

# **The Study of Some Properties of Silorane Composites as Compared to those of Conventional Resin Composites.**

**Thesis  
Submitted to the faculty of Dentistry  
Ain-Shams University,  
in partial fulfillment of the requirements for the Master  
Degree in Dental Biomaterials.**

**By  
Tarek Ahmed Ahmed  
B.D.S 2002  
Demonstrator in the Biomaterials department  
Faculty of dentistry  
Ain-Shams University**

**Ain-Shams University  
2010**

# **Supervisors**

***Prof. Dr. Ghada Atef Alian***

Professor and Head of Biomaterials Department  
Faculty of Dentistry  
Ain- Shams University

***Dr. Amr Sherif Fawzy***

Lecturer of Biomaterials  
Dental Biomaterials Department  
Faculty of Dentistry  
Ain-Shams University

Ain-Shams University  
2010

# *List of Contents*

<b>Subject</b>	<b>Page</b>
<b>INTRODUCTION</b>	<b>1</b>
<b>REVIEW OF LITERATURE</b>	
<b>1- Resin-based restorative composites.</b>	<b>4</b>
<b>1.1. Historical background.</b>	<b>4</b>
<b>1.2. Composition.</b>	<b>5</b>
<b>1.3. Classifications.</b>	<b>8</b>
<b>1.4. General properties.</b>	<b>10</b>
<b>2- Water sorption and solubility of resin-based restorative composites.</b>	<b>11</b>
<b>2.1. Water sorption.</b>	<b>12</b>
<b>2.2. Water solubility.</b>	<b>14</b>
<b>3- Strength properties of resin-based restorative composites.</b>	<b>15</b>
<b>3.1 Tensile strength.</b>	<b>16</b>
<b>3.2 Flexural strength.</b>	<b>17</b>

<b>4- Fracture toughness of resin-based restorative composites.</b>	<b>19</b>
<b>4.1 Overview.</b>	<b>19</b>
<b>4.2 Modes of fracture.</b>	<b>20</b>
<b>4.3 Methods for testing fracture toughness.</b>	<b>21</b>
 <b>5- Polymerization shrinkage and stresses of resin-based restorative materials.</b>	 <b>23</b>
<b>5.1 Overview.</b>	<b>23</b>
<b>5.2 Phases of polymerization shrinkage.</b>	<b>25</b>
<b>5.3 Origin of stress in polymerizing dental composite.</b>	<b>25</b>
<b>5.4 Factors involved in the development of polymerization shrinkage stress in resin-based composites.</b>	<b>27</b>
<b>5.4.1 Volumetric shrinkage of the composite due to polymerization.</b>	<b>28</b>
<b>5.4.2 Visco-elastic behavior.</b>	<b>30</b>
<b>5.4.3 Restriction imposed on composite shrinkage.</b>	<b>31</b>
<b>5.5 Methods for measuring polymerization shrinkage.</b>	<b>33</b>
<b>5.5.1 Dilatometry.</b>	<b>33</b>
<b>5.5.2 Optical method.</b>	<b>34</b>
<b>5.5.3 The bonded disk method.</b>	<b>34</b>
<b>5.5.4 Linometer.</b>	<b>34</b>

<b>5.6</b>	<b>Methods for measuring polymerization stress and strain.</b>	<b>35</b>
5.6.1	Force transducer (Tensilometer).	35
5.6.2	Photo-elastic analysis.	36
5.6.3	Finite element analysis.	37
5.6.4	Computational micromechanics.	38
5.6.5	Ring slitting method.	38
5.6.6	Strain gauges.	38
<b>5.7</b>	<b>Strategies to reduce polymerization shrinkage.</b>	<b>40</b>
5.7.1	Reduction of reactive sites per unit volume.	40
5.7.2	The use of alternative curing techniques.	41
5.7.3	Attempts done to control polymerization rate.	43
5.7.4	The use of low-elastic modulus liners as stress-breaking layers.	44
5.7.5	Experimental attempts to modify the composition of resin-based composites.	45
<b>6-</b>	<b>Siloranes.</b>	
<b>6.1.</b>	<b>Overview.</b>	<b>50</b>
<b>6.2.</b>	<b>Composition.</b>	<b>52</b>
6.2.1.	The silorane resin.	52
6.2.2.	The initiating system.	52
6.2.3.	The fillers.	53
6.2.4.	The silane layer.	54

<b>AIM OF THE STUDY.</b>	<b>55</b>
<b>MATERIALS AND METHODS.</b>	<b>56</b>
<b>RESULTS.</b>	<b>72</b>
<b>DISCUSSION.</b>	<b>82</b>
<b>SUMMARY AND CONCLUSIONS.</b>	<b>92</b>
<b>REFERENCES.</b>	<b>96</b>
<b>ARABIC SUMMARY.</b>	

## *List of Contents*

<b>Subject</b>	<b>Page</b>
<b>INTRODUCTION</b>	<b>1</b>
<b>REVIEW OF LITERATURE</b>	
<b>1- Resin-based restorative composites.</b>	<b>4</b>
<b>1.5. Historical background.</b>	<b>4</b>
<b>1.6. Composition.</b>	<b>5</b>
<b>1.7. Classifications.</b>	<b>8</b>
<b>1.8. General properties.</b>	<b>10</b>
 <b>2- Water sorption and solubility of resin-based restorative composites.</b>	 <b>11</b>
<b>2.1. Water sorption.</b>	<b>12</b>
<b>2.2. Water solubility.</b>	<b>14</b>
 <b>3- Strength properties of resin-based restorative composites.</b>	 <b>15</b>
<b>3.1 Tensile strength.</b>	<b>16</b>
<b>3.2 Flexural strength.</b>	<b>17</b>

<b>4- Fracture toughness of resin-based restorative composites.</b>	<b>19</b>
<b>4.1 Overview.</b>	<b>19</b>
<b>4.2 Modes of fracture.</b>	<b>20</b>
<b>4.3 Methods for testing fracture toughness.</b>	<b>21</b>
<b>5- Polymerization shrinkage and stresses of resin-based restorative materials.</b>	<b>23</b>
<b>5.1 Overview.</b>	<b>23</b>
<b>5.2 Phases of polymerization shrinkage.</b>	<b>25</b>
<b>5.3 Origin of stress in polymerizing dental composite.</b>	<b>25</b>
<b>5.4 Factors involved in the development of polymerization shrinkage stress in resin-based composites.</b>	<b>27</b>
<b>5.4.1 Volumetric shrinkage of the composite due to polymerization.</b>	<b>28</b>
<b>5.4.2 Visco-elastic behavior.</b>	<b>30</b>
<b>5.4.3 Restriction imposed on composite shrinkage.</b>	<b>31</b>
<b>5.5 Methods for measuring polymerization shrinkage.</b>	<b>33</b>
<b>5.5.1 Dilatometry.</b>	<b>33</b>
<b>5.5.2 Optical method.</b>	<b>34</b>
<b>5.5.3 The bonded disk method.</b>	<b>34</b>
<b>5.5.4 Linometer.</b>	<b>34</b>



<b>5.6</b>	<b>Methods for measuring polymerization stress and strain.</b>	<b>35</b>
5.6.1	Force transducer (Tensilometer).	35
5.6.2	Photo-elastic analysis.	36
5.6.3	Finite element analysis.	37
5.6.4	Computational micromechanics.	38
5.6.5	Ring slitting method.	38
5.6.6	Strain gauges.	38
<b>5.7</b>	<b>Strategies to reduce polymerization shrinkage.</b>	<b>40</b>
5.7.1	Reduction of reactive sites per unit volume.	40
5.7.2	The use of alternative curing techniques.	41
5.7.3	Attempts done to control polymerization rate.	43
5.7.4	The use of low-elastic modulus liners as stress- breaking layers.	44
5.7.5	Experimental attempts to modify the composition of resin-based composites.	45

## **6- Siloranes.**

<b>6.1.</b>	<b>Overview.</b>	<b>50</b>
<b>6.3.</b>	<b>Composition.</b>	<b>52</b>
6.3.1.	The silorane resin.	52
6.3.2.	The initiating system.	52
6.3.3.	The fillers.	53

6.2.4. The silane layer.	54
<b>AIM OF THE STUDY.</b>	<b>55</b>
<b>MATERIALS AND METHODS.</b>	<b>56</b>
<b>RESULTS.</b>	<b>72</b>
<b>DISCUSSION.</b>	<b>82</b>
<b>SUMMARY AND CONCLUSIONS.</b>	<b>92</b>
<b>REFERENCES.</b>	<b>95</b>
<b>ARABIC SUMMARY.</b>	

## ***Lists of Tables***

	Page
<b>Table (1) Description of the two materials used in the study.....</b>	<b>56</b>
<b>Table (2) Mean and standard deviation values of the degree of expansion, shrinkage strains after 40 seconds and shrinkage strains after 340 seconds for both Z250 and P90.....</b>	<b>73</b>
<b>Table (3) Mean and standard deviation values of water sorption and solubility, diametral compression test, flexural strength and fracture toughness for both Z250 and P90.....</b>	<b>76</b>

## *List of Figures*

	Page
<b>Figure (1)    Chemical formula of Bis-GMA.....</b>	<b>6</b>
<b>Figure (2)    Chemical formula of TEGDMA.....</b>	<b>6</b>
<b>Figure (3)    Chemical formula of UDMA.....</b>	<b>7</b>
<b>Figure (4)    Structure of siloxane, oxirane and silorane.....</b>	<b>50</b>
<b>Figure (5)    Photoinitating system for cationic cure.....</b>	<b>53</b>
<b>Figure (6)    Light curing of an unpolymerized specimen inside the                  mold with the strain gauge in place to monitor the                  polymerization strains.....</b>	<b>59</b>
<b>Figure (7)    The Teflon mold used for the preparation of the                  specimens for water sorption and solubility                  testing.....</b>	<b>61</b>
<b>Figure (8)    The mold used for the preparation of the specimens for                  tensile strength testing.....</b>	<b>64</b>
<b>Figure (9)    The experimental setup used for tensile strength testing.....</b>	<b>65</b>
<b>Figure (10)   The mold used for preparation of the specimens for the                  flexural strength testing.....</b>	<b>66</b>

<b>Figure (11)</b>	<b>The experimental setup used for flexural strength testing...</b>	<b>68</b>
<b>Figure (12)</b>	<b>The mold used for the preparation of the specimens for fracture toughness testing.....</b>	<b>69</b>
<b>Figure (13)</b>	<b>The experimental setup used for fracture toughness testing.</b>	<b>70</b>
<b>Figure (14)</b>	<b>Representative curves of the variation in the polymerization strains vs. recording time, as measured by The strain gauge, for both of the microhybrid resin-based restorative composite (Z250) and the silorane-based restorative composite (P90).....</b>	<b>72</b>
<b>Figure (15)</b>	<b>Box &amp; whisker plot for the mean and standard deviation values of the degree of expansion in <math>\mu\text{m}</math> for Z250 and P90 at the beginning of polymerization.....</b>	<b>74</b>
<b>Figure (16)</b>	<b>Box &amp; whisker plot for the mean and standard deviation values of the polymerization shrinkage strain in <math>\mu\text{m}</math> for Z250 and P90 after 40 seconds of polymerization.....</b>	<b>75</b>
<b>Figure (17)</b>	<b>Box &amp; whisker plot for the mean and standard deviation values of the polymerization shrinkage strain in <math>\mu\text{m}</math> for Z250 and P90 after 340 seconds of polymerization.....</b>	<b>75</b>
<b>Figure (18)</b>	<b>Box &amp; whisker plot for the mean and standard deviation values of water sorption test in <math>\mu\text{gm}/\text{mm}^3</math> for Z250 and P90.....</b>	<b>77</b>

<b>Figure (19)</b>	<b>Box &amp; whisker plot for the mean and standard deviation values of water solubility test in <math>\mu\text{gm}/\text{mm}^3</math> for Z250 and P90.....</b>	<b>78</b>
<b>Figure (20)</b>	<b>Box &amp; whisker plot for the mean and standard deviation values of diametral compression test for tension in MPa for Z250 and P90.....</b>	<b>79</b>
<b>Figure (21)</b>	<b>Box &amp; whisker plot for the mean and standard deviation values of flexure strength in MPa for Z250 and P90.....</b>	<b>80</b>
<b>Figure (22)</b>	<b>Box &amp; whisker plot for the mean and standard deviation values of fracture toughness in MPa. <math>\text{M}^{1/2}</math> for Z250 and P90.....</b>	<b>81</b>

# **Introduction**