electron Microscopy 29
3.3.6. Secondary ion mass spectroscopy 31
3.4. Importance of surface texture analysis in dentistry 32
3.5. Amplitude parameters 33
3.5.1. Roughness Amplitude Parameters 34

CHAPTER 4 TRIBOLOGY 41
4.1. Adhesive wear 43
4.2. Abrasive wear 43
4.3. Fatigue wear 46
4.4. Erosive wear 48
4.5. Fretting wear 48

CHAPTER 5 CERAMICS 50
5.1. Historical background 50
5.2. Modern Dental Ceramics 51
5.3. Chemical structures of dental ceramics 51
5.4. Classifications of dental ceramics 54
5.5. Predominately Glass Ceramics 56
5.6. Particle Filled Glass Ceramics 57
5.6.1. Glass Ceramics (subgroup of Particle Filled Glass Ceramics) 57
5.6.1.1. Leucite-reinforced glass ceramic- IPS Empress CAD 58
5.6.1.1.1. Microstructure 58
5.6.1.1.2. Chemical composition 59
5.6.1.1.3. Physical 59
5.6.1.2. Lithium disilicate glass ceramic- IPS e.max Pressed and CAD blocks 60
5.6.1.2.1. Standard chemical composition 60
5.6.1.2.2. Physical properties 61
5.6.1.2.3. Processing and manufacturing 62
5.6.1.2.4. Microstructure lithium disilicate IPS e.max CAD Blocks 62
5.6.1.2.5. Microstructure IPS e.max Press 65
5.7. Polycrystalline ceramics 66
5.7.1. Alumina-based ceramic 67

5.7.2. Zirconia-based ceramic 68

CHAPTER 6 IN-VITRO CERAMIC WEAR TESTING 71

6.1. Considerations of *in vitro* ceramic wear testing 71

6.2. Quantification of wear 71

6.3. Standardising wear simulation research protocols 72

6.4. *In vitro* ceramic wear research test parameters 73

6.4.1. Chewing simulators 73

6.4.1.1. Willytec chewing simulator 73

6.4.2. Loads applied to specimens 74

6.4.3. The force actuator 74

6.4.4. Number of cycles 74

6.4.5. Exogenous abrasive materials 75

6.4.6. Lubrication and pH variations 75

6.4.7. Specimen geometry 76

6.5. The outcome of *in vitro* test parameter variation 77

6.6. Factors influencing enamel wear when opposed by ceramic 77

6.6.1. Ceramic Physical Microstructural Properties 78

6.6.2. Hardness 78

6.6.3. Frictional resistance 79

6.6.4. Fracture toughness 79

6.6.5. Porosity 80

6.6.6. Crystals 81

6.6.7. Ceram Layer 82

6.6.8. Effect of surface finish 83

6.7. Ceramic surface texture and tooth wear 83

CHAPTER 7 MINIMISING SURFACE ROUGHNESS 87

7.1. Ceramic Clinical Polishing 87

7.1.1. Polishing Engineering Principles 87

7.2. Glaze Process 89

7.3. Ceramic surface texture and different surface finishing protocols 90

7.4. Ceramic surface texture and mechanical properties 96

SECTION TWO 99

CHAPTER 8 RATIONALE, AIMS AND HYPOTHESIS 100

8.1. Rationale 100

8.2. Study Aims 100

8.3. Hypothesis 101

CHAPTER 9 MATERIALS AND METHODS 102
9.1. STUDY A 102
9.1.1. Sample preparation 102
9.1.2. Ceramic samples 102
9.1.3. Surface texture altitude parameters 104
9.1.3.1. Double Determinations for surface texture analysis 105
9.1.3.2. Programat CS Furnace 105
9.1.3.3. Slow speed Saw 106
9.1.3.4. Finishing diamonds 108
9.1.3.5. Optrafine polishing system 108
9.1.3.6. Sof-Lex discs 109
9.1.3.7. Glazing 110
9.2. STUDY B 110
9.2.1. Preparation of tooth specimens 110
9.2.2. Mounting specimens of Scanning Electron Microscopy (SEM) studs 111
9.2.3. Assessment of tooth and ceramic wear 114
9.2.3.1. Optical Microscope 3D assessment: Leica MZ16FA stereo microscope 114
9.2.3.2. Three Dimensional Scanning and quantitative results 115
9.2.3.2.1. 3D PIX-4 scanner 116
9.2.3.2.2. "Dr.PICZA" software 116
9.2.3.2.3. Matlab 6.5 117
9.2.3.2.4. Validity and reliability of 3D Scanning and quantitative results 120
9.2.3.3. Scanning Electron Microscopy (SEM) and qualitative results 120
9.2.3.3.1. Fabrication of specimen replicas 120
9.2.3.3.2. Scanning Electron Microscopy (SEM) observations 120
9.2.4. Tooth wear simulator protocol 122
9.2.4.1. Willytec tooth wear design 123
9.2.4.1.1. Method of lubrication 127
9.2.5. Statistical analysis 128
9.2.5.1. Double Determinations for volumetric analysis 128

CHAPTER 10 RESULTS STUDY A – SUFACE ROUGHNESS 130
10.1. SEM analysis 130
10.2. Leica MC 90 light microscope surface texture analysis 135
10.2.1. Surface characteristics before wear simulation 135
10.2.1.1. Leucite-reinforced ceramic 135
10.2.1.2. Lithium disilicate ceramic 137
10.3. Surface finishing protocols and glass ceramics 139

CHAPTER 11 RESULTS STUDY B - WEAR 140
11.1. SEM analysis 140

11.2. Leica MC 90 light microscope surface texture post wear analysis 140
11.2.1. Leucite-reinforced ceramic 140
11.2.2. Lithium disilicate ceramics 141
11.2.3. Surface texture comparison between ceramics after wear simulation 142
11.2.4. Enamel specimens 143
11.3. Volumetric analysis of enamel opposing leucite-reinforced ceramic 144
11.4. Volumetric analysis of enamel opposing lithium disilicate ceramic 146
11.5. Volumetric analysis of enamel when abraded against an enamel specimen 147
11.6. Volumetric loss of enamel when abraded against enamel, leucite-reinforced and lithium disilicate ceramic specimens 147

SECTION THREE 149

CHAPTER 12 DISCUSSION 150
12.1. Importance of ceramic surface texture and effectiveness of finishing methods 150
12.2. Visual appearance of the effect of different finishing protocols 150
12.3. Efficacy of Optrafine finishing system and leucite-reinforced ceramics 151
12.4. Efficacy of Optrafine finishing system and lithium disilicate ceramics 151
12.5. Efficacy of Sof-Lex finishing method 152
12.6. Efficacy of diamond polishing paste finishing method 153
12.7. Surface texture comparison of leucite-reinforced and lithium disilicate ceramic before after wear simulation 153
12.8. Comparison of enamel specimen surface texture before and after wear simulation 153
12.9. Limitations of *in vitro* wear studies 154
12.10. Current *in vitro* study parameters 155
12.11. Influence of ceramic initial surface texture and, finishing methods on opposing enamel wear rate 155
12.12. Influence of ceramic hardness on opposing enamel wear rate 157
12.13. Influence of the ceramic material on opposing enamel wear 158
12.14. Influence of the ceramic microstructure porosity and flaws on opposing enamel wear 159

CHAPTER 13 CONCLUSIONS 161

SECTION FOUR 162

CHAPTER 14 REFERENCES **163**

SECTION FIVE 189

CHAPTER 15 APPENDICES 190

FIGURES.....212

PREFACE

This thesis reports on research completed during my Doctorate of Clinical Dentistry at the School of Dentistry, The University of Adelaide, from January 2010 to December 2012. There were two aims of the research project. Firstly to determine the polishability of modern CAD glass ceramic restorative material and secondly to investigate what influence the surface texture of modern CAD glass ceramics had on the wear rate of opposing enamel tooth structure.

ABSTRACT

There has been a significant increase in the delivery of all ceramic restorations especially with the global explosion of CAD CAM technology. Frequently, the ceramic restorations require refinements to the surfaces with abrasives prior to or after cementation. If adjustments are made to a glazed or non-glazed surface after cementation, only mechanical polishing is an option to restore the surface texture.

Surface roughness of ceramic restorations influences the aesthetics, functional and biological parameters of the restoration [1, 2]. A relatively rough surface can negatively influence the strength [3, 4] and longevity of a restoration [5, 6], increase friction [7] and rate of wear of the restoration [8] and opposing tooth structure [9], promote gingival inflammation [10], adverse soft tissue reactions [11], and the accumulation of stains and plaque on the surface [12-14]. Recent low fusing ceramics have properties which improve the surface characteristics and allows a relatively smoother surface to be achieved either by glazing or polishing [15, 16].

The aim of this study is to increase the understanding of the surface characteristics produced from either glazing or polishing and what impact the surface texture produced from such finishing methods has on the wear rate of opposing enamel. Clinically this will assist with decision making regarding the most effective method to achieve an optimal ceramic surface finish.

DECLARATION

This work contains no material which has been accepted for the award of any other degree or diploma in any other university or other tertiary institution to Michael Zaninovich and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I certify that no part of this work will, in the future, be used in a submission for any other degree or diploma in any university of other tertiary institution without the prior approval of the University of Adelaide.

I give consent to this copy of my thesis when deposited in the University library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library catalogue, the Australasian Digital Theses Program (ADTP) and also through the web search engines, unless permission has been granted by the University to restrict access for a period of time.

MICHAEL ZANINOVICH

Dated this……..day of ……..2013

ACKNOWLEDGEMENTS

I take this opportunity to express my thanks to many people who have provided their assistance in the production of this report and throughout my time at the School of Dentistry, The University of Adelaide.

I would like to sincerely thank my supervisors Professor Lindsay Richards, Dr Tom Berekally and Dr Vladimir Hotinski for their wise and thoughtful advice and support. My benefit from their broad experience and knowledge is greatly appreciated.

My thanks also extends to Winthrop Professor Paul Abbott from the University of Western Australia for allowing me the opportunity to the use of the Willytec chewing simulator, Mr Angus Netting from the Centre of Electron Microscopy and Microstructure Analysis at The University of Adelaide and Geoff Staples and Mr Peter Lobo from Ivoclar Vivadent.

I would like to thank my friends and fellow prosthodontic students Dr Amal Mamdouh Bakey and Dr Sofie Diem Bui for their wonderful friendship. It has been a great pleasure to study with you both.