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# Shear bond strength evaluation of new computer-aided design – computer-aided manufacturing chromium-cobalt alloy (Sintron) with two different types of cement: An *in vitro* study

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## ABSTRACT

**Background:** Any deficiency or problem in the shear bond strength between restoration and tooth surface can lead to recurrent decay, gingival issues, and associated esthetic concerns. Cement acts as a material to bond restorations to the tooth surface, filling the void space between the tooth and the restoration to establish this bond. This study aims to investigate the bonding strength of two common types of cement – polycarboxylate and zinc phosphate – with Sintron alloy (chromium–cobalt) in dental restorations.

**Materials and Methods:** This research is conducted *in vitro* on 24 Sintron alloy discs cemented with two types of polycarboxylate (Poly-F, Dentsply, US) and zinc phosphate cement (Harvard Cement, Germany) on 24 extracted maxillary central incisors. Teeth were sandblasted with 50-micrometer aluminum oxide ($Al_2O_3$) particles. Disc-shaped alloy specimens with specific dimensions were prepared. The specimens were then bonded to the teeth surface using each cement and were subjected to shear bond strength testing using a Universal Testing Machine (Instron, 3367, Canton, MA, USA). An independent sample *t*-test was performed with *P* value significance of lower than 0.05.

**Results:** The *t*-test with $P = 0.150$ showed no significant difference between the zinc phosphate and polycarboxylate cement groups.

**Conclusion:** The study found no statistically significant difference in the bond strength of Sintron alloy when using zinc phosphate and polycarboxylate cement. Therefore, it can be concluded that the bond strength is similar for both cements.

**Key Words:** Chromium–cobalt alloys, dental bonding, polycarboxylate cement, zinc phosphate cement

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## INTRODUCTION

The bond strength between restorations and teeth is crucial clinically, as any flaws in this bond can lead to issues such as recurrent caries, gingival problems, and esthetic concerns. Cement is a material used to adhere restorations to the tooth surface, creating this bond by occupying the empty space between the tooth and the restoration.[1] A luting material, by creating a mechanical bond, chemical bond, or both, preserves indirect restorations.

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Luting materials can be classified as nonadhesive, chemical, or micromechanical adhesive cement based on their bonding mechanism. Chemical bonding agents can create molecular interactions with tooth structures to form a chemical bond, whereas micromechanical bonding agents achieve bonding through micromechanical bonding between the adhesive and tooth surfaces.[2] Nonadhesive cements include eugenol-containing cements such as zinc oxide-eugenol and noneugenol cements, whereas chemical bonding agents include polycarboxylates and glass ionomer.[1] Zinc phosphate cements are the longest-standing materials used in dentistry and are often considered the "gold standard" for permanent dental cements.[3] Zinc phosphate cement, composed of zinc oxide powders and a liquid mix of phosphoric acid, water, and aluminum phosphate, acts as a luting agent by creating a mechanical bond rather than adhering to the tooth structure. Its high mechanical strength and moderate compressive strength make it suitable for cementing cast metal postcore restorations.[1]

Polycarboxylate cement, developed in 1968, was designed to combine the strength of zinc phosphate with the adhesion and biocompatibility of zinc oxide eugenol.[4] Polycarboxylate cement, made from zinc oxide and polyacrylic acid, forms through an acid–base reaction. It can create weak chemical bonds with hard tissues by chelating calcium in hydroxyapatite, but its adhesion is mainly mechanical. Compared to zinc phosphate, polycarboxylate cement causes less pulp irritation and has higher tensile strength, although it has lower compressive strength and a much lower modulus of elasticity.[5]

Furthermore, nowadays, due to advantages such as lower cost, lower density, high strength, the possibility of providing thinner and stronger restorations, and the ability to form a stable oxide layer on its surface (necessary for bonding with porcelain), base metal alloys are used compared to noble alloys.[6] On the other hand, the alloys used in the oral environment, besides being reasonably priced, must have a suitable bond strength with various cements. Today, the use of cobalt–chromium–molybdenum alloys (Sintron) manufactured by computer-aided manufacturing (CAM)/computer-aided design (CAD) method is rapidly increasing, especially in the construction of partial restorations. Its mechanical properties and corrosion resistance make it a potential material for dental posts. Different alloy compositions have significantly different chemical and physical properties. However, the basic composition pattern of these alloys usually includes 68%–63% cobalt and 30%–25% chromium, plus minor elements such as molybdenum, manganese, iron, carbon, silicon, and a very small amount of other metals. Changes in the amounts of chromium, cobalt, molybdenum, and other metals used can have a significant effect on the chemical and physical properties of the prepared alloy.[7] The advantages of using Sintron (chromium–cobalt) alloys include low weight, extraordinary hardness, and high resistance. Since Sintron alloy is a new alloy and few studies have been conducted on its bond strength, and it can be very useful in dental restorations, this study will investigate the bond strength of two common cements with this alloy using shear bond strength tests.

## MATERIALS AND METHODS

This study was conducted experimentally in laboratory conditions on 24 disks made of Sintron alloy cemented to tooth enamel by two types of cement, polycarboxylate and zinc phosphate, to determine their shear bond strength. All the experimental procedures in this study were approved by the Research Ethics Committee of the Islamic Azad University of Medical Sciences, Tehran, Iran (ethical code: IR. IAU. DENTAL. REC.1402.046). Twenty-four extracted central maxillary teeth were prepared and stored in physiological serum after cleaning the periodontal fibers and remaining soft tissues on the root. Before the bonding procedures, all extracted teeth underwent a disinfection process by immersing the teeth in a 0.5% chlorhexidine solution for 10 min. Then, the teeth were placed almost perpendicular in cylindrical plastic containers using self-curing acrylic (Cold-cure acryl, Acropars, Iran). To create a smooth and even surface, the surfaces of these teeth were trimmed. The teeth were sandblasted with 50-µ aluminum oxide ($Al_2O_3$) particles at a distance of 10 mm and then washed and dried. Next, sandpaper was used to abrade the surfaces further, achieving a smooth cross-sectional area with a diameter of 7 mm. The 7-mm cross-sectional area was obtained by precisely abrading the surface with sandpaper until the desired dimensions were achieved [Figure 1].

Twenty-four disk-shaped samples were prepared to achieve final dimensions with a thickness of 5 mm and a diameter of 3 mm in the Green State condition

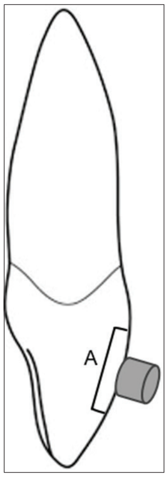


**Figure 1:** Schematic picture of the tooth preparation, A: 7 mm prepared surface for bonding.

using a milling machine (Ceramill Argotherm, AmmanGirrbach, Austria). Then, the disks were sintered in a special furnace (Ceramill Argotherm, AmannGirrbach, Austria) under argon gas pressure and cooled at room temperature after sintering. Cements in each group were mixed according to the manufacturer's instructions, and a thin layer of polycarboxylate cement in the first group and zinc phosphate cement in the second group was applied to the cylindrical disk surface using a micro brush applicator (Benda Micro applicators; Centrix Inc, US). Then, the disk samples were bonded to the trimmed tooth surface by hand pressure, and the excess was removed. The appropriate consistency for cementing was obtained when about 1 inch of the spatula was drawn. Then, the samples will be kept in distilled water at 37°C for 24 h. After 24 h, the samples will be subjected to 5000 cycles in a thermocycler with temperatures of 5°C and 55°C, with a dwell time of 20 s and a rest time of 10 s (TC3000, Vafai Industrial Co., Tehran, Iran). This is equivalent to 6 months in the oral environment.

Subsequently, the samples ($n$ = 12) were subjected to shear bond strength testing using a Universal Testing Machine (Instron, 3367, Canton, MA, USA). For this purpose, a rod with a width of 0.5 mm was brought into contact with the interface between the disks and the tooth surface parallel to the contact surface. The force was applied at a speed of 0.5 mm/min until failure occurred.[8] The values of shear bond strength were measured in megapascal (Mpa) by dividing the force measured at the moment of failure (N) by the area of the sample surface ($mm^2$). If separation occurred before contact with the cutting tool, the bond strength was defined as 0 MPa.

Bonded surfaces were examined under a stereo microscope (SMZ800, Nikon, Japan) with a magnification of ×40 to accurately assess fracture patterns. The fracture patterns were determined as follows:

1. Adhesive fracture: If the fracture pattern occurred between the alloy and the cement or the tooth and the cement
2. Cohesive fracture: If the fracture pattern occurred within the cement
3. Mixed fracture: If both adhesive and cohesive fracture patterns occurred simultaneously
4. For the statistical analysis, an independent sample *t*-test was performed using PASS 11.0 software with $P$ value significance of lower than 0.05.

## RESULTS

Independent sample *t*-test was performed and $P$ = 0.150 indicated that there was no significant difference between the zinc phosphate and polycarboxylate groups [Table 1].

Fracture surfaces were examined under ×40, and the fracture patterns were determined to be a mix of adhesive and cohesive patterns [Table 2 and Figures 2 and 3].

## DISCUSSION

This study aimed to investigate the shear bond strength of two common types of cement – zinc phosphate and polycarboxylate – with the Sintron alloy. According to the results, no significant difference was observed between the two study groups in the force required to separate the alloy from the tooth. Factors such as cement dissolution, contraction during setting, and failure to create an acceptable bond to the tooth structure in a clinical environment can lead to microleakage. Avinash *et al.*[9] conducted a study to determine the bond strength of commercially pure titanium Ti 6Al 4V with three luting cements: polycarboxylate, glass ionomer, and zinc phosphate in maxillary first molars. According to the results of this study, polycarboxylate cement created higher shear bond strength compared to the other two cement but showed corrosion on titanium. The reason for this could be that during setting, polycarboxylate cement can adhere to the tooth structure by bonding calcium ions and to metal substrates by bonding metal ions, resulting in higher retention achieved by the cement

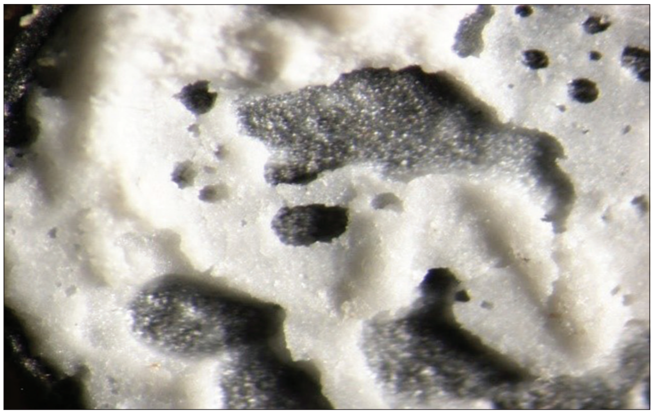

**Figure 2:** Mixed fracture pattern.

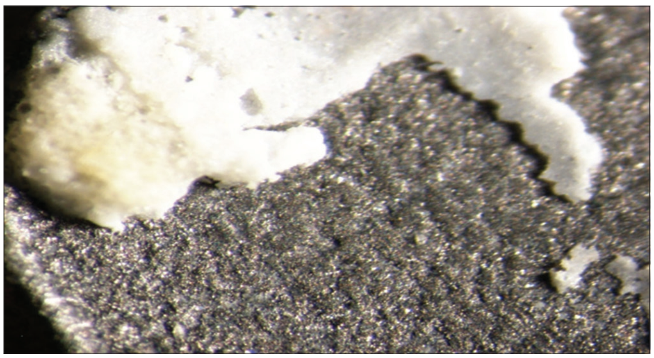

**Figure 3:** Mixed fracture pattern.

on the titanium, possibly due to the cement's adhesion to titanium. Differences in the specific cement brands or formulations and also dissimilar surface properties and corrosion behavior of titanium alloy, could affect the bond strength and therefore be a possible reason for this study's different results compared to our study. Kameli *et al.*[10] conducted a study to examine the bond strength, and microleakage of four types of cements: glass ionomer, resin-modified glass ionomer, polycarboxylate, and resin cement in stainless steel crowns of primary molars. The results showed that the microleakage of resin cement and resin-modified glass ionomer cement was lower than glass ionomer cement and polycarboxylate cement. Factors affecting microleakage include solubility, structure of set cement, thickness, thermal changes, sealing ability, and resistance to stresses.

In our study, we used Sintron alloy (chromium–cobalt alloy) due to its low weight, exceptional hardness, and high resistance. Ahmadzadeh *et al.*[6] measured the bond strength between two porcelain (VITA VMK Master and VITA VM13) and two base metal alloys (Ceramill Sintron and Verabond). The maximum bond strength was related to Verabond/VM13 (44.35 ± 7.9 Mpa) and then Ceramill Sintron/VM13 (39.33 ± 4.43 MPa) and the lowest was related to Ceramill Sintron/VMK Master (29.75 ± 3.2 Mpa). According to the results of this study, the bond strength of porcelain to Verabond was better, but the bond strength of porcelain to Ceramill Sintron was not below the standard threshold. Therefore, this new alloy produced by CAD/CAM can be a substitute for conventional base metal alloys in metal–ceramic restorations. Moreover, in a study by Izadi *et al.*,[11] the Ceramill Sintron bridge framework did not significantly differ regarding marginal gap and dimensional changes compared to conventional casting frameworks.

**Table 1: Mean shear bond strength in study groups (Mpa)**

| Groups | Mean±SD | Minimum | Maximum | *P* |
|---|---|---|---|---|
| Polycarboxylate | 2.5714±0.82211 | 2.05 | 4.38 | 0.150 |
| Zinc phosphate | 3.0446±0.72772 | 1.63 | 4.67 | |

SD: Standard deviation

**Table 2: Sample numbers and percentage of failure modes registered in each experimental group**

| Cement type | Adhesive fracture, *n* (%) | Cohesive fracture, *n* (%) | Mixed fracture, *n* (%) |
|---|---|---|---|
| Polycarboxylate | 2 (16) | 1 (8) | 9 (75) |
| Zinc phosphate | 3 (25) | 1 (8) | 8 (66) |

Similar to our study, Handa *et al.*[12] investigated the microleakage of nickel–chromium coping to implant analogs with three types: zinc oxide eugenol, polycarboxylate, and zinc phosphate cement. According to the results of this study, the microleakage of zinc phosphate cement was significantly lower than the others, and there was no significant difference between the other two cement. The possible reason for the difference in our results might be the tooth structure (natural teeth vs. implant analogs) and the testing methods (shear bond strength vs. dye penetration).

In addition, Ahsan *et al.*[13] conducted a study to evaluate the bond strength of several common dental cements in implant systems, and similar to our study, their results showed that polycarboxylate cement and then zinc phosphate and glass ionomer had higher average retention; however, their findings do not suggest that one type of cement is inherently better than another.

In a study by AlAali *et al.*,[14] the effect of resin polymer cements, resin-modified glass ionomer, and zinc phosphate cement on tensile bond strength with zirconia posts in premolars was investigated, and the samples were divided into two groups: thermocycler and nonthermocycler groups. In the thermocycler group, the samples were more prone to bond failure in the cement and had less resistance to withstand maximum force, while the highest tensile strength for the resin cement group was observed in nonthermocycler samples. Other studies have also used thermocycling with 40,000 cycles or more to simulate the oral environment, but cyclic stress may cause more bond separation in cement. However, in Mazzitelli *et al.*'s study,[15] thermocycling did not cause a loss of bond strength in self-adhesive hybrid polymer cements. This indicates that the type, composition, and mechanism of cement bonding affect the bond strength of coatings and posts to teeth. Regarding the failure pattern, in the study by AlAali *et al.*,[14] a pattern of adhesive failure is observed for zinc phosphate cement, while in our study, all failure patterns were mixed which indicates the failure of the cement itself and is bonding to the restoration surface. Our study highlights the complex interplay between adhesive and cohesive failure modes observed in the fracture surfaces of the chromium–cobalt alloy (Sintron) when bonded with two different types of cement. The analysis revealed a predominance of mixed fracture patterns, indicating that both the adhesive properties of the cement and the cohesive integrity of the alloy play significant roles in the bond performance. Previous studies have similarly reported that the type of fracture can be influenced by factors such as surface treatment and the specific materials used in the bonding process.[16]

Finally, the oral environment is a dynamic environment, and coated teeth are subjected to repeated contact with short-term but intense occlusal forces. This study evaluated static forces that have limited predictive power for bond failure and may differ clinically. Future studies should investigate the impact of these factors in the oral environment. In addition, factors related to tooth preparation, cement thickness, remaining crown height, and tooth type also affect the retention and strength of the coating. Contrary to our initial hypothesis, the results of this study revealed no significant difference in the bond strength of Sintron alloy when using zinc phosphate and polycarboxylate cement.

## CONCLUSION

Based on the results of the study indicating the lack of significant difference in the tests, it can be concluded that the bond strength of Sintron alloy with zinc phosphate and polycarboxylate cements is the same.

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### Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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