

Fracture Resistance of Endodontically Treated Upper Premolars with Different Cavity Designs

Thesis submitted to the Department of Operative Dentistry,
Faculty of Dentistry, Ain Shams University, in partial
fulfillment of the requirements of the PhD Degree in Operative
Dentistry

By

Heba Mohammad Ahmad Al-Sanafawy

B.D.S. Ain Shams University, 2008

M.Sc, Ain Shams University, 2014

Supervisors

Dr. Farid Mohammed Sabry El-Askary

Professor of Operative Dentistry
Faculty of Dentistry
Ain Shams University

Dr. Tarek Salah El-Din Hussin

Professor of Dental Biomaterials
Faculty of Dentistry
Ain Shams University

Dedication

To my family; without their love, support and encouragement throughout my life, I would not be where I am today.

Acknowledgment

I would like to express my deep and sincere appreciation to my supervisors:

Dr. Tarek Salah El-Din Hussin, Professor of Dental Biomaterials, Faculty of Dentistry, Ain Shams University, for his support, patience, and encouragement. His valuable guidance, help and advice made this thesis possible.

Special thanks to my dear friends **Dr. Dena Safwat** and **Dr. Mohammed Nasser**, Lecturers of Operative Dentistry, Faculty of Dentistry, Ain Shams University for their sincere unlimited help and support during every step of this thesis.

Last but not the least I would love to express my deep gratitude to **Dr. Khaled Aly Nour**, Associate Professor, PhD Course Director and Head of Operative Dentistry Department, Faculty of Dentistry, Ain Shams University for his mentorship and guidance throughout the path of my degree.

Table of contents

List of tables	ii
List of figures	v
Introduction	1
Review of literature	4
Aim of the study	28
Materials and methods	29
Results	70
Discussion	112
Summary and Conclusions	118
References	121
Arabic summary	

List of tables

Table 1. Materials, compositions, manufacturers and lot number.	29
Table 2. Levels of investigation.	33
Table 3. Interaction among variables.	33
Table 4. Criteria for inclusion and exclusion of the premolars in the study.	36
Table 5. Mean fracture load \pm Standard Deviations in MPa for fracture resistance of all groups.	72
Table 6. Mean fracture load \pm standard deviation in MPa of the fracture resistance of endodontically treated maxillary premolars and <i>p</i> value (effect of restoration technique).	73
Table 7. Mean fracture load \pm standard deviation in MPa of the fracture resistance of endodontically treated maxillary premolars and <i>p</i> value (effect of cavity design).	75
Table 8. Mean fracture load \pm standard deviation in MPa of the fracture resistance of endodontically maxillary premolars and <i>p</i> value. (effect of reinforcement)	76
Table 9. Effect of interaction among variables on the fracture resistance of endodontically treated maxillary premolars.	77
Table 10. Failure mode analysis following the classification proposed by Burke et al. and binary logistic regression test results.	80

Table 11. The percentage of restorable fracture within each level and binary logistic regression test results.	81
Table 12. Mean outward cuspal deflection \pm standard deviations in μm of endodontically treated maxillary premolars.	90
Table 13. Mean outward cuspal deflection \pm standard deviation in μm of endodontically treated maxillary premolars (effect of restoration technique).	91
Table 14. Mean outward cuspal deflection \pm standard deviation in μm of endodontically treated maxillary premolars (effect of restoration technique).	93
Table 15. Mean outward cuspal deflection \pm standard deviation in μm of endodontically treated maxillary premolars (effect of reinforcement).	94
Table 16. Effect of interaction among variables on outward cuspal deflection of endodontically treated maxillary premolars.	95
Table 17. Mean internal adaptation \pm standard deviations in pixel% on the internal adaptation.	98
Table 18. Mean internal adaptation \pm standard deviations in pixel% on the internal adaptation (effect of restoration technique).	99
Table 19. Mean internal adaptation \pm Standard deviations in pixel% on the internal adaptation (effect of cavity design).	100

Table 20. Mean internal adaptation \pm standard deviation in pixel % of the internal adaptation of endodontically treated maxillary premolars (effect of reinforcement).	102
Table 21. Effect of interaction among variables on the internal adaptation of maxillary premolars.	102
Table 22. Correlation of the results of all the tested variables.	107
Table 23. Correlation within direct restoration groups.	108
Table 24. Correlation within indirect restoration groups.	108
Table 25. Correlation within the no reduction groups.	108
Table 26. Correlation within the palatal reduction groups.	109
Table 27. Correlation within the palatal-buccal reduction groups.	109
Table 28. Correlation within the non-reinforced groups.	110
Table 29. Correlation within the reinforced groups.	110
Table 30. The reference group results.	111

List of figures

Figure 1. A diagram representing measuring the length of the premolars included in the study.	34
Figure 2. A diagram representing the marking points used to determine the coronal width.	35
Figure 3. Determination of crestal bone level and long axis.	38
Figure 4. Premolar after dipping the root in the wax to the crestal bone level.	39
Figure 5. The paralleling device with the tooth held along its long axis.	40
Figure 6. The split rubber mold, held on the base of the paralleling device.	41
Figure 7. Periodontal ligament simulation using polyether impression material.	42
Figure 8. Resin composite crown duplicate.	43
Figure 9. A diagram representing the guide lines for direct cavity preparation.	44
Figure 10. The device used to hold the high speed hand piece during preparation of the cavities.	45
Figure 11. A diagram representing the guide lines for indirect cavity preparation.	46
Figure 12. Checking the parallelism of the diamond bur using a right-angled triangle.	43

Figure 13. Preparation of the stents to record the proximal and the occlusal anatomy of the crown duplicate recording using Registrado Clear.	48
Figure 14. The resin composite crown duplicate for each increment.	49
Figure 15. Determining the level of insertion of the glass fibre bundle.	50
Figure 16: The assembly of the acrylic block and the tooth embedded in periodontal ligament simulation placed on the base and moved freely.	52
Figure 17. A diagram showing resin composite incrimination technique. a, restorations reinforced using resin-impregnated glass fibres and b, non-reinforced restorations.	54
Figure 18. Using the Teflon tape and the Registrado stent to standardize the resin composite increments.	55
Figure 19. Measuring the internal width of the cavity to determine the required length of resin-impregnated glass fibres.	56
Figure 20. Preparation of the resin-impregnated fibres to be placed in the cavity.	56
Figure 21. Preparation of the silicone die for indirect restoration.	58
Figure 22. The Pressure jig used to deliver load during the cementation of indirect restorations.	59

Figure 23. The restored premolar bone simulation assembly mounted on the universal testing machine.	61
Figure 24. Diagram representing different types of failure according to the modified burke et al. calcification.	62
Figure 25. Test set-up for outward cuspal deflection evaluation using laser speckles correlation.	63
Figure 26. Diagram representing the cuspal deflection testing setup.	64
Figure 27. The photo recorded for a ruler under the same magnification and zooming conditions.	64
Figure 28. The laser speckles pattern and the lines drawn to mark the reference measuring points.	65
Figure 29. A representative graph used to measure the distance between any two chosen color intensity peaks.	66
Figure 30. The acrylic block mounted on the jig of the IsoMet cutting machine.	67
Figure 31. Bar chart illustrating the mean fracture load in MPa for all the groups.	71
Figure 32. Bar chart illustrating the mean fracture load in MPa for different restoration technique (direct/ indirect).	73
Figure 33. Bar chart illustrating the mean fracture load in MPa for different cavity designs (no reduction, palatal reduction and palatal-buccal reduction).	75

Figure 34. Bar chart illustrating the mean fracture load in MPa for fracture resistance (no fibres/fibres).	76
Figure 35. Bar chart illustrating the percentage of restorable and unrestorable fractures in each group.	78
Figure 36. Representative image for type I fracture, direct restoration with palatal cusp reduction (PCR) and fibres reinforcement.	82
Figure 37. Representative image for type I fracture, indirect restoration with no cusp reduction and glass fibres reinforcement.	83
Figure 38. Representative image for type II fracture, direct restoration with no cusp reduction.	83
Figure 39. Representative image for type II fracture, direct restoration with palatal cusp reduction and glass fibres reinforcement.	84
Figure 40. Representative image for type II fracture, direct restoration with no cusp reduction and glass fibres reinforcement.	84
Figure 41. Representative image for type III fracture, indirect restoration with palatal cusp reduction, the fracture exposing the reinforcing fibres (f).	85
Figure 42: Representative image for type III fracture, b: indirect restoration with palatal-buccal cusp reduction (PCR-BCR).	85

Figure 43: Representative images for type III fracture, direct restoration with palatal-buccal cusp reduction.	86
Figure 44: Representative image for type IV fracture, direct restoration with palatal cusp reduction.	86
Figure 45. Representative image for type IV fracture, direct restoration with palatal-buccal cusp reduction.	87
Figure 46. Representative image for type IV fracture, direct restoration with no cusp reduction.	87
Figure 47. Bar chart illustrating the mean outward cuspal deflection in μm .	89
Figure 48. Bar chart illustrating the mean outward cuspal deflection in μm for different restoration technique (direct/ indirect).	91
Figure 49. Bar chart illustrating the mean outward cuspal deflection in μm for different cavity designs.	93
Figure 50. Bar chart illustrating the mean outward cuspal deflection in μm for reinforced and non-reinforced groups.	94
Figure 51. Bar chart illustrating the mean internal adaptation in percentage.	97
Figure 52. Bar chart illustrating the mean internal adaptation in pixel% for different restoration technique (direct/ indirect).	99
Figure 53. Bar chart illustrating the mean internal adaptation in pixel % for different cavity designs.	100

<p>Figure 54. Bar chart illustrating the mean internal adaptation in pixel% for the effect of reinforcement on the internal adaptation.</p>	101
<p>Figure 55. Stereomicrograph of cut section in MOD cavity of endodontically treated premolar with direct restoration and palatal cusp reduction without fibre reinforcement showing dye penetration along the wall and the cavity corner whereas the area of cusp reduction is free from dye penetration.</p>	103
<p>Figure 56. Stereomicrograph of cut section in MOD cavity of endodontically treated premolar with a direct restoration with cusp reduction showing dye penetration along the wall, the cavity corner and the junction between the cusp reduction and the wall.</p>	104
<p>Figure 57. Stereomicrograph of cut section in MOD cavity of endodontically treated premolar with indirect restoration with resin-impregnated glass fibres reinforcement free from dye penetration.</p>	105
<p>Figure 58. Stereomicrograph of cut section in MOD cavity of endodontically treated premolar with indirect restoration showing dye penetration between the resin cement and the composite restoration and along the cavity corner.</p>	105
<p>Figure 59. Stereomicrograph of cut section in MOD cavity of endodontically treated premolar with direct restoration with no cusp reduction showing dye penetration along the wall.</p>	106

<p>Figure 60. Stereomicrograph of cut section in MOD cavity of endodontically treated premolar with direct restoration and fiber reinforcement showing dye penetration at the junction between the cavity wall and the glass fibres also at the cavity corner.</p>	106
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-----