Fatigue Resistance of Different Customized Crown-Abutment Combinations for Single Implant-Supported Restorations

A thesis submitted for the partial fulfillment of the Doctor Degree of Science requirements in Fixed Prosthodontics, Faculty of Dentistry, Ain Shams University

By Ingy Mohamed Hany Gamal El Din Nouh

B.D.S., Faculty of Dentistry, Ain Shams University, 2008 M.Sc., Faculty of Dentistry, Ain Shams University, 2014



Dr. Amina Mohamed Hamdy

Professor, Fixed Prosthodontics Department, Faculty of Dentistry, Ain Shams University

Dr. Ahmed Ezzat Sabet

Lecturer, Fixed Prosthodontics Department, Faculty of Dentistry, Ain Shams University

Dr. Ahmed Khaled Aboelfadl

Lecturer, Fixed Prosthodontics Department, Faculty of Dentistry, Ain Shams University

Dedication

This work is dedicated to

The Soul of My Dearest Father, the reason for everything I have become,

My Dearest Mother, the one who would dedicate everything in her life just to see me happy,

My Beautiful Hearted Husband, Thank you for baring with me and supporting me throughout my studies.

My little angle and piece of my heart, my son Selim, I hope I can make you proud of me one day.

My precious sister & brother, Thank you for taking care of me.

Acknowledgment

First and foremost, thanks are due to Allah the beneficent and merciful.

I would like to express my greatest gratitude to **Dr. Amina Mohamed Hamdy,** Professor of Fixed Prosthodontics

Department, Faculty of Dentistry, Ain Shams University, for dedicating her time and effort throughout the study and providing me with her valuable advice. Her care and keenness cannot be expressed.

I would also like to express my deepest appreciation to my mentors and my backbones **Dr. Ahmed Ezzat Sabet and Dr. Ahmed Khaled Abo Elfadl**, Lecturers of Fixed Prosthodontics Department, Faculty of Dentistry, Ain Shams University, for their guidance, support, encouragement and help day by day throughout this work. They have taught me everything about fixed prosthodontics since I was an undergraduate and they still do, so a thank you would never be enough.

I also wish to extend my deepest appreciation to our role model in fixed prosthodontics and boss **Dr. Tarek Salah Morsi**, Associate Professor and Head of Fixed Prosthodontics Department, Faculty of Dentistry, Ain Shams University, for sharing his knowledge, support throughout my way and for

always making us feel that we are one family. I learned from him a lot not in only in dentistry, but in all aspects of life.

Finally, I wish to express my sincere thanks to my professors, colleagues and staff members of Fixed Prosthodontics Department, Faculty of Dentistry, Ain Shams University and special thanks to **Dr. Ayman Galal El-demery** for his generosity in teaching me a lot throughout my career, he is truly a one of kind with his passion and devotion in teaching and to my dear colleague **Dr. Kamal Ebeid**, who helped and supported me a lot.

Table of Contents

LIST OF FIGURES	
LIST OF TABLES	VII
INTRODUCTION	1
REVIEW OF LITERATURE	3
SURVIVAL RATES OF IMPLANT-SUPPORTED RESTORATIONS:	
Prefabricated versus customized abutments:	4
CAD/CAM TECHNOLOGY:	
DIFFERENT IMPLANT ABUTMENT MATERIALS:	
1. Titanium abutments:	
2. All-ceramic Abutments:	
A. Alumina abutments:	
B. Zirconia Abutments:	
Problems with zirconia abutments:	10
a) Fracture at the apical part:	
b) Loosening of zirconia abutments:	
c) Long-term performance of zirconia abutments:	
C. Hybrid-Abutments: I. Zirconia abutments with titanium inserts:	12 14
ii. Lithium disilicate abutments with titanium inserts:	14 20
HYBRID-ABUTMENT-CROWN (ONE-PIECE) VERSUS HYBRID-ABUTMENT (TWO-	20
	23
PIECE): FATIGUE RESISTANCE:	
The Willytec chewing simulator:	
FRACTURE RESISTANCE:	
■ STATEMENT OF PROBLEM:	
AIM OF THE STUDY	37
MATERIALS AND METHODS	38
I. Materials:	38
1. Zenostar zirconia blanks:	
2. IPS e.max CAD blocks.	
II. METHODS:	
1. Samples Preparation:	
2. Scanning:	
3. Samples Grouping:	
4. Designing:	
5. Milling:	
6. Sintering and Glazing:	
7. Cementation Protocol:	51 54
7. Comencation i lotocol.	27

A. Cementation of hybrid-abutment-crown (One-piece):	55
B. Cementation of hybrid-abutment plus monolithic crown (two-piece):	63
8. Loading Protocol:	
A. Fatigue Loading:	 68
B. Fracture Load test:	70
9. Data management and analysis:	
RESULTS	74
I. Fatigue Resistance:	74
II. Fracture Resistance:	
A. Normality Test:	
B. Descriptive statistics:	78
C. Analytical Statistics:	79
III. Mode of Failure:	88
A. Failures in titanium inserts:	88
i. Bending of titanium insert:	89
ii. Fractures in titanium inserts:	90
B. Failures in Ceramic part:	93
i. After Chewing Simulation	93
i. After Fracture load test:	95
DISCUSSION	102
SUMMARY AND CONCLUSION	117
REFERENCES	121
ARABIC SUMMARY	

List of Figures

Figure 1: 16mm Translucent zirconia blank.	39
Figure 2: IPS e.max CAD blocks.	41
Figure 3: Implants embedded in polyester resin in brass tubes.	43
Figure 4: Scan body seated and screwed to the implant.	44
Figure 5: Implant, titanium insert and crown-abutment combination	46
Figure 6: Screenshot of hybrid-abutment-crown.	47
Figure 7: Screenshot of hybrid-abutment plus monolithic crown. Red: Abu	ıtment,
Green: Crown	47
Figure 8: Details of Titanium insert design.	48
Figure 9: Schematic diagram showing the dimensions of: A. Hybrid-ab (two-piece). B. Hybrid-abutment-crown (one-piece) in a bucco-lingual dimensions.	nension
Figure 10: Schematic diagram showing the dimensions of A. Hybrid-ab (two-piece). B. Hybrid-abutment-crown (one-piece) in a mesio-distal dim	ension.
Figure 11: Group Z1 after sintering.	53
Figure 12: Group L2 after crystallization.	53
Figure 13: Materials used for the cementation procedure.	54
Figure 14: Titanium insert before & after sandblasting.	
Figure 15: Application of 5% hydrofluoric acid gel to the bonding sur group L1 samples.	
Figure 16: Non-bonding surfaces covered with acrylic resin and black ma	
bonding surfaces before sandblasting in group Z1.	57
Figure 17: A sample in group Z1 after sandblasting and resin removal.	
Figure 18: Application of Monobond Plus to hybrid-abutment-crown, a	sample
from L1 group.	58
Figure 19: Application of Monobond Plus to titanium insert.	58

Figure 20: Application of Multilink hybrid abutment cement to titanium insert.
59
Figure 21: Cementation of hybrid-abutment-crown to titanium insert 59
Figure 22: Plastic sprue inserted in screw channel and micro-brush used to
remove excess cement at the margins60
Figure 23: Application of air-inhibiting gel (liquid strip) at the margins while
cementing under loading apparatus60
Figure 24: Electronic implant torque controller to calibrate the torque wrench
before use61
Figure 25: Controlled screwing of hybrid abutment crowns to implant model.62
Figure 26: Hybrid-abutment-crown after screwing and sealing screw access
channel with light-cured composite. A: Occlusal View. B: Proximal View 62
Figure 27: Application of Monobond Plus to hybrid-abutment. A sample from
L2 group63
Figure 28: Cementation of hybrid-abutment to titanium insert. A sample from Z2
group63
Figure 29: Sealing of screw access channel64
Figure 30: Bonding surfaces of hybrid-abutment and crown covered with black
marker and non-bonding surfaces covered with acrylic resin before sandblasting,
group Z265
Figure 31: Etching of bonding surface of the crowns, group L266
Figure 32: Application of Monobond Plus to bonding surface of crown, group
L266
Figure 33: Application of Monobond Plus to the bonding surface of hybrid-
abutment, group L266
Figure 34: Application of SpeedCEM Plus inside the crown67
Figure 35: Cementation of monolithic crown onto hybrid-abutment (two-piece).
67
Figure 36: Close-up view on one sample from group Z1 in the chewing simulator.
68

Figure 37: Willytec chewing simulator69
Figure 38: Software screen displaying the number of cycles done, remaining and
frequency of cycles69
Figure 39: Sample loaded in the universal testing machine70
Figure 40: Loading point marked with articulating paper before static loading.
71
Figure 41: Close up of loaded sample71
Figure 42: Normality Q-Q plots for the 4 groups77
Figure 43: Box plot showing fracture resistance median values of zirconia and
lithium disilicate crown-abutment combinations80
Figure 44: Box plot showing fracture resistance median values of hybrid-
abutment-crowns and hybrid-abutment82
Figure 45: Box plot showing the fracture resistance median values of different
crown-abutment combinations using two materials and two designs84
Figure 46: Pairwise comparison test showing the intercation between the four
groups. Yellow lines indicate significant differences, black lines indicate no
significant differences86
Figure 47: Load to displacement curve showing the amount of bending in μm (y-
axis) in relation to load applied (x-axis)89
Figure 48: Fracture in titanium insert after chewing simulation in group L291
Figure 49: Close up of cracks in titanium insert under light microscope using
35X magnification after chewing simulation, group Z191
Figure 50: Bending and cracks in titanium insert seen under light optical
microscope 10X after fracture load test, group Z292
Figure 51: Close up view on cracks in titanium insert seen under light optical
microscope using magnification 20X after fracture load test, group Z292
Figure 52: Chipping at the bucco-cervical margin in group L1 after chewing
simulation94
Figure 53: Fracture at the bucco-cervical margin in group L2 after chewing
simulation. Cracks in titanium insert is also seen 94

Figure 54: Adhesive failure between titanium insert and ceramic abutment.
Cement remnants seen on both interfaces95
Figure 55: Fracture of zirconia hybrid-abutment-crown into 2 halves after
fracture load test96
Figure 56: Fracture of buccal cusp in zirconia hybrid-abutment-crown group. 96
Figure 57: Zirconia hybrid-abutment-crown fractured into 3 fragments97
Figure 58: Bending of zirconia hybrid-abutment-crown towards the buccal
surface with no fractures detected in the ceramic parts97
Figure 59: Fracture of monolithic crown into multiple fragments, intact
abutment98
Figure 60: Fracture of abutment and monolithic crowns into multiple fragments.
98
Figure 61: Fracture of lithium disilicate hybrid-abutment-crown accompanied
with fractures in titanium insert at the bucco-cervical margin99
Figure 62: Fracture of lithium disilicate hybrid-abutment-crown into multiple
fractures 99
Figure 63: Fracture of lithium disilicate hybrid-abutment and monolithic crown
into multiple fractures accompanied with bending in titanium insert 100
Figure 64: Bar chart showing different failure modes in each group after chewing
simulation and after fracture load test 101

List of Tables

Table 1: Materials used in the study	38
Table 2: Standard composition of Zenostar blanks.	39
Table 3: Technical data of Zenostar blanks.	40
Table 4: Standard composition of IPS e.max CAD.	41
Table 5: Technical data of IPS e.max CAD.	42
Table 6: Experimental Factorial Design	45
Table 7: Sintering cycle for the zirconia group.	52
Table 8: Crystallization cycle for lithium disilicate.	52
Table 9: Surface Treatment	54
Table 10: Fisher exact test showing the relation between material and design	on
the fatigue resistance of crown-abutment combinations.	74
Table 11: Mode of Failure after chewing simulation	75
Table 12: Test of Normality for the different crown-abutment combinations.	
Table 13: Descriptive statistics for fracture resistance median and IQR value	ies.
	78
Table 14: Median and IQR values of fracture resistance of crown-abutm	ent
combinations regardless the design.	79
Table 15: Median and IQR values of fracture resistance of crown-abutm	ent
combinations regardless the material.	81
Table 16: Effect of interaction of material and design on fracture resistance.	83
Table 17: Kruskal- Wallis testing the null hypothesis.	85
Table 18: Pairwise comparison test to determine the significant differen	ces
between the groups.	86
Table 19: Failure in titanium inserts	
Table 20: Failures in ceramic parts after chewing simulation.	93
Table 21: Failure modes after chewing simulation and after fracture load t	est.
1	101