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# Evaluation of hardness and wear resistance of interim restorative materials

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## ABSTRACT

**Background:** The interim restorative materials should have certain mechanical properties to withstand in oral cavity. The aim of this study was to evaluate the hardness and wear resistance of interim restorative materials.

**Materials and Methods:** Fifteen identical rectangular shape specimens with dimensions of 2 mm × 10 mm × 30 mm were made from 7 interim materials (TempSpan, Protemp 3 Garant, Revotek, Unifast LC, Tempron, Duralay, and Acropars). The Vickers hardness and abrasive wear of specimens were tested in dry conditions and after 1 week storage in artificial saliva. The depth of wear was measured using surface roughness inspection device. Data were subjected to Kruskal–Wallis and Mann–Whitney tests. The Pearson correlation coefficient was used to determine the relationship between hardness and wear ($\alpha$ =0.05).

**Results:** TempSpan had the highest hardness. The wear resistance of TempSpan (in dry condition) and Revotek (after conditioning in artificial saliva) was significantly higher ($P < 0.05$). There was no statistically significant correlation between degree of wear and hardness of the materials ($P = 0.281$, $r = -0.31$).

**Conclusion:** Hardness and wear resistance of interim resins are material related rather than category specified.

**Key Words:** Acrylic resins, composite resins, dental restorations, dental restorations wear, hardness

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## INTRODUCTION

The interim fixed restorations have an important role in success of definitive restorations. Interim restorations must satisfy biologic, mechanical, and esthetic requirements until placement of definitive restorations.[1,2] These restorations should protect pulp and periodontal tissues, provide occlusal function and stability, and esthetics.[1,3] In addition, interim restorations may be used for providing diagnostic information, changing the vertical dimension, correcting the occlusal plane, and altering the gingival contours especially for implant-supported fixed restorations.[1,4,5] Thus, these restorations may be needed to function for a long time in oral cavity due to orthodontic or endodontic therapies, temporomandibular joint disorders and during the osseointegration periods of implants.[6] Because of complex environment of oral cavity, they should have certain mechanical properties, such as flexural strength, hardness, and wear resistance.[7-10]

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There are several types of interim materials for fixed prostheses. They are classified as methyl methacrylates, ethyl methacrylates, bis-acryl resin composites, and light-cured composites. In previous studies, researchers investigated the physical properties of interim resin materials and concluded different findings.[6-8,11]

Wear of the interim restorations, especially for an extended period, may provide some problems for clinicians; for example, in absence of occlusal contacts following the wear process, the antagonist teeth may be over erupted and the occlusal clearance may be decreased. Thus, the definitive restoration will be interfered with vertical dimension of occlusion. In these situations, it will be time-consuming both for clinician and patient to adjust the occlusion and in some cases, the preparation have to be corrected and made another impression to construct new restoration.

Hardness is one of the mechanical characteristics which is used to predict the wear behavior of the material. It is related to ease of finishing and polishing, too. There is controversy about the correlation between the hardness of a material and its wear resistance.[12] There are a few studies about the wear and hardness of interim materials for fixed restorations.[7,13] Previous studies showed that mechanical properties of interim restorative materials such as hardness and flexural strength were influenced by food simulating liquids.[13,14]

The aim of this study was to evaluate the wear resistance and hardness of different interim restorative materials before and after conditioning in artificial saliva. The null hypothesis was that there is no difference between wear resistance and hardness of the interim restorative materials. The second null hypothesis was that there is no correlation between hardness and wear resistance of the interim restorative materials.

## MATERIALS AND METHODS

The interim restorative materials evaluated in this study are shown in Table 1. These materials are representative of different interim restorative materials. A plexiglass split mold was used to make rectangular shape specimens with dimensions of 2 mm × 10 mm × 30 mm. Five specimens for microhardness test and 10 specimens for wear test were made from each material according to the manufacturer's directions [Table 1].

The specimens were prepared by placing the materials into the split mold and pressing the mold between two glass slabs under 1.5 kg load to extrude any excess material and to provide smooth surfaces. After 24 h storage to allow completion of the polymerization reaction, specimens were grounded and polished with 1000 grit silicon carbide paper.

The hardness of the interim materials was measured and determined by hardness tester instrument (Metallux 3, Leitz Co., Germany) and expressed as VHN. For each hardness measurement, three indentations were made and each indentation was implemented at different points on each specimen. The average value was determined to provide mean value hardness for each selected material. A load of 15.15 g was applied to each specimen with 10 s dwell time.

In order to study the wear behavior of the specimens, two body sliding wear test was carried out using a pin-on-plate laboratory tribotester under dry condition and a normal load of 40 N at room temperature (22-25°C) and a humidity of 15-25%. The cylindrical pins (5 mm diameter and 10 mm height) were prepared from hardened tool steel and they were changed for each wear test. The plates were prepared from each type of interim restorative materials. The pin was held against the counterface (plate on a horizontal plane) and a go-back sliding movement was performed. All the tests were implemented at constant speed of 0.1 m/s and the total sliding distance of 300 m. Wear behavior of the specimens was studied through determination of the surface roughness at an identified straight path using Surface Roughness Inspection Device (Surtronic Duo, Taylor Hobson

**Table 1: Materials tested**

| Product name | Manufacturer | Lot number | Resin type | Polymerization method* |
|---|---|---|---|---|
| Acropars | Marlic Medical Co., Tehran, Iran | UCB 4067 | Ethyl methacrylate | Auto-polymerization, hand mix (P/L=2/1) |
| Duralay | Reliance Dental Co. Worth, Ill, USA | DTX 002 | Methyl methacrylate | Auto-polymerization, hand mix (P/L=3/1) |
| Protemp 3 Garant | 3M ESPE, St.Paul, MN, USA | NR.FA 02204 | Bis-acryl | Light polymerization, auto-mix |
| Tempron | GC, Aichi, Japan | 0519151 | Ethyl methacrylate | Auto-polymerization, hand mix (P/L=2/1) |
| TempSpan | Pentron, Wallingford, CT, USA | 140105 | Bis-acryl | Dual polymerization, auto-mix |
| Unifast LC | GC America, Alsip, Ill, USA | 0506081 | Methyl methacrylate | Light polymerization, hand mix (P/L=2/1) |
| Revotek | GC America, Alsip, Ill, USA | 23014 | Bis-acryl | Light polymerization, one component |

*P/L: Powder to liquid ratio, The light and dual cure specimens were light polymerized using blue phase C8, Ivoclar Vivadent AG, Schaan, Liechtenstein for 20 s from both side

Limited Co., Leicester, England) before and after the tests and the results were expressed as mean (standard deviation). Then, the specimens were conditioned in artificial saliva for 1 week and the hardness and wear tests were conducted again. The other side of the specimens was used to determine hardness and wear resistance of the interim materials tested after conditioning in artificial saliva.

Data were analyzed using Kruskal–Wallis test and materials were ranked with Mann–Whitney U test because the homogeneity of variance assumption was not satisfied for both row and log-transformed data. Pearson correlation coefficient was used to find any relation between hardness and wear resistance of interim materials. A significant level of $\alpha$ =0.05 was used for all statistical analysis.

## RESULTS

The mean values (standard deviation) of microhardness (VHN) of the tested interim materials are presented in Table 2. The Kruskal–Wallis test showed that there was significant difference between microhardness of the tested materials in both conditions ($P < 0.01$). TempSpan had the highest hardness in both conditions ($P < 0.05$) [Table 2]. VHN of the most materials tested decreased after conditioning in artificial saliva but this difference was not significant ($P = 0.44$).

Table 3 shows the wear values of the interim materials in dry condition and after 7 days conditioning in artificial saliva. There was significant difference in wear behavior among the materials tested in both conditions ($P < 0.001$). The wear resistance of TempSpan in dry condition and Revotek after conditioning in artificial saliva had the highest wear resistance ($P < 0.05$). The wear rate of TempSpan was same in both conditions, but the wear resistance of the other interim materials was significantly improved after conditioning in artificial saliva except Protemp 3 Garant which its wear resistance decreased after conditioning ($P < 0.05$).

The Pearson correlation coefficient was used to determine any relationship between hardness and wear resistance of the tested materials [Figure 1]. There was no statistically significant correlation between degree of wear and hardness of the materials ($P = 0.281$, $r = –0.31$).

## DISCUSSION

In this study, seven commercially available interim resin materials were tested to determine the hardness

**Table 2: Mean (standard deviation) and mean rank of Vickers hardness (kg/mm²) of the tested interim materials in dry and wet conditions**

| Resin type | Mean (SD) Dry condition | Mann–Whitney groups* | Mean rank | Mean (SD) Wet condition | Mann–Whitney groups* | Mean rank |
|---|---|---|---|---|---|---|
| TempSpan | 29.28 (6.34) | A | 67.20 | 24.46 (3.07) | A | 63.80 |
| Tempron | 13.86 (1.20) | B | 47.50 | 11.92 (1.21) | B | 34.00 |
| Duralay | 12.70 (0.89) | B | 39.90 | 12.16 (0.82) | B | 36.50 |
| Unifast | 12.83 (1.99) | BC | 38.60 | 13.06 (3.01) | B | 37.70 |
| Acropars | 12.34 (1.58) | BC | 37.10 | 10.92 (2.68) | BC | 20.90 |
| Revotek | 10.45 (1.39) | C | 18.90 | 9.6 (0.22) | C | 9.40 |
| Protemp 3 Garant | 10.43 (1.45) | C | 17.60 | 12.13 (3.60) | BC | 27.90 |

*There is significant difference between the means which are characterized by the different letters ($P<0.05$)

**Table 3: The mean (standard deviation) and mean rank of wear behavior (groove depth μm) of the tested materials in dry and wet conditions**

| Resin type | Mean (SD) Dry condition | Mann–Whitney groups* | Mean rank | Mean (SD) Wet condition | Mann–Whitney groups* | Mean rank |
|---|---|---|---|---|---|---|
| TempSpan | 0.64 (0.30) | A | 19.67 | 0.75 (0.32) | B | 22.40 |
| Tempron | 6.39 (1.51) | D | 74.33 | 0.88 (0.34) | B | 26.40 |
| Unifast LC | 5.11 (1.85) | CD | 69.00 | 2.33 (1.34) | C | 46.17 |
| Protemp 3 Garant | 1.17 (0.78) | AB | 30.75 | 1.92 (0.46) | C | 45.67 |
| Revotek | 1.54 (0.27) | B | 42.33 | 0.18 (0.15) | A | 4.60 |
| Acropars | 3.53 (0.71) | C | 60.83 | 0.54 (0.21) | B | 16.50 |
| Duralay | 4.88 (2.35) | CD | 67.17 | 1.05 (0.87) | BC | 25.83 |

*There is significant difference between the means which are characterized by the different letters ($P<0.05$)

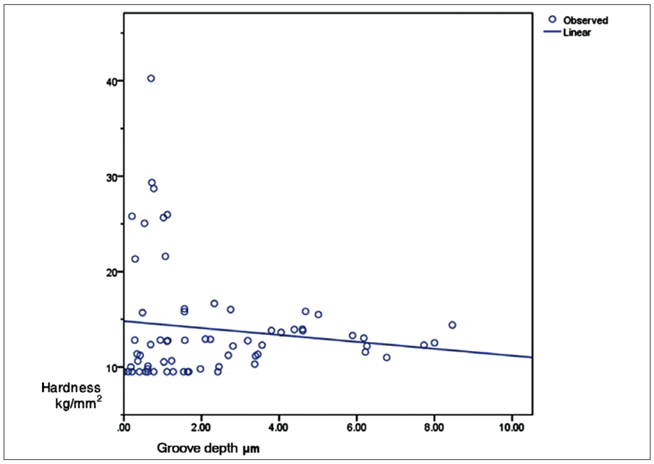


**Figure 1:** Scatter plot of Vickers hardness and wear resistance. There was no significant difference ($r = -0.31$, $P = 0.281$)

and two-body wear resistance. VHN and wear resistance of the interim materials tested were significantly different ($P < 0.01$), thus the first null hypothesis is rejected.

TempSpan showed the highest VHN among the materials experienced in both conditions ($P < 0.05$). TempSpan is a dual-cured bis-acryl resin that may increase the degree of polymerization.[8] The properties of resin materials are affected by degree of polymerization and concentration of cross-linking agents.[8,15] An increase in degree of conversion and a high concentration of cross-linking agents will result in harder material.[15] The type of resin matrix and degree of conversion influence the resin material properties, especially in the oral environment.[16] It was shown that the greatest change in hardness value of composite resin materials may occur within the first 7 days of conditioning in the food-simulating solvents.[13,17,18] The hardness of tested materials decreased after 7 days conditioning in artificial saliva except Protemp 3 Garant and Unifast LC which slightly increased but there was no significant difference between hardness of the test materials in both conditions ($P = 0.44$).

It was shown that bis-acryl resins have more favorable mechanical properties than conventional methacrylate resins.[6,8] Bis-acryl composite resins contain multifunctional monomer (Bisphenol A-glycidyl methacrylate; Bis-GMAs or Triethylene glycol dimethacrylate; TEGDEMA) and are capable of cross-linking with other monomers which increase the strength.[19] Conventional methacrylate resins contain monofunctional monomers with low molecular weight, linear molecules which decrease strength and rigidity.[6,19] But in this study, there was no superiority in hardness of bis-acryl to methacrylate resins. There are few studies with different results about the hardness of interim materials.[15,20]

Akova, *et al*.[13] suggested an increase in Knoop hardness value of the interim materials after 7 days conditioning in water. Diaz-Arnold, *et al*.[20] reported that bis-acryl resin composite materials exhibited superior microhardness in comparison to methyl methacrylate resins and the hardness of most materials decreased after 14 days conditioning in artificial saliva. Wang, *et al*.[7] found no superiority of one category of resin materials but the lowest hardness values were recorded for ethyl methacrylate materials. Yap, *et al*.[14] concluded that the hardness of provisional materials had no significant changes after 7 days storage in water except Unifast LC and Provipoint DC which showed decreased values. The results of this study are not consistent with these studies. It may be related to difference in materials, methodology, and specimen configuration.

In oral cavity, the wear of dental materials is a complex process, which may involve mechanical, thermal, and chemical reactions.[21]

TempSpan and Protemp 3 Garant demonstrated statistically less wear rates than the other tested materials in dry condition ($P < 0.05$). Although Revotek showed significantly the least wear rates after conditioning in artificial saliva ($P < 0.05$). Revotek is a light-polymerized composite resin material. It was shown that Urethane Dimethacrylate-based (UDEMA) matrix composites had better wear resistance than that of bis-GMA formulation.[22]

Wang, *et al*.[7] studied toothbrush abrasion of interim materials. They found that bis-acryl resins had more wear resistance than methyl methacrylate resins.

The wear rate of TempSpan was same in both conditions, but the wear resistance of the other interim materials was significantly improved after conditioning in artificial saliva (except Protemp 3 Garant) ($P < 0.05$). It can be explained by lubricating effect of saliva because salivary films may affect the friction coefficient and the wear rates.[23,24] Salivary glycoproteins, including the proline-rich glycoproteins and mucins have lubricatory roles.[25]

In this study, there was no statistically significant correlation between wear resistance and hardness for all materials tested. Thus, the second null hypothesis was not rejected. There are conflicting reports on the correlation between hardness and wear resistance of a material. A general relationship was reported between these variables in dental materials textbooks. However, this relationship was not found in composite materials.[12] This may be related to complex nature of wear process.

Hardness and wear resistance are two properties of interim resin materials. Clinician should consider all attributes of these materials and select an appropriate interim material for each clinical situation. For example, it was shown that Revotek has high bacterial adhesion and poor stability.[26]

In this study, only two-body wear resistance of interim resin materials was evaluated. The effects of dietary solvents on hardness and wear resistance of interim resin materials were not studied in this investigation. These materials may be softened by various foods and liquids, organic acids, and food and liquid constituents.[27,28] In addition, there are many combinations of occlusal contact conditions and the wear behavior of these interim resin materials can be different opposing the other materials.

## CONCLUSION

Within the limitations of this study, the following conclusions can be drawn:

1. TempSpan was the hardest interim material in dry and wet conditions.
2. There was no significant change in microhardness of the tested interim materials after 1 week conditioning in saliva.
3. TempSpan and Protemp 3 Garant showed the highest wear resistance in dry condition and Revotek in wet condition.
4. The wear resistance of tested interim materials significantly increased in wet condition except TempSpan and Protemp 3 Garant.
5. There was no relationship between hardness and wear resistance of the studied interim materials.

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