Original papers

The bond shear strength of methacrylate materials used to reduce dental and alveolar undercuts

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Abstract

Background. The reduction of dental and alveolar undercuts on plaster models is an important issue in the process of planning partial and complete prostheses. In recent years, new materials such as methacrylate resins that can be used to reduce undercuts have emerged. Their great advantage is high temperature insensitivity and relatively high ease of use.

Objectives. The study aimed at determining the factors that affect the shear bond strength, and which material can be better used at the laboratory stage of preparing the plaster model to facilitate the denture bearing area and reduce the traumatizing impact of the prosthesis.

Material and methods. In the study, 2 composite materials Block-Out Gel LC (VOCO GmbH, Cuxhaven, Germany) and LC Block-Out Resin (Ultradent Products Inc., South Jordan, USA) were used for tests on the Tewerock and Stodent plaster. Specimens consisted of 20 mm × 10 mm × 10 mm plaster blocks as a base, and composite cylinders of 3 mm diameter and 5 mm height, attached to the blocks. The base of the sample was combined with a composite cylinder in the Individo Light Box halogen lamp (VOCO GmbH, Cuxhaven, Germany). A total of 120 samples were studied. The shear bond strength (SBS) test was performed using the Hounsfield H5KS model HTE S/N D83281 fitted with a 5.000-N head using a cutting knife speed of 5 mm/min.

Results. LC Block-Out Resin and Block-Out Gel LC materials deposited on class III plaster and polymerized at temperatures of up to 100°C had the best SBS (5.59 MPa and 4.0 MPa, respectively). Samples made of LC Block-Out Resin and class IV plaster showed no statistically significant differences between all the groups. Additional polymerization under 2.4 bar was the most effective in improving SBS among Block-Out Gel LC and class IV plaster samples.

Conclusions. The results of the studies show that both the plaster type and the polymerization process have a significant effect on the SBS of light-cured methacrylate material to plaster.

Key words: shear bond strength, composite materials, dental and alveolar undercuts, undercuts reduction, methacrylate resins

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Introduction

One of the current problems in dental prosthetics is the reduction of dental and alveolar undercuts, leading to the facilitation of the denture bearing area.[1–4] It is a very important issue after a paralelometric analysis and affects the accuracy of the prosthesis.[5,6] Up to now, waxes, phosphate cements and silicone materials have been used to reduce undercuts. These materials did not provide sufficient precision of prosthetic devices, because they combined with the plaster model mechanically rather than chemically and, therefore, there was a need to replicate the plaster model.[7,8] Block-Out Gel LC and LC (VOCO GmbH, Cuxhaven, Germany) Block-Out Resin (Ultradent Products Inc., South Jordan, USA) are the most often used methacrylate undercuts reduction materials. Block-Out Gel LC is made mainly of urethaneacrylate oligomer, triethylene glycol dimethacrylate and catalyst. LC Block-Out Resin is made mainly of diurethane dimethacrylate and triethylene glycol dimethacrylate. Differences in the composition of both products may influence bonding with the plaster. Both of these materials are light-cured resins, colored blue for the ease of use. They combine strongly with the plaster model. Therefore, there is no need to duplicate it. This has a positive effect on the accuracy of the prosthesis and reduces the costs. In a laboratory, the abovementioned materials are used for the reduction of undercuts on plaster models. It should be emphasized that these materials have not been subjected to such an analysis before.

Objectives

The aim of the study was to determine the factors that affect the shear bond strength and to establish which material can be better used at the laboratory stage of preparing the plaster model for the treatment of patients in whom there is a need to reduce undercuts, facilitate the denture bearing area and decrease the traumatizing impact of the prosthesis.

Material and methods

Two composite materials Block-Out Gel LC and LC Block-Out Resin (Ultradent Products Inc., South Jordan, USA) were analyzed in order to determine which of them better meets the laboratory-clinical requirements. Shear bond strength (SBS) of these substrates from plaster surface was investigated. To compare SBS of both composite materials, they were attached to plaster blocks made of Tewerock class IV (Kettenbach GmbH & Co. KG, Eschenburg, Germany) and Stodent class III (Zhermack SpA, Badia Polesine, Italy) of different hardness. Experimental tests of SBS were carried out at the Department of Dental Techniques and Technologies of Poznan University of Medical Sciences using the Hounsfield H5KS test machine model HTE S / N D83281 fitted with a 5.000-N head using a cutting knife speed of 5 mm/min. Specimens consisted of 20 mm × 10 mm × 10 mm plaster blocks as a base, and composite cylinders of 3 mm diameter and 5 mm height, attached to the blocks. The base of the sample was combined with a composite cylinder in the Individo Light Box halogen lamp (VOCO GmbH, Cuxhaven, Germany). In general, 120 samples were prepared and tested to determine the SBS [MPa] – 60 of them were made from Block-Out Gel LC (30 on Tewerock plaster blocks and 30 on Stodent blocks). The next 60 samples were made of LC Block-Out Resin (30 on Stodent plaster blocks and 30 on Tewerock blocks). The sample types were then divided into 3 groups. The control group (group I) did not undergo any transformation (n = 10). Group II was subjected to polymerization under the pressure of 2.4 bar (n = 10). Group III was polymerized at 100°C (n = 10).

The statistical analysis was performed using the Kruskal-Wallis test and the Friedman test with STATISTICA v. 12 software (StatSoft Inc., Tulsa, USA). Post-hoc tests were used in order to decide which groups were significantly different from each other. Statistical significance was set at the $p \leq 0.05$ probability level. The Shapiro-Wilk test showed that the distributions of values of some groups were not normal, thus the non-parametric tests were used for all analyses.

Results

All results are presented in Table 1.

In the control group, the SBS of LC Block-Out Resin and Block-Out Gel LC attached to Stodent class III plaster was 2.67 MPa and 2.29 MPa, respectively. After polymerization under 2.4 bar pressure (group II), SBS significantly decreased (0.91 MPa and 0.88 MPa, respectively; $p \leq 0.05$). For samples made of LC Block-Out Resin after polymerization in 100°C (group III), SBS increased (5.59 MPa; $p \leq 0.05$). Also for samples made of Block-Out Gel LC, SBS increased after polymerization in 100°C, but it was statistically significant only when compared to group II.

In the control group, the SBS of the LC Block-Out Resin and Block-Out Gel LC attached to Tewerock class IV plaster was 4.00 MPa and 2.41 MPa, respectively. In group II, SBS was 2.21 MPa and 3.37 MPa, respectively, and in group III – 2.39 MPa and 2.41 MPa, respectively. For samples made of Block-Out Gel LC, SBS in group II after additional polymerization under 2.4 bar was higher when compared to group III ($p \leq 0.05$). However, there were no differences regarding SBS between the control group and other groups.

Comparing the studied materials in the control group, we found no statistical significance between samples regarding SBS. In group II, SBS was statistically the highest for Block-Out Gel LC attached to Tewerock class IV plaster (3.37 MPa). In group III, the highest SBS was proved for samples made of LC Block-Out Resin attached to Stodent class III plaster (5.59 MPa).

Table 1. Comparison of the shear bond strength values between different samples

Studied samples		Group I control				Group II polymerization under 2.4 bar				Group III polymerization at 100°C			
		Q1	median	mean	Q3	Q1	median	mean	Q3	Q1	median	mean	Q3
		[MPa]				[MPa]				[MPa]			
1.	LC Block-Out Resin + Stodent III	1.73	3.02 II, III	2.67 II, III	3.55	0.53	$0.79^{\#}$ I, III	$0.91^{\#}$ I, III	1.16	4.01	$4.45^{\$\&}$ I, II	$5.59^{\$\&}$ I, II	6.02
2.	Block-Out Gel LC + Stodent III	1.63	2.41 II	2.29 II	3.04	0.44	0.76^{*} I,III	0.88^{*} I,III	1.20	2.82	4.21 II	4.0 II	4.64
3.	LC Block-Out Resin + Tewerock IV	2.49	3.70	4.0	4.54	1.61	1.68	2.21	1.80	1.48	$2.01^{\$}$	$2.39^{\$}$	3.06
4.	Block-Out Gel LC + Tewerock IV	1.51	2.20	2.41	3.01	3.13	$3.19^{\#*}$ III	$3.37^{\#*}$ III	3.76	2.07	$2.46^{\&}$ II	$2.41^{\&}$ II	2.88

$^{\#}$ $p < 0.05$ in comparison between LC Block-Out Resin + Stodent III and Block-Out Gel LC + Tewerock IV; * $p < 0.05$ in comparison between Block-Out Gel LC + Stodent III and Block-Out Gel LC + Tewerock IV; $^{\$}$ $p < 0.05$ in comparison between LC Block-Out Resin + Stodent III and LC Block-Out Resin + Tewerock IV; $^{\&}$ $p < 0.05$ in comparison between LC Block-Out Resin + Stodent III and Block-Out Gel LC + Tewerock IV; I – $p < 0.05$ in comparison with group I (control); II – $p < 0.05$ in comparison with group II (polymerization under 2.4 bar); III – $p < 0.05$ in comparison with group III (polymerization at 100°C).

Discussion

As the following research topic is not common and studied materials have not been subjected to such an analysis before, there is not much research in the literature that could be used in the discussion.

The reduction of undercuts using methacrylate resin obtains higher precision of partial and complete prostheses, which exerts a less traumatic effect on the denture bearing area.[9–12] As a consequence, blocking out undercuts reduces the number of the patient's visits, since there is no need to make as many adjustments of the prosthesis.[13–16]

In group II and III, the class of the plaster had an impact on SBS. Additional polymerization at 2.4 bar caused an increase of SBS for class IV plaster when compared to class III plaster. Additional polymerization at 100°C increased SBS for class III plaster. It was the most effective method of increasing SBS for class III plaster. These results may be related to the structure determined by the plaster type. The class of plaster determines its increased hardness and applicability. Class III plaster requiring less precision is most often used for prosthetic treatment. Class IV plaster is more rigid and undergoes only slight deformations. The smaller diameter of the plaster grain determines a better quality of the model. At the same time, it is associated with its lower porosity.

The results of the study showed that not only the plaster type, but also additional polymerization processes had a significant effect on the bonding strength of light-cured methacrylate material to plaster. Generally, additional polymerization at 100°C increased or did not statistically affect SBS at all when compared to the control group. The best parameters presented specimens made of LC Block-Out Resin and Stodent class III plaster after polymerization at 100°C. On the other hand, polymerization under pressure in most cases significantly decreased or did not affect SBS.

Therefore, the analysis of the results may suggest that models with lower hardness and greater porosity, i.e., class III plaster should be used for the reduction of the undercuts with the composite material, but only after additional polymerization at 100ºC. Polymerization under pressure seems to be inefficient in most cases.

Conclusions

It is important to underline that additional laboratory stages increase total costs and time of denture fabrication. Polymerization can improve SBS, however not always. The polymerization at 100°C was the most efficient among LC Block-Out Resin attached to class III plaster samples. LC Block-Out Resin and Block-Out Gel LC seem to have sufficient adherence to the surface of models made of Stodent class III and Tewerock class IV plaster in the process of blocking out the dental and alveolar undercuts. Both the composite material and the plaster type had a significant impact on SBS.

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