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The Effect of Aging and Different Surface Treatments on Temporary Cement Bonding of Temporary Crown Materials

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Research Article

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ABSTRACT

Objectives: The purpose of this research was to determine the effect of different surface treatments and aging on the bond strength of different temporary restorative materials with temporary cements.
Methods: 252 temporary crown materials 2 mm thick with a 10 mm diameter were prepared. No surface treatment was administered to the control group. 4% hydrofluoric acid gel was administered to one of the other groups and sandblasted to the other. Two types of temporary cement were used. After a 5000-cycle thermal cycle was administered to half of the materials, cement bond strengths were measured.
Results: It was found that the material used, the type of cement, the aging treatment, the material*aging treatment, and the material-cement interaction ($p<0.001$) were statistically very significant, the material*cement*aging treatment interaction ($p<0.05$) were significant, and the other interactions were insignificant ($p>0.05$).
Conclusion: Within the limitations of this in vitro study, it was found that the tested cements and surface treatments could not be implemented for all materials tested. It was found that the cement bond strength increased significantly in the temporary crowns administered by sandblasting. In the case of long-term use of the temporary restoration tested by evaluating the simulation of the oral environment, the use of a sandblasting surface treatment may be appropriate. It may be said that polymethylmethacrylate temporary crowns obtained by the conventional method have better bonding with eugenol-containing cements.

Keywords: Temporary dental restoration, luting agents, dental bonding, surface properties, thermocycling.

Farklı Yüzey İşlemlerinin ve Yaşlandırmanın Geçici Kuron Malzemelerinin Geçici Siman ile Yapıştırılmasına Etkisi

Süreç

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ÖZ

Amaç: Bu araştırmanın amacı, farklı yüzey işlemlerinin ve yaşlandırma işleminin, farklı geçici restoratif materyallerin geçici simanlarla bağlanma dayanımına etkisini belirlemektir.
Yöntemler: 2 mm kalınlığında 10 mm çapında 252 adet geçici kuron materyali hazırlandı. Kontrol grubuna herhangi bir yüzey işlemi uygulanmadı. Diğer gruplardan birine %4'lük hidroflorik asit jeli, diğer gruba kumlama uygulandı. İki tür geçici siman kullanıldı. Malzemelerin yarısına 5000 döngü (6 ay) termal siklüs uygulandıktan sonra makaslama bağlanma dayanımları ölçüldü.
Bulgular: Kullanılan materyal, siman tipi, yaşlandırma işlemi, malzeme*yaşlandırma işlemi ve malzeme-siman etkileşimi ($p<0.001$) istatistiksel olarak çok anlamlı, malzeme*siman*yaşlandırma işlemi etkileşimi ($p<0.05$) anlamlı ve diğer etkileşimler anlamsız bulundu ($p>0.05$).
Sonuç: Bu in vitro çalışmanın sınırlamaları dahilinde, test edilen simanların ve yüzey işlemlerinin test edilen tüm materyaller için uygu olmadığı bulunmuştur. Kumlama uygulanan geçici kronlarda makaslama bağlanım dayanımının önemli ölçüde arttığı bulundu. Ağız içinin simülasyonu değerlendirilerek test edilen geçici restorasyonun uzun süreli kullanımının söz konusu olduğu durumunda, kumlama yüzey işlemi uygun olabilir. Konvansiyonel yöntemle elde edilen polimetilmetakrilat geçici kronların öjenol içeren simanlarla daha iyi bağlandığı söylenebilir.

Anahtar Kelimeler: Geçici restoratif materyaller, geçici simanlar, yüzey işlemleri, yaşlandırma.

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Introduction

The use of temporary restorative materials is of great importance in the success of fixed prosthetic restorations until the completion of the final restoration. An ideal temporary restoration guides the healing of soft tissues and is also of the essence in maintaining pulp and gingival health, preventing elongation of abutment teeth, and providing aesthetics.[1]

These crown materials can be prepared by direct and indirect techniques. Temporary restorative materials were designed using CAD/CAM technology; thus, it was produced with the use of digital dentistry in many areas.[2]

It has been reported that bis-glidyl methacrylate-based and bis-acryl-based materials showed lower polymerization shrinkage and have better mechanical properties compared to acrylic resin-based materials.[3] However, the prolongation of the time spent at the chairside with direct technique has increased the popularity of temporary restorative materials produced by digital methods.[4]

Long-term use of temporary restorations may be required in implant applications and occlusal reconstruction situations.[5] The stability of physical and mechanical properties, which increase in importance in long-term use, has been argued to be sufficient in temporary crown materials produced with CAD/CAM.[2] It has been argued that the blocks are more homogeneous due to the pre-polymerization and that there is no polymerization shrinkage, compared to the polymethylmethacrylate (PMMA) blocks prepared by the traditional method in the temporary crown materials produced with CAD/CAM.[2,6] All restorative materials used in the oral environment must be resistant to masticatory forces.[3]

Bonding cements have a supporting role between the fixed prosthesis and the cut tooth.[7] Bonding cements prevent the movement of the restoration against the masticatory forces and prevents the teeth from interacting with the external environment. They not only bond the restoration with the tooth but also fills the gap between the two structures and provide resistance against vertical and lateral forces.[7] The strength of the cement to which the restorative material is adhered to the tooth and its bonding to the tooth and restorative material are also important in the success of fixed prosthetic restorations. By bonding the restorations with ideally prepared cements, the health of the surrounding tissues of the teeth and abutments will also be preserved. Adhesive agents and mechanical and antibacterial properties should be good.[8]

The marginal adaptation of cementation techniques in temporary crowns was investigated[7], and the effect of different surface treatments on bonding in the repair of temporary crown materials was evaluated[9]; however, no study has been found which examined the bond strength of temporary restorative materials with temporary cement and the way in which this strength is affected by different surface treatments and thermal cycles.

The aim of this study was to investigate the effect of aging treatment and surface treatments on the bond strength of temporary restorative materials prepared by the conventional method and CAD/CAM with temporary cements with different contents.

In the study, the H0 hypothesis showed that surface treatment application would increase bond strength, and the H1 hypothesis showed that aging treatment would reduce bonding.

Material and Methods

This study was approved with the decision taken in Ataturk University Faculty of Dentistry (Date: 22.06.2021 Issue No: 43) meeting of the Ethics Committee.

The temporary restorative materials shown in Table 1 were used in this study. A total of 252 samples were prepared with a diameter of 10 mm and a thickness of 2 mm. In the main hypotheses of the research, the differences between the independent groups were planned to be investigated, and the sample size was calculated at a 95% confidence level using the G Power-3.1.9.2 program. According to the analysis result, the minimum sample size of 52 per group (180 for total sample size), based on a theoretical power of 0.80, α value of 0.05, and a standardized effect size of 0.25 (moderate).

A metal plate with circular cavities with a diameter of 10 mm and a thickness of 2 mm was used as a mold for the temporary crown materials (Imicryl Imident, Konya, Türkiye; 3M ESPE Protemp™ 4, 3M Deutschland GmbH Dental Products Carl-Schurz-Str.1 41453 Neuss-Germany) prepared by the conventional method. The materials prepared according to the manufacturer's instructions were placed in the mold, and slightly pressure was applied to the cement glass in order to obtain a smooth shape. Polymethylmethacrylate (PMMA) blocks (Tempo Cad., On-Dent Ltd, Izmir, Türkiye) were digitally designed and prepared and smoothed with a diamond burr**.** The samples were kept in 37°C distilled water for 24 hours.

Samples prepared with an autopolymerizing acrylic resin (Imicryl, SC, Konya, Türkiye) were placed in silicone molds with a diameter of 15 mm and a height of 20 mm obtained in order to fit the test device on which the experiment would be performed. The samples were washed in an ultrasonic cleaner for 15 minutes and prepared for surface treatments by air drying. Each material was randomly divided into three groups and surface treatments were applied. No surface treatment was applied to the samples in the first group. A thin layer of 4% hydrofluoric acid gel (Porcelain etchant, Bisco, Schaumburg, IL, 60193, USA) was applied for 120 seconds to samples in the second group. Then the samples were washed for 120 seconds and dried for 10 seconds.[9] Sandblasting was performed on the samples in the third group by applying 50 µm aluminum oxide powder (Korox, Bego, Canada) for 10 seconds from a distance of 10 mm with an air abrasion device.

A silicone mold with an internal clearance diameter of 5 mm and a height of 4 mm was prepared to apply the cements. Temporary cements which were mixed in accordance with the manufacturer's instructions containing eugenol (Temp-Bond™, Kerr, Italy) and calcium hydroxide cement (Life Regular Set, Kerr, Italy) were placed one by one in the molds, covered with a cellulose tape and hardened by applying with finger pressure. The samples were cut from the silicone mold by means of lancet and removed slowly. Half of the samples (n=7) were kept in distilled water at 37 °C for 24 hours before measuring the cement bond strength.[10] 5000 aging treatment were applied to the other half in the baths with 5 and 55 °C (Esetron Smart Robotechnologies, mod dental, 220 V AC – 50 Hz – 3500 W, Ankara, Türkiye) so that the transfer time between baths would be 60 sec.[10]

The samples were fixed to the metal test equipment, and the test was placed at one end of the device. The edge was placed in the form of a knife-edge and ended in accordance with the round section of the sample at the other end of the test device.[9] Loading was done on a Universal test device (Instron, Model 2710-003, Instron Corp., USA) with a 0.5 mm/min head speed. The maximum load was recorded when the fracture occurred. The bond strength was calculated by using the following formula:[9] $\sigma = F / A$ (σ, bond strength (MPa); F, load at fracture (N); and A area of cement (mm^2).

Statistical Analysis

Statistical analysis was performed using the Statistics 20.00 (SPSS Inc., Chicago, IL., USA) computer program at 95% confidence interval and p=0.05 significance level. The conformity of the variables to the normal distribution was examined using the Shapiro Wilk test, which is one of the analytical methods, and it was found to be suitable. The data obtained in this study were evaluated with three-way analysis of variance multiple comparison (Tukey) test.

Results

As a result of the analysis of variance; it was found that the material used, the type of cement, the type of aging treatment, the material*aging treatment, and the material-cement interaction ($p<0.001$) were statistically very significant, the material*cement*aging treatment interaction (p0.05) were significant, and the other interactions were insignificant (p0.05). (Table 2)

The average bond strength values and standard deviations of all groups are shown in Table 3.

Table 1. Temporary restorative materials used in the study

Materials		Manufacturer	Feature
CAD/CAM	(Tempo Cad. PMMA Block)	On-Dent Ltd, Izmir, Türkiye	polymethylmethacrylate Block
Conventional Method	Protemp	3M Deutschland GmbH Dental Products Carl-Schurz-Strabe 141453 lieuss-Germany	nano-filled bis-akrilik composite
	Imicryl	Imıcryl Imıdent; Konya, Türkiye	Chemically polymerized cadmium-free polymethylmethacrylate

Table 2. Analysis of variance

	Sum of Squares	df	Mean Square	F	p
Materials (M)	11.80	8	1.47	12.27	< .001
Aging Treatment (AT)	3.06	1	3.06	25.47	< .001
Cements (C)	2.82	1	2.82	23.45	< .001
M * AT	4.34	8	0.54	4.52	< .001
M * C	4.29	8	0.54	4.46	< .001
AT * C	0.29	1	0.29	2.43	0.121
M * Yi * S	2.46	8	0.31	2.56	0.011
Total	25.95	216	0.12		

Table 3. The average bond strength values and standard deviations

MATERIALS	Surface Tratments	Aging Treatment							
		Without Aging Cements				With Aging Cements			
		Tempbond		Dycal		Tempbond		Dycal	
		Means	SD	Means	SD	Means	SD	Means	SD
CAD/CAM (polymethylmethacrylate block)	Control	0.23	0.13	0.37	0.26	0.14	0.10	0.44	0.25
	HF acid	0.40	0.16	0.27	0.12	0.29	0.23	0.18	0.12
	Sandblasting	0.63	0.18	0.64	0.40	0.56	0.17	0.65	0.44
Protemp (nano-filled bis-akrilik composite)	Control	0.10	0.20	0.38	0.16	0.30	0.88	0.46	0.17
	HF acid	0.11	0.14	0.59	0.14	0.30	0.27	0.46	0.29
	Sandblasting	0.52	0.20	0.67	0.23	0.41	0.26	1.49	0.72
Imicryl (cadmium-free polymethylmethacrylate)	Control	0.35	0.18	0.42	0.23	0.65	0.24	0.72	0.32
	HF acid	0.46	0.10	0.42	0.29	0.68	0.20	0.63	0.35
	Sandblasting	1.87	0.92	0.78	0.20	0.86	0.50	0.75	0.22

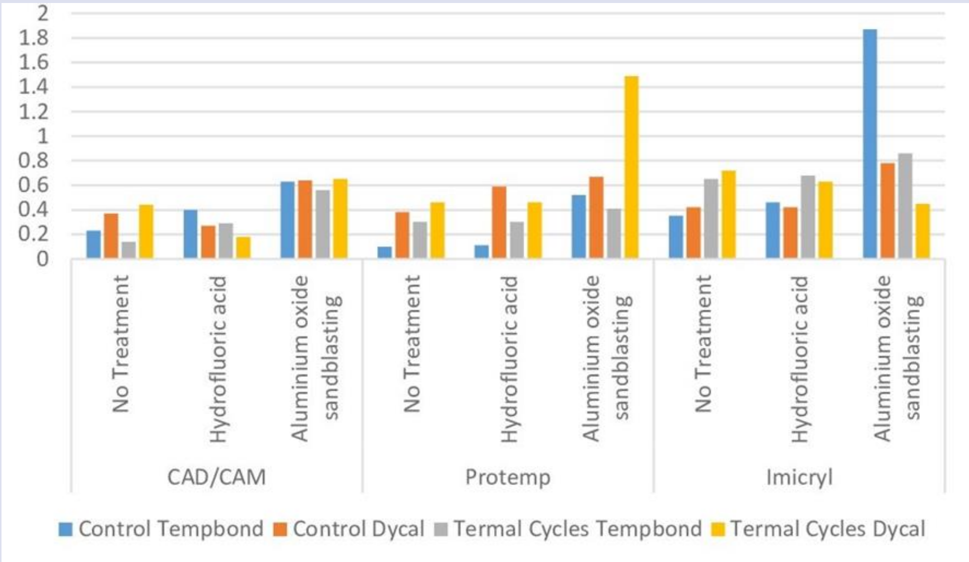

Figure 1. *Distribution of bond strength of luting cements*

It was found that the highest bond strength was in the (Imicryl) (1.87 MPa) samples without aging applied with eugenol-containing cement (Tempbond) applied with sandblasting, and the lowest bond strength was in the control group Protemp samples (0.10 MPa) bonded with untreated eugenol-containing cement (Tempbond).

Figure 1 shown distribution of bond strength of luting cements according to surface treatments.

As a result of the multiple comparison (Tukey) test of material* cement* aging treatment interaction:

In the samples which were sandblasted Protemp, treated with aging, and bonded with calcium hydroxide cements (Dycal),

A statistically significant difference was found at the $p<0.001$ level in the samples that were sandblasted Imicryl, treated with aging, and bonded with calcium hydroxide cements (Dycal).

The bond strength values obtained with the acid-treated samples were similar to those of the untreated samples.

Discussion

The hypotheses of the study were accepted since it was found that the bond strength increased in the samples that were sandblasted, and the aging treatment reduced bond strength.

Bond strength of temporary cements to dentin, implant abutments, and restorative materials is particularly important if they are to be used long-term. It was emphasized that it may be beneficial to increase the surface roughness to improve bond strength and promote mechanical joints.[11] It was found that surface treatments showed different effects on different materials in a study in which temporary restorations were repaired with related material.[9]

It has been reported that the roughness on the surfaces of the sandblasted temporary crown materials increased significantly; SEM images confirm the presence of micromechanical retention and show visible changes in the topographic model.[12]

To increase the surface roughness, in this study, mechanical methods including sandblasting with 50 µm Al_2O_3 particles and etching with 4% hydrofluoric acid were used.[9] These methods are easily available in all dental clinics and are easy to apply.[9,11] Standardization attempted by smoothing the surface of each material with a diamond burr. Some authors recommend the use of SiC paper with 220-grain for this purpose.[13] However, it is not possible to sand the inside of the crown in the clinic. At the clinic, inside surface of the crown may gently be removed by a carbide or diamond burr in some cases.

In studies, it has been reported that sandblasting increases the bond strength by creating the micro-retaining areas on the surface of the composite resin material.[9,11,14] It has been emphasized that micromechanical adhesion is very important in the repair processes of composite resin.[15,16] In this study, the increase in the cement bond strength in all samples can be explained by an increase in micromechanical retention. Sandblasting is thought to be an effective surface treatment for cement bonding.

Hydrofluoric (HF) acid gel provides micromechanical adhesion by abrading the glass particles in the matrix to form porous surfaces and voids.[17] In one study, it was reported that the application of HF acid did not affect the bond strength in polymethylmethacrylate or even reduce it, and it was stated that this may be due to the low amount of glass particles and high hydrophobic monomer content of polymethylmethacrylate.[9] It was found to have a bond strength similar to the untreated surfaces on the acid-treated surfaces in this study. It has also been reported that the surface of polymethylmethacrylate softens and its roughness decreases when HF acid is applied.[18,19] It was found that the shear bond strength increased with the application of HF acid in bis-acrylic resins such as Protemp.[9] This was attributed to the resin containing more than 24%

filler by its volume rate.[9] It has been stated that the erosivity of HF acid depends on the amount and type of filler.[9] and that the use of HF acid might be inconvenient in cases where the resin content of the restorative material is unknown.[17-19] In this study, similar bond strength values were obtained in all bis acrylic resin groups including the groups treated with HF acid and the groups without surface treatment. It would be more appropriate to choose calcium hydroxide cements in this type of temporary crown materials.

Shear tests are applied frequently on the grounds that results are more able to be estimated.[20] However, the distribution of the applied load is standardized.[21] Teeth and restorative materials are exposed to complex forces in the oral environment.[22] This is one of the limitations of the study.

It was found that the polymethyl methacrylate samples prepared with CAD/CAM were not superior to the polymethyl methacrylate produced by the conventional method in bond strength with eugenol-containing cement. It was found that the type of cement to be used in the bis-acrylic composite-based temporary restorative material that can be prepared directly at the chairside is important. In this sense, it was found that bonding bis-acrylic composite-based temporary restorations with calcium hydroxide cement and bonding polymethyl methacrylate temporary restorations obtained by conventional method with eugenol-containing cement were better. It was found that a sandblasting surface treatment can be applied in cases requiring long-term use.

The most important function of temporary cements is to seal, thus preventing marginal seepage and irritating the pulp.[23] Temporary cements should be easy to remove when necessary. However, they must be sufficiently retentive to perform their functions. Little is known about the retentive properties of temporary cements, but it has been stated that there is a strong relationship between the holding properties of temporary cements and their compressive strength.[24]

It has been found that aging treatments reduce the time that temporary cements remain functional.[25] It is known that not only the retention properties of cements but also the shaping of the crown has a significant effect on retention.[26]

It has been found that the stress causing dislocation movement is higher in polymethyl methacrylate crowns than in composite crowns for temporary cements. However, it has been found that there is a reverse situation when using eugenol-containing cement (Temp-Bond). In the same study, calcium hydroxide cements were found to be more resistant to dislocation forces than eugenol-containing cement (Temp-Bond) in polymethylmethacrylate temporary crowns.[27] For this reason, eugenol-containing cement and calcium hydroxide cement was used in the study. These are temporary cement materials frequently used, and in other respects, the temporary cements used in the present study were economical and easily accessible.

Being sufficient bonded with cement will increase the resistance of the restoration. Long-term use of temporary restorations may be possible with the selection of the appropriate material and surface treatment and the use of the appropriate cement. It was found that the cement bond strength of all the materials used in this study increased with sandblasting surface treatment. However, it was seen that not all types of cement can be used with all types of materials.

The thermal cycle is a method used to simulate the oral environment. As *in vivo*, no evidence of the number of possible cycles was found. However, it has been reported that 10,000 thermal cycles per year correspond to approximately one year of *in vivo* function.[28] The use of 5000 cycles in this study corresponds to a six-month retention time in the mouth. This period is likely to be applicable in the clinical setting when long-term temporary crown use is required.

The polymethylmethacrylate samples produced by CAD/CAM, which is one of the materials subjected to 5000 thermal cycles (5 C and 55 C) in a study examining the effect of thermal cycling on the properties of temporary restorative materials, showed better marginal accuracy than bis-acryl materials. It has been reported that CAD/CAM temporary crowns can be recommended for long-term treatments.[29] In this study, it was found that the sandblasting increased the cement bond in the polymethylmethacrylate samples produced with CAD/CAM. However, it was found that the polymethylmethacrylate samples produced by the conventional method were superior in the long term and when calcium hydroxide cement was used. In addition, it was found that the bond of nano-filled bis-acrylic composite-based temporary crown materials with eugenol-containing cements was very weak. It was seen that the bond values of the polymethylmethacrylate produced with CAD/CAM are similar with this type of cement. It is known that eugenol and resin polymers are incompatible.[30,31] In this study, the bond of a eugenol-containing cement to the bisacryl composite-based temporary crown material and the polymethylmethacrylate produced by CAD/CAM was slightly increased by sandblasting.

Conclusions

Cement selection is important depending upon the material used in temporary crown materials. Sandblasting surface treatment increased bonding. The thermal cycle application had a negative effect on the cement bond. The reason for the decrease in cement bonding over time according to the time it remains in the mouth should be examined.

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Conflicts of Interest Statement

The authors have no conflicts of interest

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