Research on bonding strength to the surface of tooth with usage of scratch test method

This study was conducted at:
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Introduction:
In dentistry different methods and tools are used to work with cavities. The methods used mechanical slow and speed drilling turbines and hand pieces, air abrasion devices, laser and chemical methods. In the literature and studies we can meet the views on tooth surface and bonding strength after the treatment by air abrasion. The bonding strength is a major issue for the quality of dentistry works and therefore has been an issue which has drawn attention for many scientific researches to develop methods for stronger adhesion – bonding strength.

Manufactures of air abrasion devices claim that by using air abrasion the adhesion and bonding strength is significant better. Furthermore manufacturers claim several other advantages by using air abrasion such as avoiding any micro fractures during treatment avoiding any secondary caries to develop and many other advantages by using air abrasion.

This independent study although only will test and compare 3 methods of cavity preparation:
1. Traditional drilling method
2. Air Abrasion with relatively high pressure and adding water spray using 2 different sizes of aluminum oxide powder 29 micron and 45 micron
3. Low pressure Air Abrasion and dry working conditions using 2 different sizes of aluminum oxide powder 29 micron and 45 micron

Above 3 methods were tested on 3 different bonding materials:
- Prime nbond
- Exite Ivoclar
- 3M Edsper

The research was conducted with the help of microcombi tester and a scanning by electron microscope.
Summary:

- This study confirmed the validity of the assumptions presented by manufacturers to air abrasion. In fact the bonding strength for different bond materials on the tooth surface is significant higher than for conventional drilling method using a turbine.

- From table No. 1 the empiric data shows that the bonding strength increases from 72 % - 117 % between using Sandman Futura low pressure air abrasion and traditional drilling method. These figures shows that the increase is so significant that is will have major impact on dental clinic works using this method. This result also confirms many previous studies documenting this fact. E.g. a study from Leuven Catholic University, Dental Department, 2007-2008 by Professor Van Meerbeck and Professor Lambrechts.

- Furthermore this study also shows significant higher bonding strength using low air abrasion than high pressure air abrasion adding water spray.

- The conclusions are based on the empiric data from this study.

- The preferred method for treatment of tooth surface is using air abrasion without adding water spray.

- Secondly the study shows that using the 45 micron particle size give a stronger bonding surface but using 29 micron still gives a far stronger binding strength that the other methods and can reduce any possible sensibility.

- Furthermore by using the air abrasion method the risk of micro fractures are eliminated avoiding possible well known future complications such as secondary caries and loss of fillings.

Research of the bonding strength on tooth surface using a scratch test method.

In dentistry different methods and tools are used to work with cavities. The methods used mechanical slow and speed drilling turbines and hand pieces, air abrasion devices, laser and chemical methods. During the preparation of the cavity in the tooth using air abrasion device a pressurized stream of air mixed with particles of alumina oxide powder comes out of the nozzle. Using the
principles for kinetic energy, it is possible effectively to excavate and prepare cavities for filling procedures.

**Research methodology:**

The samples used for the study were extracted teeth which were placed in sterile bags and stored in a refrigerator at about 4 ° C. Before starting the test, they were embedded in acrylic basis to get a parallel surface to facilitate the exact measurements.

The selected 3 methods for cavity preparations:

- Air abrasion - low pressure system. Manufacturer device – Sandman Futura
- Air abrasion - system with added water spray – Aquacut Quattro
- High speed turbine

For the different methodologies following procedures were followed:

- Air abrasion – low-pressure system around 3 BAR - surface preparation time 20 second
- Air abrasion system with added water spray - operating pressure of about 6.5 BAR - surface preparation time 20 seconds
- Turbine preparation with constant speed - working time 20 seconds

**Description of the test method**

The adhesion tests were conducted using the method of a scratch-test performed on an open platform equipped with micro-kombi tester built by SWISS company CSM in accordance with the norm used for such devices. The tests were made using the features of the penetrator - Rockwell diamond cone - with a gradual increase in the normal force loading the penetrator to the prepared surface.
Critical force, which is a measure of adhesion, is the smallest normal force resulting in the loss of adhesion of the coating to the substrate - delamination of the bond placed on the surface. To estimate the value of the critical force during the tests changes of acoustic emission signals were recorded, also the friction force and the coefficient of friction and microscopic observations were made on an scanning optical microscope, which is an integral part of the Platform.

The study was performed at the growing strength while increasing loading of the cone from 0.03 ÷ 30N and work with the following parameters:

- load speed - 10N/min,
- the speed of the table - 0.17 mm / min,
- the length of the scratch - 0.5 mm

For each tooth analysis were made after two measurements performed.

Drawing no 1a) model methods scratch

Drawing no 1b) open platform CSM equipped with micro-kombi tester
The results of the test indicate a diverse adhesion of the analyzed bonds to tooth enamel. This is evidenced by the values of individual parameters defined on the basis of measurements - Table 1, Figure 2 ÷ 13. During the test was discovered the influence of the powder used and its grain on adhesion to tooth enamel. Based on the obtained results, the best characterized adhesion was found using the type of Sandman powders, where the values of critical load (Lc) was in the range of 20.6 ÷ 26.2 = N (Table 1, Figure 2, 3, 7, 8, 11, 12).

On the other hand the weakest adhesion was observed during the test of the samples treated by powder AquaCut where the forces were measured between Lc = 16.7 ÷ 21.0 N (Table 1, Figure 4, 9, 13).

Regardless of the method used for improved adhesion of the bond, better surface bonding was found in the samples treated with powder with a larger grain size (45mq) - Table 1, Fig 3, 8, 12.

The smallest adhesion was characterized by tooth prepared with the usage of turbine, where the value of the critical force was estimated: Lc = 11.8 N (Prime_nbond_densply), Lc = 12.3 N (Exite_ivoclar_vivadent), Lc = 17.7 N (3M_Esper_AdgerSingleBond) - Table 1, Figure 5, 6, 10.

Regardless of the bond used during the study there was no acoustic emission signal found which indicates that the energy of the bond between the coating and the substrate was too low to hear a distress signal.
<table>
<thead>
<tr>
<th>Method used for preparation of the samples</th>
<th>Force for total delamination of surface during the test Fn, N</th>
<th>Strength each bonding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Attempt 1</td>
<td>Attempt 2</td>
</tr>
<tr>
<td>Prime_nbond_aquacut_29mq</td>
<td>17,5</td>
<td>15,9</td>
</tr>
<tr>
<td>Prime_nbond_sandman_29mq</td>
<td>22,6</td>
<td>18,6</td>
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<tr>
<td>Prime_nbond_sandman_45mq</td>
<td>26</td>
<td>24,9</td>
</tr>
<tr>
<td>Prime_nbond_densply turbine</td>
<td>10,1</td>
<td>13,4</td>
</tr>
<tr>
<td>Exite_ivoclar_sandman_29mq</td>
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<td>19,7</td>
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<td>19,8</td>
</tr>
<tr>
<td>3M_edesper_AdgerSingleBond turbine</td>
<td>16,7</td>
<td>18,7</td>
</tr>
</tbody>
</table>

Table no 1: The results of the sheer adhesion bonding strength measured with scratch test method
Drawing no 2. The results of bonding tests 3M ESPE Sandman 29
(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth,
μ - fiction factor, Rd – residual depth)
Drawing no 3. The results of bonding tests 3M ESPE Sandman 45
(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth, 
µ - fiction factor, Rd – residual depth)
Drawing no 4. The results of bonding tests 3M ESPE Aquacut 29
(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth,
µ - fiction factor, Rd – residual depth)
Drawing no 5. The results of bonding tests 3M ESPE AdgerSingleBond
(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth,
µ – fiction factor, Rd – residual depth)
Drawing no 6. The results of bonding tests Exite Invoclar Vivadent
(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth,
µ - fiction factor, Rd – residual depth)
Drawing no 7. The results of bonding tests Exite Invoclar Sandman 29
(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth,
µ - fiction factor, Rd – residual depth)
Drawing no 8. The results of bonding tests Exite Invoclar Sandman 45
(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth, 
μ - fiction factor, Rd – residual depth)
Drawing no 9. The results of bonding tests Exite Invoclar Aquacut 29

(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth,
µ - fiction factor, Rd – residual depth)
Drawing no 10. The results of bonding tests Prime BondNT Densply

(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth, 
µ - fiction factor, Rd – residual depth)
Drawing no 11. The results of bonding tests Prime Bond Sandman 29
(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth,
µ - friction factor, Rd – residual depth)
Drawing no 12. The results of bonding tests Prime Bond Sandman 45
(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth, 
µ - friction factor, Rd – residual depth)
Drawing no 13. The results of bonding tests Prime Bond Aquacut 29
(Ft – friction force, Fn – force strength, Pf – surface profile, Pd – penetration depth,
µ - fiction factor, Rd – residual depth)
Conclusions:

On the basis of measurements the staff performing the research came to the following conclusions:

- Obtained results indicate diversion of the analyzed bonds with difference of adhesion strength to tooth enamel,
- The best adhesion strength is clearly by using Sandman air abrasion system with low pressure and abrasive 45 micron powder, while the weakest strength of bonding prepared by air abrasion method, was observed in the teeth prepared air abrasion with added water spray and 29 micron powder.
- Regardless of the improved adhesion of the bond system higher strength was found under usage of the powder with a larger grain size,
- Regardless of the bond used during the study there was no acoustic emission signal registered which indicates that the energy of the bond between the coating and substrate was too low
- Regardless of the bond the far weakest adhesion was characterized by teeth prepared with turbine. The figures in table 1 clearly indicate this.

In order to determine the reasons for these differences regarding the 2 air abrasion methods it is recommended to continue this study by analyzing the tooth surface structure obtained by the different air abrasion methods. In Appendix 1 images are presented of the different surface structures with different zoom levels.