In Vitro Evaluation of the Solubility of Zinc Phosphate and Polycarboxylate as Orthodontic Band Cements

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Abstract

Objective: Different cements are used for cementation of orthodontic bands each requiring special considerations in terms of technique sensitivity during the setting reaction, water solubility and decomposition over time. Each of these factors may lead to debonding, decalcification and caries in long term. This study was designed to assess the weight changes of different zinc phosphate and polycarboxylate cements used in orthodontic treatments.

Methods: This experimental study was conducted on two available conventional cements (zinc phosphate and polycarboxylate) in the Department of Dental Materials, SBMU School of Dentistry, Tehran, Iran. The cements were categorized according to the ANSI/ADA specification No.8 and data were analyzed with electronic balance. Samples were immersed in water for 6 weeks and weight changes were evaluated and analyzed afterwards using Repeated Measures ANOVA.

Results: The mean weight loss was the highest for Aria Dent zinc phosphate cement and the lowest for Adhesor zinc phosphate cement at day 42. Difference in weight at day 42 compared to the baseline value at day one was the highest for Aria Dent polycarboxylate cement compared to other conventional polycarboxylate cements. This rate was the lowest for Durelon polycarboxylate cement.

Conclusion: Aria Dent zinc phosphate and polycarboxylate cements displayed the greatest weight changes during the study period compared to other conventional cements.

Keywords: Solubility, Zinc phosphate, Polycarboxylate, Orthodontic bands

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Introduction:

Despite the availability of bonded brackets as a part of fixed orthodontic treatments, more than 85% of orthodontists still use orthodontic bands on molars (1,2). One of the inevitable principles of fixed orthodontic treatments is that the bands have to remain fixed on the tooth surface throughout the treatment course. If the bond between the tooth and band fails tooth surface decalcification and mechanical treatment failure may occur resulting in unscheduled and time consuming visits (2). Bands are more resistant against occlusal forces and increase treatment consistency. Thus, their adequate retention is a necessity that is achieved mechanically and chemically. Application of cement provides chemical retention. Mechanical retention is also achieved by the penetration of cement into the porosities. Therefore, complete adaptation of band on tooth enamel surface stabilizes the mechanical retention obtained by the use of cements (1, 2). Glass ionomer, zinc phosphate and polycarboxylate cements are used for cementation of orthodontic bands (3-5). Zinc phosphate cement is used for cementation of orthodontic bands since 1878. This cement has high compressive strength, low tensile strength
and high solubility at presence of organic acids which results in microleakage and tooth enamel demineralization (6-8). In some cases, after removal of orthodontic bands cemented by zinc phosphate cement extensive decalcifications are observed which are most probably due to the dissolution of cement between the band and tooth providing a suitable environment for bacterial accumulation (3,9). Polycarboxylate cement was introduced in early 1970. Among its advantages we may name its chemical adhesion to tooth surface while low tensile strength, high solubility and short working time are among its drawbacks. For the polycarboxylate cement, increasing the powder/liquid ratio and working on a cold glass slab have been suggested to increase the working time and strength and reduce solubility (3,7). Hajmiragha et al, in their study in 2008 evaluated the solubility of glass ionomer, zinc phosphate and polycarboxylate cements in artificial saliva. They reported that the polycarboxylate cement had the highest solubility. Also, cements had the greatest solubility when placed in moderately acidic environment which indicates the role of environmental pH in the solubility of cements (10). Sabouhi et al, in an in vitro study in 2009 compared the solubility of Ariadent and Harvard zinc phosphate and polycarboxylate cements and found statistically significant differences between the solubility of Ariadent and Harvard zinc phosphate cements. The solubility of Harvard cement was higher (11). Posterior teeth are subjected to the greatest tensile and shear forces of mastication which make the bands on molars susceptible to loosening and fracture. However, other factors like the time period after which the function of band is evaluated, patient’s demographic characteristics (age, sex, motivation for treatment and type of malocclusion), dentist-related factors (method of mixing the cement, choosing the correct band and mechanics used in treatment) may also play a role in this respect (2).

Considering the growing popularity of orthodontic treatments in the community and consequent increased use of orthodontic bands, the need for suitable cements is undeniable. To date, several studies have evaluated different cements like glass ionomers but information on zinc phosphate and polycarboxylate cements are scarce. The present study aimed to determine weight changes of two cements of zinc phosphate and polycarboxylate as orthodontic band cements after immersion in distilled water.

**Methods:**

This in-vitro controlled experimental study was conducted on experimental models in Dental Material Laboratory of SBMU, School of Dentistry. Three different types of polycarboxylate and zinc phosphate cements were used (Table 1). According to the manufacturer’s instructions, powder and liquid of the cements were mixed, poured into a mold (10 mm length and one millimeter depth) and pressed using two glass slabs at the two sides of the mold for 20 seconds. The excess cements were removed. Since the cements were self-cured, sufficient time was allocated to complete their setting. Samples were separated from the metal mold and placed in an incubator for 60 minutes. Six samples were prepared from each cement type. Samples were divided into three groups according to the ANSI/ADA specification No.8. Two samples in each group were immersed in a glass flask containing 50ml of distilled water. The specimens were then placed in an incubator for 6 weeks at 37°C (55 L PECO, PI455 model, Pooya Electronic Co, Shiraz, Iran). Samples were removed for short time periods in between test periods for weighing with a digital balance (Acculab ALC/104, Sartorius Group, Germany) and after that were transferred to a new flask. According to ISO 4049, samples were extracted
from water, placed in desiccators for an hour and then weighed. Obtained data were analyzed using digital balance. This process was repeated at days 3, 4, 5, 6, 7, 14, 21, 28, 35 and 42. After each weighing, samples were transferred to a new flask filled with 50 ml of distilled water. Flasks were placed in an incubator at 37°C and remained there until weighing. Data were entered SPSS version 16 software and weight changes at different time points were evaluated and compared with the baseline values using Repeated Measures ANOVA.

Table 1- Understudy cements

<table>
<thead>
<tr>
<th>Cement type</th>
<th>Brand</th>
<th>Manufacture</th>
<th>Abbreviation</th>
<th>Lot no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc phosphate cement</td>
<td>Harvard Dental GmbH, Germany</td>
<td>ZPC (A)</td>
<td>Pow:1940904</td>
<td>Liq:1900904</td>
</tr>
<tr>
<td></td>
<td>Adhesor</td>
<td>Kerr Company, USA</td>
<td>ZPC (B)</td>
<td>1869232-2</td>
</tr>
<tr>
<td></td>
<td>Aria Dent ApadanaTak, Iran</td>
<td>ZPC (C)</td>
<td>ZF020</td>
<td></td>
</tr>
<tr>
<td>Pholy Carboxylate cement</td>
<td>Durelon 3M ESPE AG, Germany</td>
<td>PCC(A)</td>
<td>354289</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hoffman’s Hoffmann Manufaktur, Germany</td>
<td>PCC(A)</td>
<td>1704E04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aria Dent ApadanaTak, Iran</td>
<td>PCC(A)</td>
<td>ZP038</td>
<td></td>
</tr>
</tbody>
</table>

Results:

The mean difference in weight of cements at day 42 and day one is as follows: Ariadent zinc phosphate -0.0069±0.0127 g, Adhesor zinc phosphate -0.0007±0.0043 and Harvard zinc phosphate -0.0012±0.0022 (Table 2 and Figure 1).

Table 2- The mean (±SD) difference in weight of zinc phosphate cements at day 42 compared to day one

<table>
<thead>
<tr>
<th>Type of cements</th>
<th>Mean difference in weight</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ariadent</td>
<td>-0.006900</td>
<td>0.0127686</td>
</tr>
<tr>
<td>Adhesor</td>
<td>-0.000733</td>
<td>0.0043624</td>
</tr>
<tr>
<td>Harvard</td>
<td>-0.001250</td>
<td>0.0022563</td>
</tr>
</tbody>
</table>

The obtained results showed that the mean weight loss was the highest in Ariadent zinc phosphate cement at day 42 compared to other zinc phosphate cements. This rate was the lowest for Adhesor zinc phosphate cement. The mean weight change of various zinc phosphate cements at days 2-42 compared to day one is demonstrated in Table 3 and Figure 2.
Significant differences were observed in weight change of three zinc phosphate cements at different time points (P<0.001). Weight change of Ariadent zinc phosphate cement was more than that of Harvard zinc phosphate cement (P=0.023). Adhesor zinc phosphate cement had a significant difference with Ariadent zinc phosphate cement in this respect (P=0.028). However, the difference between the Adhesor and Harvard zinc phosphate cements in this regard was not statistically significant (P=0.357).

Table 3- Comparison of mean weight change in three zinc phosphate cements

<table>
<thead>
<tr>
<th>I cement</th>
<th>J cement</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZP Ariadent</td>
<td>ZP Harvard</td>
<td>0.023</td>
</tr>
<tr>
<td>ZP Ariadent</td>
<td>ZP Adhesor</td>
<td>0.028</td>
</tr>
<tr>
<td>ZP Harvard</td>
<td>ZP Adhesor</td>
<td>0.357</td>
</tr>
</tbody>
</table>

Figure 2- Difference in mean weight change of various zinc phosphate cements at days 2-42 compared to day one

Differences in mean weight of polycarboxylate cements at day 42 compared to day one are as follows: Ariadent polycarboxylate cement $0.0071\pm0.0369$ g, Durelon polycarboxylate cement $0.0031\pm0.0068$ g and Hoffman’s polycarboxylate cement $0.0035\pm0.0343$ g (Table 4 and Figure 3).

Table 4- The mean (±SD) difference in weight of polycarboxylate cements at day 42 compared to day one

<table>
<thead>
<tr>
<th>Type of cement</th>
<th>Mean difference in weight</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ariadent</td>
<td>0.007183</td>
<td>0.369505</td>
</tr>
<tr>
<td>Durelon</td>
<td>0.003100</td>
<td>0.0068596</td>
</tr>
<tr>
<td>Hoffman’s</td>
<td>0.003517</td>
<td>0.343014</td>
</tr>
</tbody>
</table>

Figure 3- Error bar of mean and 95% CI of weight changes after 42 days

Results revealed that the mean weight change in Ariadent polycarboxylate cement during the 42-day period was the greatest compared to other polycarboxylate cements. This rate was the lowest for Durelon polycarboxylate cement. Mean difference in weight of polycarboxylate cements at days 2-42 compared to day one is demonstrated in Table 5 and Figure 4.

Table 5- Comparison of mean difference in weight of three polycarboxylate cements

<table>
<thead>
<tr>
<th>I cement</th>
<th>J cement</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC Ariadent</td>
<td>PC Hoffman’s</td>
<td>0.507</td>
</tr>
<tr>
<td>PC Ariadent</td>
<td>PC Durelon</td>
<td>0.161</td>
</tr>
<tr>
<td>PC Hoffman’s</td>
<td>PC Durelon</td>
<td>0.705</td>
</tr>
</tbody>
</table>

Figure 4- Mean difference in weight of three polycarboxylate cements at days 2-42 compared to day one
Difference in weight of three polycarboxylate cements at different time points was not statistically significant (P<0.001).

Discussion:

The present study aimed at determining weight changes in two cements of zinc polycarboxylate and zinc phosphate after immersion in distilled water. The results revealed that weight changes at different time points between the three zinc phosphate cements were statistically significant. Weight change in Ariadent zinc phosphate cement was higher than in Harvard zinc phosphate cement. Adhesor zinc phosphate cement had a statistically significant difference in this respect with Ariadent zinc phosphate cement. However, the difference between Adhesor and Harvard zinc phosphate cements was not statistically significant. For polycarboxylate cements, the difference in weight change at different time points between the three types was not statistically significant.

Correct adaptation and integrity of orthodontic appliances are necessary for the continuity of orthodontic mechanics. Retention to tooth structure is an important characteristic for orthodontic bands. Mechanical retention of orthodontic bands is usually provided by the tooth morphology while the chemical retention is achieved by the use of cements. Solubility of cements in oral fluid is among the primary factors responsible for loosening or fracture of bands. Retention of orthodontic bands is influenced by the mechanical properties of the applied cement, adhesion between the cement and band, and cement and enamel and effect of repeated mechanical stress on the adhesion and cohesion of cements. Clinically, retention of bands and solubility of cement in the oral environment are of special significance because loose bands and highly soluble cements result in the accumulation of plaque below the bands which have been demonstrated in some studies to cause primary enamel caries during a 3-week period. Therefore, use of cements with low solubility in the oral cavity increases the efficacy of orthodontic mechanics, reduces the rate of microleakage and decreases the risk of caries.

Various studies have evaluated the mechanical and chemical characteristics, solubility and weight changes of cements especially glass ionomers. However, information regarding zinc polycarboxylate and zinc phosphate cements are scarce. Therefore, comparison of the present study results with those of others in terms of weight changes of these cements is not possible (12-14).

In the present study, all three zinc phosphate cements initially showed weight gain which can be due to the water absorption by the cement. Ariadent zinc phosphate cement showed the highest weight change at day 5 (0.0075 g). Until day 21, process of weight loss had a slow trend but from day 21 to day 42 this trend became more prominent and at day 28 approached its baseline weight at day one and reduced afterwards. At day 42, weight of cement was 0.0075 g less than its baseline value at day one. Weight change after 42 days was almost zero for Harvard zinc phosphate cement. From day 2 to 28 weight loss trend followed a slow path. From day 28 to day 42 this trend became more prominent and at day 42 weight change was almost zero compared to day one which indicates release of ions from the cement since day 28. Adhesor zinc phosphate cement also had a descending weight loss trend. At day 35 this rate was almost zero. At day 42 the cement weighed 0.0007 g less than its baseline value which may be due to the release of ions. However, the final weight of samples was almost similar to their baseline values. In the present study, all three polycarboxylate cements initially showed weight gain. Durelon polycarboxylate cement had the greatest weight gain at day 4 which shows considerable water absorption by day 4. From day 4 to 42, weight
change had a descending trend that can be attributed to the release of ions. At day 42, cement weighed 0.003 g more than day one. Hoffman’s polycarboxylate cement had the highest weight gain at day 6 and after that a descending trend was observed till day 42. At day 42, its weight change was similar to that of Durelon. Ariadent polycarboxylate cement had an ascending weight gain trend until day 6 which can be due to water absorption. At days 7 and 14, its weight remained unchanged and the greatest weight gain was observed at day 21 which was followed by a descending trend of weight loss which can be attributed to the release of ions. However, weight of cement at day 42 was greater than its baseline value at day one.

Dastjerdi et al, in 2010 (15) performed an in vitro study on weight changes of three glass ionomer cements (Ariadent, Bandtite and Resilience) used for orthodontic banding following immersion in distilled water. All three glass ionomer cements showed weight gain at first. Difference in weight of different cements was statistically significant. Ariadent glass ionomer cement showed maximum weight gain at day 4 in an amount of 29 g. From day 4 to 42 trend of weight changes decelerated. Resilience glass ionomer cement showed the smallest weight change equal to 8.2 mg weight loss. Bandite glass ionomer cement showed 5.7 mg weight gain in a 42-day period.

Hajmiragha et al, in 2008 (10) assessed the solubility of three cements of zinc phosphate, polycarboxylate and glass ionomer in artificial saliva with a pH of 2 and 3. Results revealed significant differences between the cements and the two environments with different pH. Glass ionomer cement had the lowest solubility in the two environments. Polycarboxylate cement in both environments had greater solubility compared to zinc phosphate cement. Solubility of cements was greater in acidic environment.

Saleem et al, in 2011 (16) demonstrated that the solubility of zinc phosphate and glass ionomer cements increases with decreased pH; but, the solubility of glass ionomer cement at similar time and pH conditions was higher than that of zinc phosphate cement. However, Oilo et al, in 1991 (17), Pluim et al, in 1984 (18) and Duymus et al, in 2004 (19) reported higher dissolution resistance in glass ionomer cement compared to zinc phosphate.

Hersek and Canay in 1996 (20) demonstrated that the solubility of zinc phosphate and zinc polycarboxylate cements was the same while glass ionomer cement had a significantly lower solubility than the mentioned two cements.

Sabouhi et al, in 2009 (11) conducted an in vitro study for comparison of the solubility of Ariadent and Harvard zinc phosphate and zinc polycarboxylate cements and reported solubility rates within the normal range in the 4 groups. No statistically significant difference was detected in the solubility of Harvard and Ariadent polycarboxylate cements. However, a significant difference was observed in the solubility of Ariadent and Harvard zinc phosphate cements and the solubility rate in Harvard zinc phosphate cement was significantly higher.

Different weight changes in cements can be due to their difference in terms of size of particles, powder/liquid ratio, method of mixing them, and their different compositions. Immersion of cements in water results in water absorption (weight gain) or cement dissolution (weight loss). In a clinical setting, rate of water absorption, dissolution and weight alterations should be calculated because these factors have a direct correlation with changes in structure of cement, its adhesion to enamel and other physical characteristics such as polymerization, strength, shrinkage, fluoride release, structural durability and biocompatibility.

**Conclusion:**

Among zinc phosphate cements, the mean weight change in Ariadent cement at day 42
compared to day one was the greatest while this rate was the lowest for Adhesor cement. Among polycarboxylate cements, the mean difference in weight of cements at day 42 compared to the baseline value at day one was the highest for Ariadent and the lowest for Durelon cements.

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**References:**