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Original research

THE EFFECTS OF DIFFERENT COLORS AND LIGHT SOURCES ON THE BOND STRENGTH OF CEREC FELDSPATHIC BLOCKS BONDED TO LIGHT-CURED RESIN CEMENT

ABSTRACT

Objectives: To evaluate the bonding with resin cement of different colored prefabricated feldspathic ceramic blocks used in the computer aided design and computer aided manufacturing (CAD-CAM) technique when different light sources were used beneath the ceramics.

Materials and Methods: Specimens of 2 mm thickness were prepared in nine different colors. All the groups were bonded to composite resin blocks using a light-cured resin cement beneath plasma arc (PAC, 2400 mW/cm^2), light emitting diode (LED, 1600–1800 mW/cm^2) and quartz tungsten halogen (QTH, 800–1200 mW/cm^2) light sources. Following the cementation, all the specimens were kept in distilled water for 24 hours in closed cups before the shear test was performed. The data were analysed by means of a two-way analysis of variance (ANOVA) and the Tukey HSD test ($p<0.05$).

Results: The highest light power was observed in the PAC groups, while the lowest light power was observed in the QTH groups, and the difference was found to be statistically significant ($p<0.05$). The highest bond strengths were obtained in the S2M and S2T color groups without the discrimination of the light source, and no statistically significant difference was found between these groups. The lowest bond strength was obtained in the S4O color group.

Conclusions: This in vitro study found that the bond strength of feldspathic ceramic restorations is directly related to the utilised light source and, further, that the bond strength decreases as the ceramic color becomes darker.

Keywords: CAD-CAM, resin cement, bond strength.

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INTRODUCTION

Dental ceramics are the oldest aesthetic materials still used daily in the field of dentistry. Ceramic material has two basic applications in fixed dentures, namely ceramic systems with a metal substructure and all-ceramic systems. Metal-ceramic systems are widely used in fixed prosthetic restorations. However, increasing attention is now being paid to all-ceramic systems due to the disadvantages of the metal substrate blocking light transmission and causing both corrosion and metal reflection at the gingival margin.[1,2]

The superior aesthetic qualities of all-ceramic systems are considered the most important factor behind such systems being preferred by clinicians and patients in recent years. The color and translucency properties of all-ceramic restorations are important determinants of the final aesthetics because they affect the diffuse and specular reflection of light.[3-5]

CAD-CAM restorations are generally preferred over the other restorative options because the prefabricated blocks used in CAD-CAM systems can be produced with a higher degree of homogeneity and fewer errors.[6-14] Resin-based bonding cements, which are widely used nowadays, are preferred because of their high mechanical strength, low solubility and high aesthetic properties in relation to the cementation of all-ceramic restorations. Clinical and laboratory studies comparing adhesive cements have indicated that the use of resin cements in all-ceramic restorations serves to increase the success of such restorations.[15-17]

The mechanical properties of resin-based bonding cements are closely related to the amount of filler used, the structure of the cement and the degree of polymerisation. The polymerisation of the bonding cement is important in terms of the biocompatibility of the resin cement and the reduction of the residual monomer content.[18,19] For the cementation of all-ceramic restorations, light-polymerised, chemically polymerised, and both light and chemically polymerised (dual-cured) resin cements can be used. Resin cements that are polymerised with light are preferred because they exhibit better color stability in aesthetic applications.[20,21]

This study aimed to investigate the bond strength with different light sources between light-cured resin cement and different colored prefabricated feldspathic ceramic blocks when used in CAD-CAM systems.

The study hypothesised that the use of different colored feldspathic ceramics will affect the bonding strengths of resin cements with different light sources.

MATERIALS AND METHODS

The study protocol was carried out according to the principles of the Helsinki Declaration, including all amendments and revisions. Collected data were only accessible to the researchers. Feldspathicceramic blocks (Cerec Blocs, Sirona Dental Systems, Bensheim, Germany) were used 12 x 14 x 18 mm in size and in nine different colors (S2-T, S3-T, S4-T, S2-M, S3-M, S4-M, S2-O, S3-O, S4-O). The sectioning process was conducted by using a precision cutter (IsoMet 1000, Buehler, Lake Bluff, IL, USA) under water cooling at a speed of 300 rpm, and samples were obtained in size of 2x5x6 mm. All ceramic specimens evaluated with a digital caliper (Mitutoyo, Tokyo, Japan) for the required final thickness (±0.1 mm). For nine different colors, three polymerization units (QTH, LED, PAC) and each group has 10 specimens (n=10) a total of 270 ceramic samples were prepared. Than the prepared cylindrical molds were filled with auto-polymerizing acrylic resin (Paladent 20, Heraus Kulzer, Germany) and sockets were prepared on the top and center of the acrylic molds in a depth of 2 mm and width of 7 mm. The prepared sockets were filled with composite resin filling material (Voco Arebesk, VOCO GmbH, Cuxhaven, Germany) and polymerized 45 seconds with LED (1600 mW/cm2). The samples were held on a polishing machine (Minitech 233, Grenoble - France) for 1 minute under running water with 240, 400, 800 and 1200 grit abrasive polishing discs at 500 rpm to provide surface smoothness. The samples were cleaned with distilled water using a 53 kHz ultrasonic cleaner (Kudos, Shanghai, China) for 90 seconds. Adhesive surfaces of the ceramic samples were roughened for 60 seconds with 9.5% hydrofluoric acid gel (9.5% Buffered Hydrofluoric Acid Gel, BISCO, Schaumburg, U.S.A.) in accordance with the manufacturer's instructions, then washed with 20 seconds with air-water spray and dried for 20 seconds with oil-free air. Silane (Monobond S, Ivoclar Vivadent, Schaan, Liechtenstein) was applied to the bonding surfaces of the ceramic samples for 60 seconds and air-dried for 2-5 seconds. After the silane application a bonding agent (Heliobond, Ivoclar Vivadent, Schaan, Liechtenstein) applied 10 second by a disposable brush and air dried 2-3 second. After surface treatments of the ceramic specimens, light cure medium value (MV 0) resin luting cement (Ivoclar Vivadent, Schaan, Liechtenstein) was used for cementation. The light cure adhesive resin was directly applied to the adhesion surface of the ceramic by being directly squeezed from the tube. The ceramic samples were placed on prepared composite surface with a presser and fixed with a constant pressure of 500 grams by using a cementation apparatus, then excess cement was removed with the help of a brush. An oxygen-blocking agent (Liquid Strip, Ivoclar Vivadent, Schaan, Liechtenstein) was applied to the cementation site for 2 minutes. Polymerization was provided using a QTH light device for 40 second, LED light device for 20 second, and a PAC light device for 3 seconds on the top and center of the ceramics. At the end of the polymerization process with light, ceramic discs were removed from the cementation apparatus and stored in closed dark cups in distilled water for 24 hours. The shear bond strength between ceramic and composite resin was measured using a universal test machine (Shimadzu AGS-X, Shimadzu Corp., Tokyo, Japan) taking ISO TR 11405 criteria into consideration. The blade, which is placed parallel to the ceramic and composite resin interface, is placed on the bonding interface and applied force with a speed of 0.5 mm/min. The maximum force at which the fracture occurred was recorded at N (Newton). This data was then divided to surface area (mm^2) of the samples to obtain results in MPa (Megapascal's); $\sigma = P / A$ (P: Force at break N (Newton) A: Bonding area (mm^2)). The data were analyzed by IBM SPSS V.23 (SPSS Statistics, IBM, Somers, New York, USA). Normal distribution of the data was tested with Shapiro Wilk. Two-way analysis of variance (ANOVA) was used to compare the data. The homogeneity of variance was assessed by the Levene test and the multiple comparison of different groups were performed by Tukey HSD. The results were presented as mean ± standard deviation. Significance level was taken as $p < 0.05$.

RESULTS

Following the two-way analysis of variance (ANOVA) in which different light sources and different color groups were assessed, the light and color effects were found to be statistically significant in relation to the bond strengths ($p<0.001$). The color interaction with the light polymerisation systems exerted a statistically significant effect on the bond strength ($p<0.001$) (Table 1).

Table 1. Two way ANOVA. The color interaction with light polymerization system.

	Sum of Squares	df	Mean Square	F	p
Light Source	864.47	2	432.23	252.73	p<0.001
Color	7253.93	8	906.61	530.11	p<0.001
Light Source*Color	182.38	16	11.39	6.6	p<0.001

According to the results of the Tukey HSD test comparing the light sources, there was a statistically significant difference between the bond strengths ($p<0.001$). The average value in the QTH light group was 16.10 MPa, while the average in the LED light group was 18.16 MPa and in the PAC light group was 20.48 MPa. The highest value was obtained in the PAC group, while the lowest value occurred in the QTH light group. Further, according to the results of the Tukey HSD test comparing the colors for all the polymerisation units, there was a statistically significant difference between the groups (p<0.001). The maximum bond strength values were obtained in relation to the S2T and S2M colors, and there was no statistically significant difference between the groups. This was followed by the S3T, S3M, S2O and S4T colors, and there was a statistically significant difference among them. There was no significant difference between the S3O and S4M colors. In terms of the S4O color, the lowest bond strength was obtained and a statistically significant difference was found between it and all the other color groups. A comparison of the mean and standard deviation values concerning the bond strengths for each color for the QTH, LED and PAC light sources is presented in Table 2 and Figure 1.

Table 2. Comparison of bond strength in light sources for each color (p<0.05).

Color	QTH		LED		PA		p
S2T	^{a}24.7 ± 1.7	A	^{a}25.5 ± 2.0	A	^{a}25.8 ± 1.4	A	0.332
S3T	^{b}20.2 ± 1.7	A	^{b}22.6 ± 1.3	B	^{ab}24,8 ± 1.2	C	<0.001
S4T	^{d}12.6 ± 0.9	A	^{d}14.4 ± 1.3	B	^{d}17.6 ± 1.5	C	<0.001
S2O	^{c}15.7 ± 1.3	A	^{c}18.4 ± 1.4	B	^{c}21.8 ± 1.3	C	<0.001
S3O	^{d}12.2 ± 1.0	A	^{d}12.9 ± 1.2	A	^{e}15.7 ± 1.1	B	<0.001
S4O	^{e}8.6 ± 0.8	A	^{e}10.1 ± 1.3	B	^{f}12.3 ± 0.8	B	<0.001
S2M	^{a}23.8 ± 1.2	A	^{a}25.7 ± 1.6	B	^{a}26.3 ± 1.6	B	0.002
S3M	^{c}16.1 ± 1.3	A	^{b}21.0 ± 1.2	B	^{b}23.9 ± 1.0	C	<0.001
S4M	^{d}11.0 ± 1.4	A	^{d}12.9 ± 1.0	B	^{de}16.2 ± 1.1	C	<0.001

A, B, C: There is no difference between light sources with the same character for each color

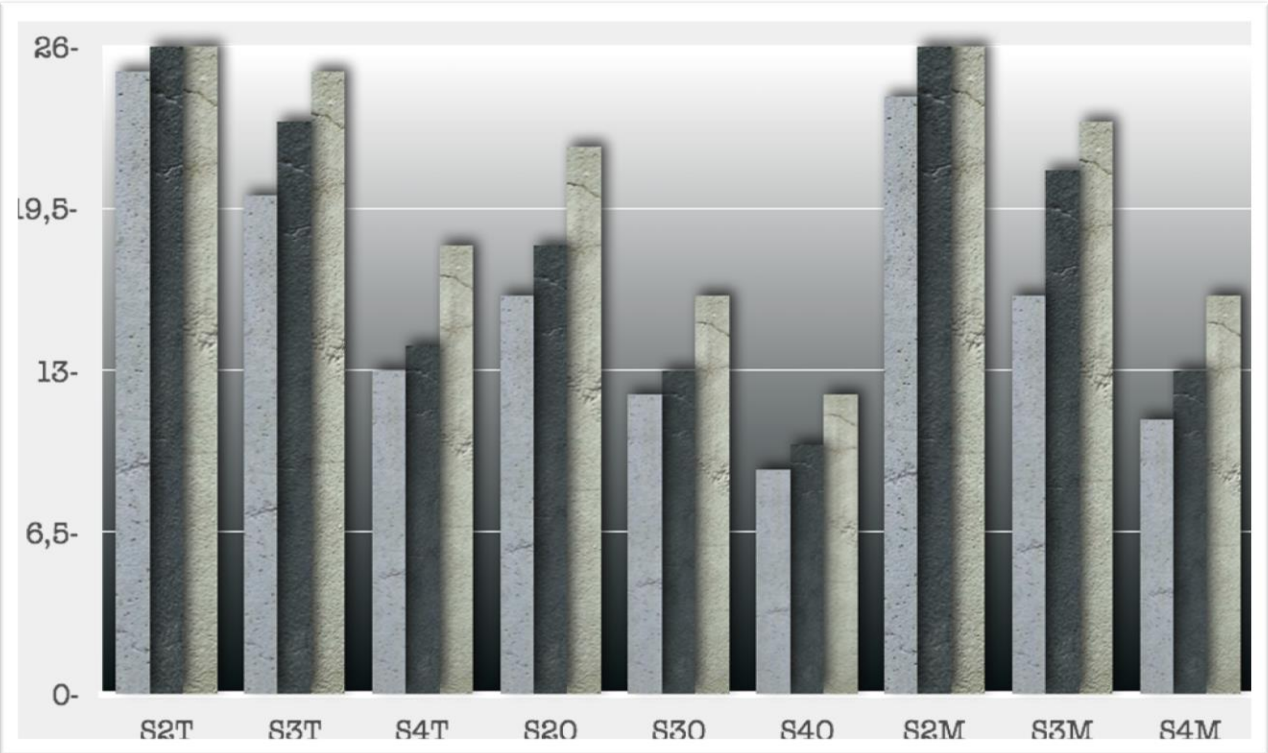

Fig. 1. Mean standard deviation graph of light sources defining colors

DISCUSSION

The hypothesis of the present in vitro study was accepted. The bond strengths of the CAD-CAM feldspathic porcelain samples of nine different colors and using three different light sources were evaluated and found to be different.

In clinical applications, the adhesive cementation of all-ceramic restorations can be performed using resin-based adhesive cements that are polymerised by light, by chemicals or by both. The advantages offered by the light-cured resin cements are that they can be easily cleaned, have different opacity and color choices, have a long working time and allow the physician to polymerise when he wants.[22-25] Dual-cured resin cements allow for the completion of the polymerisation with chemical initiators when the light transmission is limited. The polymerisation starts with light and then continues chemically, even if there is not enough light transmission. The most important disadvantage of dual-polymerised resin cements when compared to light-polymerised resin cements is that the color stability is worse. This is due to the aromatic tertiary amine present in the dual-polymerised resin cement, which reacts with benzoyl peroxide to initiate the chemical reaction. To achieve acceptable color stability, the initiation of the polymerisation by means of reacting with camphorquinone represents a better approach.[20,21,26,27] However, the use of dual-cured resin cements is recommended when the restoration thickness exceeds 2 mm [28,29], since the degree of polymerisation of light-cured resin cements determines the extent of the restoration. The thickness of the ceramic used in this study was set at 2 mm because that value represents the highest thickness at which resin cement can be successfully polymerised by light, which we wanted to test.

The color, thickness and light application time of the restoration are important factors that all affect each other during cementation. In light-curing resin systems in particular, the darkening of the restoration color significantly reduces the polymerisation depth of the resin. Duran and Güler[30] used 12 different colors and three different thicknesses of zirconium samples, and they reported that when the color increased, the light transmission decreased. Palta *et al.*[31] showed that, for all the monolithic zirconia specimens, the light transmission values decreased in the order of 0.5>1.0>2.0 mm in all the color groups and in the order of A1>A2>A3>A4 in all the thickness groups. The researchers, therefore, noted that the light transmission was affected by the color and the thickness of the monolithic zirconia.

Soares *et al.*[32] reported that the effect of the ceramic restoration shade was less significant than that of the thickness when they compared different thicknesses (1 mm, 2 mm and 4 mm) and different shades (A1, A2, A3, A3 and A3.5). Peixoto *et al.*[33] found a significant difference in the light transmittance between the lightest and darkest colors of each group in the A, B and C color groups of the Vita color scale at 1.5 mm and 2 mm ceramic thicknesses. In this study, the highest bonding values were obtained in the S2M and S2T color groups regardless of the light device used, and no statistically significant difference was found between these groups. The lowest resistance was obtained in the S4O color group. Kılınç *et al.*[34] used four different colors and four different ceramic thicknesses to test the light transmission, and they concluded that when the color became darker, the passage of light was reduced. Cardash *et al.*[35] found that the light transmittance decreased as the color became darker when using ceramic samples of 2 mm thickness. In this study, parallel results were obtained, since as the color became darker, the bonding values decreased.

In studies using samples of feldspathic and compressible ceramics, the thickness and color of all the ceramic restorations are referred to as the light-polymerising agent, which affects the degree of polymerisation. Generally, in the case of thicker and darker restorations, the power of the available light source is of the utmost importance in terms of achieving the optimal polymerisation of the material. The minimum light output power required to achieve the activation of camphorquinone is 280–300 mW/cm^2.[36]

In this study, light sources with output powers ranging from 800–2400 mW/cm^2 were used. With regards to the comparison of the different color groups for the QTH light device, the highest bond strengths were obtained in the S2T and S2M groups, and no statistically significant difference was found between these groups. The lowest value was obtained in the S4O groups. For the LED light device, the S2T and S2M groups showed the highest bond strengths, and there was no statistically significant difference between them. The next highest bond strengths were found in the S3T and S3M groups, and there was no significant difference between them. The S4O groups showed the lowest bonding resistance. In terms of the PAC device, the S4O groups showed the lowest bond strength, while the S2T, S3T and S2M groups showed the highest bond strengths, and there was no statistically significant difference between any of these groups. The polymerisation efficiency was increased for more color groups when the output power was increased. Further, when compared to the other light sources, in the case of all the colors, the PAC polymerisation unit showed the highest light transmission values.

Duran and Güler[30] evaluated the light transmission using halogen, LED-1, LED-2, Bluephase and PAC light units. There were statistically significant differences identified among the transmitted light powers. The highest light transmission of all the groups was observed with the PAC light unit, while the lowest was observed with the halogen lamp. The Bluephase light unit exhibited higher light transmission than the LED-2, while the LED-2 exhibited higher transmission than the LED-1. Rasetto *et al.*[36] examined the polymerisation of resin cement under a ceramic veneer, and they found that high output power lamps demonstrated more effective polymerisation under a ceramic veneer than conventional halogen lamps. The inadequate polymerisation of resin cement under a restoration may adversely affect the mechanical properties and the dimensional stability of that restoration.[37,38] In this study, the bonding values were found to be higher in the light devices with high output power.

The bond strength of the feldspathic ceramic samples used in this study was directly related to the light source. The PAC light source showed the highest values in this regard. The conventional QTH lamp, which had a lower value than the other polymerisation units in terms of the output power, proved to be the polymerisation unit that gave the lowest bonding value under the ceramic. This study further found that the bonding value decreased as the color became darker, without distinguishing the light device. The findings of similar prior studies support these results.[30-32,34] According to the results of this study, light units with higher output power may be preferred in order to compensate for the reduced light transition observed in relation to high chroma values. Where light devices with higher output power cannot be used, rather than light-cured resin cements, it may be advisable to use dual-cured resin cements, in which the polymerisation begins with light and then continues chemically. To confirm the findings of this study concerning the feldspathic ceramics used in the CAD-CAM system and to extend them to other ceramic types currently used in the clinic, additional studies are needed in this area.

CONCLUSIONS

Bearing in mind the limitations of this study, it can be asserted that the bond strength of feldspathic ceramic restorations is directly related to the light source and, further, that the bond strength decreases as the ceramic color becomes darker. Based on these results, it appears that the use of dual-polymerised resin systems may prove safer than the use of light-cured resin systems, which are polymerised by light in dark restorations of 2 mm thickness. Further studies are needed to understand that this study on feldspatic ceramics used in CAD-CAM system gives similar results to other types of ceramics currently used in the clinic.

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CONFLICTS OF INTEREST STATEMENT

The authors report no conflicts of interest.

Farklı Renklerdeki Cerec Feldspatik Blokların Farklı Işık Kaynakları Kullanılarak Rezin Simanla Olan Bağlantısının Değerlendirilmesi

ÖZ

Amaç: *Bu çalışmanın amacı farklı renklerdeki CAD-CAM üretim tekniğinde kullanılan prefabrike feldspatik seramik blokların, farklı ışık kaynakları altında rezin simanla olan bağlantısının değerlendirilmesidir.* ***Materyal ve Metot:*** *Çalışmada 2mm (±0,1 mm) kalınlıkta ve 9 farklı renk grubunda Cerec feldspatik seramik örnekler hazırlandı. Bütün örnekler Plazma ark (2200 mw/cm^2), LED (1450 mw/cm^2) ve halojen (1000 mw/cm^2) ışık kaynakları kullanılarak ışıkla sertleşen rezin simanla polimerize edildi. Simantasyondan 24 saat sonra makaslama testi uygulandı. Elde edilen sonuçlar istatistiksel olarak iki yönlü varyans analizi (ANOVA) ve Tukey HSD testi kullanılarak değerlendirildi (p<0,05).* ***Bulgular:*** *Çalışmanın sonuçları istatistiksel olarak değerlendirildiğinde, gruplar içerisinde plazma ark en yüksek ortalama değere sahipken, en düşük değer*

halojendedir. Işık cihazı ayırt edilmeksizin en yüksek bağlantı dirençleri S2M ve S2T renk gruplarında elde edilmiş ve bu gruplar arasında istatistiksel olarak anlamlı bir farklılık bulunamamıştır. En düşük bağlantı direnci ise S4O renk grubunda elde edilmiştir. ***Sonuç:*** *Yapılan bu in vitro çalışmanın sonucunda feldspatik seramik restorasyonların bağlantı direncinin kullanılan ışık kaynağı ile doğrudan ilişkili olduğu ortaya çıkmış ve seramik rengi koyulaştıkça bağlantı direnci düşmüştür. Çıkan sonuçlar ışığında, 2 mm kalınlığındaki koyu renkli restorasyonlarda ışıkla polimerize olan rezin siman sisteminin yerine dual olarak polimerize olan rezin sisteminin kullanımının daha güvenli olabileceği söylenebilir.* ***Anahtar Kelimeler:*** *CAD-CAM, rezin siman, bağlanma dayanımı*

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