Shear Strength Between Adhesive Cement and Yttria-Stabilized-Zirconia and Cobalt-Chrome Alloy With and Without Retentive Holes - an in vitro study

Students: Rihan Issa and Nuray Acar
Tutor: Berit Ardlin
ABSTRACT

De-bonding is the most common failure of resin-bonded fixed partial dentures. The aim was to determine if the shear bond strength (SBS) differed between a dental adhesive and a Co-Cr alloy and an yttria-stabilized zirconia (Y-TZP). Furthermore, to determine whether retention holes in the two materials and storage for 21 days in water affected the results. The hypothesis was that there are no significant differences between the compared groups. 10 embedded discs of Co-Cr alloy without and 10 with retentive holes, and 10 discs of Y-TZP without and 17 with retentive holes were sand- and steam blasted. A pillar of adhesive cement was bonded to the surface of the discs and stored in water at 37 °C for 24 hr and / or 21 days. An UltraTest machine with a crosshead speed of 1 mm/ min was used for SBS. The mean SBS after 24 hr / 21 days in water were recorded. The SBS of Co-Cr alloy without retentive hole was 16.3 MPa after 24 hr and 11.4 MPa after 21 days, the SBS of Y-TZP without retentive hole was 18.5 MPa after 24 hr and 12.6 MPa after 21 days. The SBS of Co-Cr alloy with retentive hole 13.9 MPa after 21 days and Y-TZP with retentive hole 16.9 MPa after 21 days. No statistically significant differences were found between the groups with or without retentive holes and after 24 hr or 21 days in water, p> 0.05.
INTRODUCTION

A missing tooth can be replaced with fixed partial denture (FPD), removable partial dentures (RPDs) or implant supported dentures (SBU, 2010). The tooth structures; enamel, dentin and the pulp, are unique. A living tooth has better conditions regarding force adaption than a drilled / rot filled tooth whereas the complications of the treatment of the abutment tooth might result in necrosis (Randow and Glantz, 1986). Nine % of the teeth develop necrosis under prosthetic preparation (Kontakiotis et al., 2015). There are several treatment options in which the restoration of the tooth is made with minimal surgical intervention, limited to the enamel (Alani et al., 2012). Conservative dentistry, considering maintaining tooth structure, has been highly recommended and requested (Garg and Garg, 2015).

Resin-bonded fixed partial dentures (RB-FPDs) are a treatment option which can be used on younger patients with anterior missing teeth. They are most commonly used in these situations because of the aesthetic and functional outcomes with minimal surgical intervention (Alani et al., 2012). The technique includes adhesive bonding with resin cement on etched enamel to metal or ceramic frameworks (Kuijs et al., 2016). A prosthetic construction can be retained by chemical, macro-mechanical and micromechanical methods (Ezoji et al., 2016). Different procedures on how to increase the retention of the RB-FPDs has been studied, such as different preparation techniques of the abutment teeth, surface treatment and several types of adhesive cements (Goswami et al., 2014; Arora et al., 2014). Failures in the early RB-FPDs occurred due to the weak bond between the metal alloy or ceramic and the resin cement rather than between resin and enamel (Goswami et al., 2014). However, the bond between resin cement and metal / ceramic has been enhanced by macro-mechanical retention such as extensive preparation with supplementary structures in the shape of grooves, boxes and occlusal rest. The disadvantage with this procedure is the loss of enamel, whereas enamel is critical for bonding of the RB-FPDs to tooth structure, resulting in a weak bond between cement and dentin (Koodaryan et al., 2016). Nevertheless, the retention between the resin cement and tooth can be increased by dentin roughness with different rotary instruments (Koodaryan et al., 2016).
The RB-FPDs can be made with several designs, Maryland (non-perforated) or Rochette (perforated) and with various materials, such as metal-framed with dental alloys, all-ceramic and fiber-reinforced composite (Miettinen and Millar, 2013; Sasse and Kern, 2014). The RB-FPDs can be designed as a single-abutment cantilever or with two abutments. Single-abutment cantilever showed better prognosis, higher success rate with significantly lower risk of failure than RB-FPDs with two abutments. This occurs due to the physiological movement in the abutment teeth which differs (Miettinen and Millar, 2013).

The RB-FPDs is a treatment option in juvenile patients as a transient treatment where implant therapy is adjacent (Sasse et al., 2012). The RB-FPDs has economic advantages, re-cementing opportunities and reversible impact on the tooth surface. They can be used as long-term provisional restorations. The disadvantage with RB-FPDs is that they might detach which increases the caries risk, chipping of the porcelain, sensitive cementing technique and limited longevity (Boening and Ullmann, 2012).

The prognosis of the RB-FPDs depends on biological and technical qualities, design, material and position in the dental arch. The framework design has not shown any significant effect on the prognosis of metal-ceramic RB-FPDs whereas the failure of various designs with all-ceramic has not yet been clear (Wei et al., 2016). The clinical success of restorative dental materials depends among others on the retention and resistance of the construction. Factors as preparation, pretreatment, type of material, type of luting agent and forces in the oral cavity affects the retention and resistance (Al-Helou and Swed, 2016).

In a review, the annual failure of metal-ceramic RB-FPDs was 4.6 % and 11.7 % for all-ceramic. 93 % of the metal-ceramic failed because of de-bonding. 57 % of Y-TZP failed because of fracture of the framework (Miettinen and Millar, 2013). Diverse types of pretreatments of the materials are used to increase the retention of RB-FPDs. The surface treatment of metal-ceramics such as sandblasting and electrolytic etching has proved to increase the bond strength (Goswami et al., 2014). Sandblasting is a technique where aluminum oxide particles (Al₂O₃) are blasted on the material with pressure. The
particles can differ in size between 50-250 µm in diameter. The particles result in a surface roughness that provides micro-retention of the adhesive cement (Tzanakakis et al., 2016).

Zirconia has different crystalline structures: Monoclinic, tetragonal and cubic structures, which gives the material various characteristics. Tetragonal structure is to prefer due to the properties it provides and is attained at the temperature around 1170 - 2370 °C. Stabilizing oxides is used to maintain zirconia in a tetragonal structure at room temperature (Gautam et al., 2016). Cracks, surface roughness such as drilling / sandblasting and water conditions affects the crystal form which induces a transformation from tetragonal to monoclinic phase. This procedure is called aging, and has negative effects on the adhesion to zirconia. The water also affects the luting agent by inhibiting the polymerization and causes fatigue in the binding between the luting agent and material by repeated thermal expansion and contraction (Tzanakakis et al., 2016).

The retention of the RB-FPDs also depends on which luting agent that is used (Nemoto et al., 2013). Resin cements are preferred due to the chemical bonding effect obtained because of the monomers; the monomers differ between diverse types of cements. There are several types of adhesive cements, light polymerizing, self-polymerizing and dual cured (Sabatini et al., 2013).

Shear bond strength (SBS) is the bond strength between two materials which can resist dislodging forces. It is the internal resistance of a material to shear forces. It differs from tensile strength (stretching) and compressive strength (compression) (Al-Helou and Swed, 2016). SBS is used to compare bond strength between different luting agents, materials or in studies which examine the retention by different pretreatments or designs of the specimen. Higher SBS implies better bonding of the material to tooth (Somani et al., 2016).

However, to the best of our knowledge, there is a lack of research examining the SBS between dental alloys / ceramic materials and resin cements with respect to the effect of
water storage and retentive holes in the alloy/ ceramic. Therefore, the aim of this study was to compare shear strength between dental Co-Cr alloy / Y-TZP and adhesive cement with and without retentive hole in the alloy / ceramic, and after aging in 24 hr / 21 days in water. The null hypothesis is that there are no significant differences between the compared groups.

**MATERIALS AND METHODS**

Forty-seven embedded test specimens of dental Co-Cr alloy and Y-TZP, with and without retentive holes were used in the study. Pillars of adhesive cement were applied on the surface of the materials, and the SBS between the materials and adhesive cement were registered after storage in water for 24 hr or / and after 21 days, Fig. 1.

**Test specimens**

Four groups of specimens were needed to study the effect of retentive holes and water storage; group 1: Co-Cr alloy without retentive hole, group 2: Y-TZP without retentive holes, group 3: Co-Cr alloy with retentive hole and group 4: Y-TZP with retentive hole. The discs in group 1, 2, 3 were already embedded in resin and was used in a previous study. To access the untouched surface of the discs, the plastic around the discs was removed by a milling drill. This generated a total of thirty embedded samples:

- 10 specimens without retentive holes (Ø 8.0 mm, height 7.9 mm) of dental cobalt-chromium alloy Wirobond 280 (Batch nr 133640413, Bego, Bremen, Germany)
- 10 specimens (Ø 13.0 mm, height 0.5 mm, hole Ø 0.9 mm) of Wirobond with retentive holes in the center of the specimen
- 10 specimens without retentive holes (Ø 12.7 mm, height 12.7 mm) of dental yttria-stabilized zirconia, Y-TZP Everest ZS-16 (Batch nr 101971783, Kavo, Biberach, Germany).

To produce group 4: Y-TZP with retentive holes, four cylindrical blocks of presintered Y-TZP Everest ZS-16 (Batch nr 101971783, Kavo, Biberach, Germany) was cut into 17 small slices (Ø 12.7 mm, height 1.6 mm, hole Ø 1.6 mm). A cylindrical shaped bur (Ø 1.1 mm) and a round bur (Ø 1.6 mm) were used to make a concave hole, Ø 0.9 mm to submerge and simulate the holes in Rochette bridges. The holes were made in the green stage Y-TZP under water cooling. The same drill was used for all 17 subjects. The
specimens were then sintered with a sintering program based on the manufacturer’s instructions. The mean diameter of the retentive hole after sintering were 1.6 mm. Wax were used to prevent the epoxy resin from filling out the retentive holes under the embedding procedure and later removed by steam blasting.

The 47 specimens were embedded following the manufacturer’s protocol. The cups (Ø 20 mm, height 25 mm) were taped at the bottom and the specimens were attached to the tape. The components, 25 g Epofix resin and 3 g Epofix Hardener (Struers, Ballerup, Denmark) were mixed for 2 min and rested another 2 min to reduce the bubbles in the mixture, then poured into the mold cups. The resin was solidified for 24 hr. The test subjects were then sandblasted with 110 μm aluminum oxide using 3 bars pressure and steam blasted.

**Application of adhesion cement**

The specimen was mounted in a bonding clamp with a bonding mold insert, Fig. 2a. (Ultradent Products, Inc. South Jordan, UT, USA). A pillar, (Ø 2.3 mm, height 2.0 mm), of self-adhesive cement RelyX™ Unicem 2 Automix (Batch nr 606087, 3M ESPE, Neuss, Germany) was applied on the center of the specimens. The adhesive cement was light cured during 2 sec using a portable curing light, Ivoclar Vivadent bluephase style, with a light intensity of 1200 mW / cm². The curing light was tested once during the experiment with Ivoclar Vivadent Bluephase meter II, showing an intensity of 1230 mW / cm². A pressure was applied for 3 min using a condensing instrument and additionally light-cured for 20 sec. The mold insert was gently removed from the surface. Razor blades were used to remove the excess of adhesive cement. A base clamp was used to stabilize the specimens before SBS test, Fig 2b.

Test 1: to study the aging effect of water, a pillar of resin cement was cemented on 10 Co-Cr alloy and 10 Y-TZP specimens without retentive holes and stored in Milli-Q® water at 37 °C for 24 hr before SBS test using a test speed of 1 mm / min. SBS expressed in MPa. Thereafter, the specimens were carefully sandblasted with 110 μm Al₂O₃ to remove debris from the adhesive cement and steam blasted. The specimen with retentive holes were excluded in this test due to the inability to remove the adhesive
from the holes without affecting the specimen. Furthermore, the validity of the test would have decreased because the adhesive might not only bind to the specimen but also to the underlying epoxy resin and therefore the SBS between other components would have been measured.

Test 2: to study the effect of aging on mechanical retention; the cementation procedure was repeated for all specimens and stored in Milli-Q® water for 21 days before test of SBS. The water was changed with fresh Milli-Q® water regularly. Milli-Q® water is ultrapure water which obtains its purity by undergoing many steps of filtration and deionization.

**Shear bond strength test**

The SBS between the specimens of Co-Cr alloy and Y-TZP and the adhesive cement were registered with an UltraTester (Ultradent Products, Inc. South Jordan, UT, USA), Fig. 2c. To avoid bias, all the specimens were numbered, and an online random number generator was used to randomize in which order the specimen were tested (https://www.random.org/).

**Literature search**

The database PubMed was used to collect the literature for this study. The following MeSH-terms were used: “shear strength”, “dental alloys”, “denture, partial, fixed, resin-bonded”, “chromium alloys”, “resin cements”.

Additional key-words: cantilever, zirconium oxide.

Supplementary references were acquired from related articles. The selection procedure is described in Fig. 3.

**Ethical considerations**

The study does not apply to humans or animals. The ethical reflection states that the study does not involve any physically invasive procedure. The papers included in this study has been identified, peer reviewed and published in scientific papers. The benefit for patients and the society in terms of restorative/ rehabilitative care is that it will contribute to knowledge of the various materials properties. The study has patient
benefits but no risk. The Ethics Forum at the Department of Odontology finds that appropriate ethics considerations have been integrated into this degree project.

**Statistical analysis**
The Mann Whitney test was used for the statistical analysis of SBS to evaluate the effect of mechanical retention between dental Co-Cr alloy with and without retentive hole, and between Y-TZP with and without retentive hole. A significance level of p < 0.05 was used.

Wilcoxon signed ranks test were used for the statistical analysis of SBS and the effect of water storage for 24 hr and 21 days, on Co-Cr alloy without retentive hole, and on Y-TZP without retentive hole. A significance level of p < 0.05 was used.

ANOVA was used for the statistical analysis of SBS between all studied groups to evaluate the differences. A significance level of p < 0.05 was used.

**RESULTS**

No significant differences in SBS between dental Co-Cr alloy without and with retentive hole were registered after 21 days in water, p > 0.05. Neither was any significant difference in SBS between Y-TZP without and with retentive holes registered after 21 days in water, p > 0.05, Table 1.

No statistically significant difference in SBS were registered of Co-Cr alloy specimens without retentive hole after storage in water for 24 hr or 21 days, p > 0.05, or between Y-TZP specimens without retentive hole after water storage for 24 hr or 21 days, p > 0.05, Table 1.

No significant difference in SBS were found between Co-Cr alloy and Y-TZP without retentive holes, and between Co-Cr alloy and Y-TZP with retentive holes were registered after 21 days in water, p > 0.05, Table 1.
DISCUSSION

The null hypothesis could not be rejected, there was no significant difference between the groups studied with or without retentive holes or after water storage 24 hr or 21 days.

Shear bond test is commonly used in studies to evaluate the SBS between several materials and the effect of retention increasing procedures such as surface treatments, testing methods and type of luting agent. It is regularly used because no additional process is required after the cementation procedure is completed. It reflects the clinical situation and is an easy and fast procedure (Raeisosadat et al., 2014; Murthy et al., 2014). Shear test has been criticized due to non-homogenic stress distributions at the bonded interface. There are several testing methods for SBS; micro shear strength (µSBS) and conventional SBS. The difference is the bonding area which is smaller in µSBS test and is believed to maximize SBS and giving a more precise stress distribution on the bonded interface. The sensitivity between these methods has been studied. SBS mean value was 3.5 ± 0.7 MPa for conventional SBS test and 5.9 ± 1.0 MPa for µSBS (Kim et al., 2014).

In our study, an Ultradent UltraTester machine was used to measure SBS. UltraTester is a simple portable machine and there is no need for extra education. It is fast, rigid and holds its loading forces in a linear motion. However, the difficulties in placing and lining up the specimen in the UltraTester machine might have yielded a great dispersion in our results. Another source of error in our study was that the specimen was not grinded to receive a perpendicular surface between the adhesive cement and the Y-TZP/Co-alloy to facilitate placement in the Ultradent tester. The appliance of cement was a complicated procedure which might have affected the initial bond between the resin and specimen. For instance, a possibility of force adaption to the resin pillar when the resin excess was removed using razor blades might have affected the bond. Different operators and operator experience might also have affected the results because of uncontrolled pressure appliance. To achieve a bond between the adhesion cement and the substrate, a pressure should be applied on the cement during light curing. A previous
study showed that the duration of pressure appliance affects the bond strength on dentin (Koodaryan et al., 2016).

The great dispersion in our results is believed to have occurred because of a complicated cementation and preparation procedure. Two zero values was registered in the Y-TZP without retentive holes; 21 days water storage. In these two specimen, the cementpillar unloaded when placed in the machine before the test. One might have excluded these in the statistics to reduce the spread. However 0.5 MPa and 0.8 MPa was the lowest values in this group which might still give a large spread. One might discuss the validity of the test, if we measured what we wanted to measure; the SBS between material and cement. The results indicate that the validity of the test might have been low due to the great dispersion in our results. The registered SBS values might not represent the shear bond between the materials but the sensitivity and difficulty of the preparation and cementation procedure.

An UltraTester was used in a previously published study to measure the SBS of three self-adhesive resin cements bonded to Y-TZP and base metal. The surface was treated with abrasive paper under water and sandblasted with 50 μm Al₂O₃. The mean SBS was registered after 15 min for light-polymerizing (LP) and self-polymerizing (SP) cement; 11.4 ± 0.5 MPa for LP and 3.3 ± 0.1 MPa for SP. After 24 hr; 15.8 ± 0.8 MPa, LP and 11.6 ± 0.4 MPa SP. It was concluded that the properties of the cement, compounds, setting reaction and type of substrate affects the bond strength (Sabatini et al., 2013). The registered SBS values agreed with the values of our study, Table 1. Since these values were obtained, it was concluded that UltraTester can be used as a test method of SBS.

The SBS is of interest to evaluate the effect of surface treatments such as sandblasting. The specimen in this study was sandblasted with 110 μm Al₂O₃ particles and steam blasted. According to the results in a shear test study, the influence of 50 μm sandblasting particles on Y-TZP and Co-Cr alloy was evaluated. Dual cure adhesive cement was bonded to the specimen. The mean SBS was 2.8 ± 1.3 MPa for Y-TZP and 2.9 ± 1.3 MPa for Co-Cr alloy. There were no statistically significant differences between Y-TZP and Co-Cr alloy. It was concluded that sandblasting roughened the
surface and increased bond strength between resin luting materials and dental restorative materials (Nishigawa et al., 2016). The registered mean values were lower than those recorded in our study. Corresponding to this Y-TZP was sandblasted with 80 μm particles. Two dual cure cements, Variolink II and Panavia F, and two auto-polymerizing cements, Rely X and Multilink, were bonded to Y-TZP. The auto-polymerizing cements provided lower adhesion values, 7.5 MPa, than dual cure cements, 11.7 MPa. It was concluded that sandblasting modifies the Y-TZP creating a more retentive surface. Greater SBS values are achieved by providing a better mechanical interlocking between the ceramic and the cement (Román-Rodriguez et al., 2013). In contrast, the effect of sandblasting with 110 or 250 μm Al₂O₃ particles on Y-TZP was studied using an adhesive cement. The mean SBS after sandblasting with 110 μm was 10.9 ± 0.8 MPa and 250 μm was 10.7 ± 1.2 MPa. No significant differences between control, sandblasting with 110 or 250 μm was found (Murthy et al., 2014). In the mentioned studies, SBS mean values was lower than our values but with significant differences between the studied groups. This is probably because the studies used other cements and testing machines. However, direct comparison between the studies is impractical due to the differences in test protocols, material, specimen geometry, loading condition, lack of standardization of SBS and test methods.

Mechanical holes are believed to increase the retention. Mechanical holes and grooves were studied in the design of RB-FPD, which showed greater bond strength (Nemoto et al., 2013). One source of error is the diameter size of the retentive holes in the Y-TZP specimens. After sintering the mean diameter was 1.6 mm, this is believed to be due to the uncontrolled drilling force and cracks during the preparation procedure. No previous studies have been done in the same way, which makes it difficult to compare with others results. However, it is unfair to conclude the effect of mechanical holes due to the ambiguous results in our study.

The effect of artificial aging is believed to decrease the bond strength (Blatz et al., 2004). No significant differences between SBS after 24 hr and 21 days in water were registered. Short observation time and vague results makes it impossible to draw any firm conclusions regarding the effect of aging.
There are several types of failures which occur in cemented prostheses. Adhesive failure occurs in the interface between metal/ceramic and resin, cohesive failure occurs within the metal/ceramic or within the adhesive cement, and mixed failure is a mixture of cohesive and adhesive failures (Murthy et al., 2014; Ezoji et al., 2016). Most of the specimens in our study showed mixed failures, and some showed adhesive failures. The specimens with mixed failures had resin remaining on the substrate surface either as a ring left in the outer edge or cut obliquely. This might have occurred because the bond between the metal and resin was stronger than the bond within the resin. In a previous study, regardless of surface treatment, adhesive failure was the most common failure type with resin cement remaining on the specimens (Koodaryan et al., 2016). However, other resin cement, restorative materials and testing machine was used which might yield different results. In agreement with our study, study examining the bond between Ni-Cr alloy and resin cement which showed more mixed failures than adhesive failures. This is believed to have occurred because the sandblasting procedure affects the surface of the alloy so that a chemical bond appears between the oxides on the metal surface and resin cement (Raeisosadat et al., 2014).

The aesthetics, biocompatibility, less plaque accumulation and material properties of Y-TZP makes the material highly requested in RB-FPDs. In a review, the success rate for metal-framed RB-FDB was reported as 82.8 % and for All-ceramic RB-FPD as 72.5 % after three years (Miettinen and Millar, 2013). Adhesive bonding is essential for the success rate of RB-FPD (Sasse et al., 2012). The failures in the early all-ceramic RB-FPD occurred at the connector site, which has been improved by using ceramics with stronger characteristic such as Y-TZP. The disadvantage is that the traditional retention increasing techniques used for the early all ceramic RB-FPD do not work with Y-TZP because it lacks the glass phase (Tzanakakis et al., 2016). It is highly requested to evaluate different retention increasing procedures to try and increase SBS such as retentive hole.
Failure RB-FPD - tooth substrate

If the adhesive strength would be higher between the substrate and adhesive than between the adhesive and enamel the failure would occur within the cement or between the enamel and resin. Higher SBS between the RB-FPD and tooth is desirable because de-bonding has proven to be the most commonly reason for failure (Miettinen and Millar, 2013). However, if the bond strength increases, the trauma risk of the abutment teeth increases. Therefore, de-bonding which can easily be solved by re-bonding is better than fracture of the framework of the protheses or fractures of the abutment tooth. The RB-FPD has a higher failure rate than conventional bridges. However, the failures within the RB-FDB are more acceptable because failures of conventional FDP include apical infection, caries and loss of the abutment (Miettinen and Millar, 2013).

Conclusion

More studies are needed using specimens with perpendicular grinded surfaces for optimal placement of the notch head against the adhesive cement to get more accurate SBS. The influence of longer storage time in water, several types of cements and several types of Y-TZP to study the effect of retentive holes on SBS would also be interesting to study in the future.

ACKNOWLEDGEMENT

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REFERENCES


Table 1. Shear bond strength between the bridge materials and the adhesive cement tested in MPa for the studied groups, p > 0.05.

<table>
<thead>
<tr>
<th>Material; water storage time</th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Mean</th>
<th>SD</th>
<th>CI 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-Cr alloy without retentive hole; 24 hr</td>
<td>10</td>
<td>1.9</td>
<td>32.2</td>
<td>12.9</td>
<td>16.2</td>
<td>11.4</td>
<td>8.1 - 24.3</td>
</tr>
<tr>
<td>Zirconia without retentive hole; 24 hr</td>
<td>10</td>
<td>1.3</td>
<td>32.4</td>
<td>19.5</td>
<td>18.5</td>
<td>10.2</td>
<td>11.2 - 25.8</td>
</tr>
<tr>
<td>Co-Cr alloy without retentive hole; 21 days</td>
<td>10</td>
<td>3.0</td>
<td>21.9</td>
<td>11.5</td>
<td>11.4</td>
<td>5.9</td>
<td>7.2 - 15.6</td>
</tr>
<tr>
<td>Zirconia without retentive hole; 21 days</td>
<td>10</td>
<td>0.0</td>
<td>33.3</td>
<td>6.6</td>
<td>12.5</td>
<td>13.7</td>
<td>2.7 - 22.3</td>
</tr>
<tr>
<td>Co-Cr alloy with retentive hole; 21 days</td>
<td>10</td>
<td>2.5</td>
<td>21.6</td>
<td>15.5</td>
<td>13.9</td>
<td>6.1</td>
<td>9.5 - 18.3</td>
</tr>
<tr>
<td>Zirconia with retentive hole; 21 days</td>
<td>17</td>
<td>4.5</td>
<td>27.1</td>
<td>18.3</td>
<td>16.9</td>
<td>6.9</td>
<td>13.4 - 20.4</td>
</tr>
</tbody>
</table>
Fig. 1. The experimental protocol used for evaluating the shear bond strength between a dental Co-Cr alloy and Y-TZP with and without retentive holes and an adhesive cement.
Fig. 2a. Bonding mold insert in a bonding clamp prior to cementation.

Fig. 2b. Test base clamp for positioning in the UltraTester machine.

Fig. 2c. The base clamp mounted in the UltraTester machine before testing.
Fig. 3. The selection procedure of papers used.

39258 papers identified through database searching (keywords and Mesh terms such as shear bond strength)

1479 papers after filters:
- Abstract
- 5 years
- Free text
- English

1479 papers screened by reviewing titles and abstracts

46 papers screened by reading the full-text articles

30 full text papers met the eligibility criteria

4 papers found via manual search of reference list

25 papers included in the evaluation of evidence

1433 papers excluded for the following reasons:
- Not following the objective of the study

16 papers excluded for the following reasons:
- Not following the objective of the study
- Study of low quality

9 full text papers excluded for the following reason:
- Study of low quality