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Research Article

Effect of different polishing system on bis-acryl material surface roughness and gloss: experimental study

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ABSTRACT

Introduction: Bis-acryl composite resins are commonly used for temporary crowns but are difficult to polish due to their soft resin and hard filler particles. Well-polished surface on temporary crowns offers benefits like better gingival-health, improved mastication, and better aesthetics. Multi-step aluminum oxide discs and one-step diamond discs are effective for polishing bis-acryl materials. This study aimed to analyze the surface roughness and gloss of bis-acryl provisional crowns before and after polishing with two different polishing systems. **Methods:** Total of 72 samples (10x2 mm and 16x2 mm) were divided into two groups (I and II) for roughness and gloss analysis. Each group was further subdivided into four sub-groups (IA,IIA,IB, and IIB). Groups IA and IIA were polished using the aluminum oxide multi-step system, while groups IB and IIB were polished using the diamond one-step system. All samples were pre-standardized with abrasive paper #1000 before polishing. Surface roughness and gloss were measured using profilometer and glossmeter before and after polishing. The data were analyzed using paired t-test ($p<0.05$). **Results:** After polishing, the surface roughness for the aluminum oxide group was 0.18±0.02, with gloss value of 46.55±1.31. The diamond disc resulted in surface roughness of 0.15±0.02 and gloss value of 51.08±1.76. Statistically significant differences were found in surface roughness and gloss between groups IA and IB ($p=0.0001$), delta gloss between groups IIA and IIB ($p=0.0001$). **Conclusions:** Both polishing systems produced acceptable surface roughness (0.20 μm) and gloss (40-60 GU). However, the diamond one-step system produced a smoother and glossier surface with greater efficiency.

KEY WORDS: Bis-acryl, surface roughness, gloss, aluminum oxide, diamond

Pengaruh perbedaan sistem pemolesan terhadap kekasaran dan kilap permukaan pada material bis-acryl: studi eksperimental

ABSTRAK

Pendahuluan: *Resin komposit bis-acryl sering digunakan untuk mahkota sementara, namun sulit dipoles karena kombinasi resin lunak dan partikel filler keras. Permukaan mahkota yang dipoles memberikan keuntungan dalam perawatan gigi, seperti kesehatan gusi, pengunyahan, dan estetika. Disk aluminium oksida dan disk diamond dianggap efektif untuk pemolesan bahan bis-acryl. Penelitian ini bertujuan untuk mengevaluasi kekasaran dan kilap permukaan bahan mahkota sementara bis-acryl sebelum dan sesudah pemolesan dengan dua sistem pemolesan yang berbeda.* ***Metode:*** *Sebanyak 72 sampel bis-acryl berbentuk disk (10x2 mm dan 16x2 mm) dibagi menjadi dua kelompok (kelompok I dan II) untuk evaluasi kekasaran dan kilap permukaan. Setiap kelompok dibagi lagi menjadi empat sub-kelompok (IA, IIA, IB, IIB). Kelompok IA dan IIA dipoles dengan disk aluminium oksida sistem multi-langkah, sedangkan kelompok IB dan IIB dipoles dengan disk diamond sistem satu langkah. Sebelum pemolesan, semua sampel distandarisasi menggunakan kertas abrasif #1000 dengan rotary grinder. Profilometer dan glossmeter digunakan untuk mengukur kekasaran dan gloss permukaan. Kemudian data dianalisis menggunakan uji t berpasangan ($P<0{,}05$).* ***Hasil:*** *Setelah pemolesan, kekasaran permukaan dengan disk aluminium oksida adalah 0,18±0,02 dengan gloss 46,55±1,31. Dengan disk diamond, kekasaran permukaan menjadi 0,15±0,02 dengan gloss 51,08±1,76. Uji T menunjukkan perbedaan signifikan pada kekasaran dan gloss antara kelompok IA dan IB ($p=0{,}0001$), serta perbedaan signifikan pada gloss antara kelompok IIA dan IIB ($p=0{,}0001$).* ***Simpulan:*** *Kedua sistem pemolesan menghasilkan kekasaran permukaan dan gloss yang dapat diterima, namun disk diamond menghasilkan permukaan yang lebih halus dan mengkilap dengan efisiensi lebih tinggi.*

***KATA KUNCI**: Bis-acryl, kekasaran permukaan, kilap, aluminum oksida, diamond*

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INTRODUCTION

A provisional crown is an essential part of fixed partial denture therapy. The provisional restoration must not be carelessly fabricated and must fulfil several interconnected factors categorized as biological, mechanical, and aesthetic.[1] In recent years, bis-acryl composite resin has been widely used in the manufacturing of provisional crowns. Bis-acryl exhibits very low exothermic reactions, good marginal fit, transverse strength and colour stability. Although bis-acryl is a superior material, it is more difficult to polish due to its composition, which includes a relatively soft resin matrix and hard filler particles.[2]

The peaks and valleys created by exposed filler particles after polishing might hinder the achievement of a smooth and shiny surface.[3] Although manufacturers claim that it is unnecessary for bis-acryl provisional material to be polished and that simply removing the oxygen-inhibiting layer using alcohol is sufficient.[4] However, in clinical settings contouring and finishing often result in a rough surface. Hence, polishing remains necessary to achieve a smoother finish. A clinically acceptable surface roughness should not exceed 0.2 µm. Previous research suggests that surface roughness exceeding 2 µm leads to a significant increase in biofilm formation, whereas values below 0.2 µm provide optimal surfaces for intraoral restorations.[5] Smoother surfaces reduce plaque accumulation, recurrent caries, bacterial adhesion, and discoloration in long-term restored teeth.[3]

Gloss is inversely correlated with surface roughness, meaning the gloss value increases as the surface roughness decreases. It plays a crucial role in the aesthetic appearance of provisional crowns, particularly for anterior teeth. As a benefit in achieving a smoother surface, polishing also enhances gloss, mimicking natural enamel. A smooth surface reflects light, giving the material a glossier appearance. Studies indicate that gloss value in human enamel ranges between 40-60 GU.[6] A higher gloss score minimizes the effect of colour discrepancies between provisional crowns and natural teeth, providing patients with a reference standard for their upcoming permanent restorations.[7] The final polished surface of bis-acryl is influenced by several factors, including the material composition and polishing system used. Various bis-acryl polishing systems are available in one-step and multi-step formats, such as silicon oxide, aluminum oxide-coated abrasive discs, diamond discs, and polishing pastes.[2,3]

Polishing materials for temporary crowns vary, but it is not yet clear which material is best for polishing bis-acrylate. Therefore, it is imperative that clinicians select the correct polishing material for temporary crowns that can produce a smooth surface. The smoother the surface, the higher the gloss level of the restorative material, which will restore a similar appearance to the natural tooth and improve aesthetics. The more aesthetically pleasing the restoration, the greater the patient's satisfaction and confidence. Even with a temporary crown, the patient will still be concerned about the aesthetics of the restoration.[2,6]

Aluminum oxide disc polishing material is considered a better option for bis-acryl polishing material because it is available in multi-step polishing kits with several levels of roughness, ranging from coarse to very fine particles. Diamond is the hardest mineral and can erode materials easily; however this material can also create deeper scratches on the polished surface due to its hardness. Diamond-impregnated polishing instruments in one-step or two-step polishing systems have been proven to be effective and comparable to multi-step polishing system instruments in producing a smoother and shinier surface.[8–11]

Contrary to the variety of materials available for polishing provisional restorations, there is no standardized material specifically recommended for polishing bis-acryl resin. The first null hypothesis was that there would be no difference in surface roughness and gloss on bis-acryl before and after polishing with aluminum oxide or diamond discs. The second null hypothesis was that there would be no difference in gloss change on bis-acryl after polishing with both materials.

METHODS

This study was an experimental laboratory study with a one-group pretest-posttest design. The sample size in this study was determined using hypothesis testing for the difference between the means of two paired groups. Two polishing materials and one provisional restorative material were used in this study. The properties and manufacturers of these materials are listed in Table 1.

Table 1. Provisional restorative material properties

Material	Manufac-turer	Type	Composition	Shade	LOT No
Smar-Temp™	Parkell Inc Edgewood, NY, USA	Bis-acryl	Uncured Methacrylate Ester Monomers, Silinated glass and silica fillers, Dibutyl phthalate, Benzoyl peroxide	A2	2022820228
Sof-Lex XT®	3M ESPE, St. Paul, MN, USA	Multi-step system	Aluminum oxide-coated disk	Coarse : 60 µm Medium : 29 µm Fine : 14 µm Extra fine: 5 µm	N965201
PoGo®	Dentsply/Caulk, Milford, DE, USA)	One-step system	Polymerized Urethane Dimethacrylate Resin; Fine Diamond Powder ; Silicon Dioxide;	7 µm	00012977

Thirty six disc-shaped samples (group I) were fabricated using a stainless-steel mould (10 x 2 mm) and thirty six disc-shaped samples (group II) were fabricated using a stainless-steel mould (16 x 2 mm). Glass plates and polyester strips were placed under the mould to ensure a flat surface. Bis-acryl (SmarTemp™) was automixed and inserted into the mould. Then, a polyester strip and glass plate were placed and lightly pressed over the mould to remove excess material. The material was fully polymerized within 6 minutes and 15 seconds according to the manufacturer's instructions. After polymerization, the samples were removed from the mould and wiped with alcohol-soaked gauze for 20 seconds to remove oxygen inhibiting layers. The initial surface roughness of every sample was then standardized using abrasive paper (#1000, Dae Sung®, Singapore) under running water with a rotary grinder to provide a similar baseline.[12] An ultrasonic bath (Krisbow, Indonesia) was used for 5 minutes to remove debris on the sample's surface. Prior to measurement, the instrument was calibrated to ensure accurate measurement results.

Group I and II were randomly divided into four sub-groups; IA, IIA, IB and IIB (n=18). Groups IA and IIA were polished using aluminum oxide discs (Sof-Lex XT®), while Groups IB and IIB were polished using diamond discs (PoGo®). Polishing was performed using a low-speed handpiece (NSK®, Tochigi, Japan). Group IA and IIA were polished using an aluminum oxide disc (Sof-Lex XT®) that was placed on a mandrel attached to the handpiece. Polishing was initially done with coarse disc and then followed by medium, fine, and extra fine discs in sequence. Following the manufacturer’s instructions, the coarse and medium discs operated at 10.000 rpm, while fine and extra fine discs operated at 25.000 rpm speeds for 15 seconds each.[13] Group IA and IIA were polished dry under intermittent pressure. Samples were rinsed and dried before being polished with the next disc. Group IB and IIB were polished under diamond discs (PoGo®). Each disc was used only once and discarded. Polishing was performed at 15.000 rpm for 60 seconds. Group IB and IIB were dry-polished under continuous pressure. After polishing, an ultrasonic bath was used for five minutes to remove debris from the sample surface.[14]

The surface roughness of every sample in group I was measured before and after polishing using a profilometer (SJ-210®, Mitutoyo, Japan). Measurements were taken three times, and the average value was calculated. The device was set according to the ISO 1997 standard and had a diamond stylus with a radius of 0.5 μm and moving at constant speed of 5 mm/s. The gloss of every sample in group II was measured before and after polishing using a glossmeter (ETB-0686®, Shingtao, China) 3 times at an angle of incidence and light reflection of 60°. All of the samples were covered using a black shield prior to testing to avoid light interference.[5] The measurement results were averaged to obtain a single value for each specimen. Samples from each group before and after polishing with aluminum oxide and diamond disc were prepared for surface topography analysis using scanning electron microscopy. The magnifications used were 500x, 1000x, and 5000x at the center of the sample.[15]

The paired sample T-test was used to analyse surface roughness and gloss before and after polishing, while the independent T-test was used to compare the delta gloss difference between aluminum oxide (Sof-Lex XT®) and diamond (PoGo®). The statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 26 (SPSS, IBM, Armonk, NY, USA).

RESULTS

Based on the results of the study, the following data showed that diamond disc (PoGo®) achieved the lowest surface roughness after polishing (Table 3).

Table 2. Surface roughness before and after polishing (Pair Sample T-Test).

Group I		**Surface roughness (μm)**		***P-value***
		N	$\bar{X}$ ± SD	
Aluminum oxide (A)	Before polishing	18	0,23 ± 0,01	0,0001*
	After polishing	18	0,18 ± 0,02	
Diamond(B)	Before polishing	18	0,23 ± 0,01	0,0001*
	After polishing	18	0,15 ± 0,02	

* Significant

Both polishing materials showed statistically significant differences in gloss values. Among all tested polishing systems, it was noted that the highest gloss value after polishing was achieved by diamond disc (PoGo®) (Table 3).

Table 3. Gloss value before and after polishing

Group II		***Gloss* (GU)**		***P-value***
		N	**$\bar{X}$ ± SD**	
Aluminum Oxide (A)	Before polishing	18	1,32 ± 0,11	0,0001*
	After polishing	18	46,55 ± 1,31	
	Delta Gloss	18	45,22 ± 1,31	0,0001*
Diamond (B)	Before polishing	18	1,35 ± 0,10	0,0001*
	After polishing	18	51,08 ± 1,76	
	Delta Gloss	18	49,73 ± 1,75	0,0001*

*Significance

The surface topography of bis-acryl provisional crown material before and after polishing with aluminum oxide and diamond discs was analyzed using a scanning electron microscope (SEM) at 500, 1000, and 5000x magnifications (Figure 1).

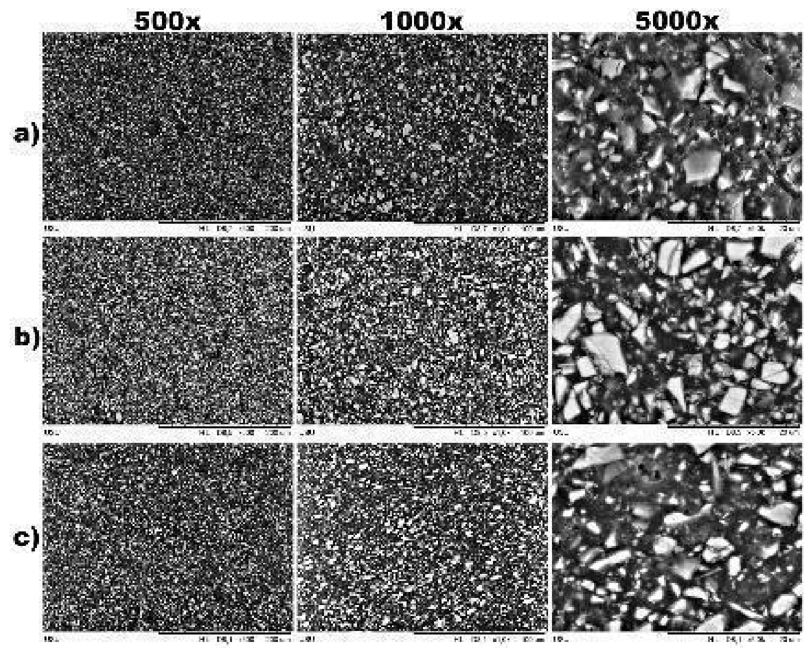

Figure 1. SEM results before and after polishing a) before polishing. b) after polishing with aluminum oxide system . c) after polishing with diamond disc system

DISCUSSION

Polishing of provisional restoration is an important step to enhance the aesthetics and longevity of the restoration. The smooth surface of a well-polished and contoured restoration can improve gingival health as rougher surfaces are associated with a significant rise in biofilm development. The smooth surface also influences gloss. A well-polished restoration enhances light's reflectivity, resulting in a glossier surface.[11] The effectiveness of any polishing device and the resultant surface roughness and gloss of the restoration are influenced by several factors, such as mechanical properties of the substrate, particle size and hardness of the abrasive, flexibility of the backing material in which the abrasive is embedded, pressure and speed of polishing, the use of lubricants, and polishing methods.[16] The total polishing time for in each sample was set at 60 seconds, as a previous study showed that this polishing time is sufficient to produce optimal results.[17] Additionally, the polishing speed was adjusted according to the manufacturer's recommendation for each group.[8]

In the present study, the surface roughness of bis-acryl after polishing with aluminum oxide discs and diamond discs was reduced and the gloss value increased. During polishing, the polishing agents abrade material from the sample surface. This process involves abrasive wear through the use of a harder material against a softer substrate. Additionally, fine scratches and irregularities may be smoothed by a smear layer, making the surface both smoother and glossier. The higher mean Ra and lower mean GU after polishing were observed on group IA and IIA which were polished with the aluminum oxide multi-step disc system. Ideally, polishing involves the sequential use of progressively finer abrasives to achieve a highly smooth and glossy surface. Each step is followed by an even finer polishing medium until no further improvement in surface finish is observed. However, the results of this study indicate that the diamond one-step disc system produced a lower mean Ra and higher mean of GU compared to the multi-step aluminum oxide system.

Diamond's superior polishing performance may be attributed to its exceptional hardness. Abrasive particles contained in the polishing materials used in this study indicate diamond particles (10 Mohs) and aluminum oxide particles (9 Mohs) are both harder than restorative material fillers (5-7 Mohs). However, diamond particles are significantly harder than aluminum oxide particles.[3,13] Other studies shows diamond particles are harder than aluminum oxide particles which can contribute to their durability and abrasive ability in polishing.[18] The fine diamond particles used instead of aluminum oxide disc and the cured urethane dimethacrylate resin delivery may be responsible for PoGo's enhanced polishing performance.[8,9,13]

The superior outcome from the use of diamond one step system disc may also be attributed to its polishing method, which involved dry polishing with continuous pressure, whereas aluminum oxide multi-step system disc was dry polished with intermittent pressure. Boroujeni, et al stated that dry-continuous polishing had the highest surface temperature increase. Based on that research, polishing of composite resins performed continuously produces the highest temperature compared to polishing performed intermittently. This study suggests that higher temperatures may enhance polishing efficiency, leading to a smoother surface.[19]

It appears that the elevated temperature at the surface during dry finishing may cause localized softening and melting.[16] This may smear the resin over any fine scratches and irregularities resulting in a smoother surface. A smoother surface contributed to increased gloss. The smooth surface improves the ability to reflect light at the same angle resulting in a glossier surface. These findings indicate that the use of a one-step diamond system produces a smoother surface and increases the gloss simultaneously. Another possibility is that elevated temperature may have some effect on the resin properties leading potentially to further cross-linking of the resin phase and result in a harder surface that might be more resistant to wear.[16,19]

SEM picture with a magnification of 500x and 1000x showed the distribution of filler particles in the group polished with a one-step system diamond disc was more evenly distributed than in the group polished under a multi-step system aluminum oxide disc.[20] This circumstance may occur because diamond polishing material cuts the matrix and the filler particles are close to the same height. The SEM picture with a magnification of 5000x showed Bis-acrylic structures polished with aluminum oxide discs showed irregular surface topography with different shapes with sizes of 4-5 μm while bis acryl structures polished with diamond discs have irregular surface topography with a smaller size distribution of 2-4 μm.

The SEM picture also showed more exfoliating areas in the group polished with the multi-step system aluminum oxide disc than in the group polished with the one-step system diamond disc. This exfoliating area occurs because the polishing material cannot cut the filler, so the filler exfoliates due to weakened matrix bonding during the polishing procedure. This situation causes a leverage effect on the filler when the polishing is continuous. These conditions create peak and valley differences that lead to rough surfaces and a decrease in gloss. Using a one-step system diamond can minimize the exfoliation of fillers, resulting in a smoother and glossier surface than polishing with multi-step aluminum oxide.[3,20]

Lassila, et al stated that an acceptable gloss value for polishing results ranges from 60 to70 GU. In this study, polishing bis-acryl composite resins using both materials decreased surface roughness below the threshold and increased gloss. Previous study showed that good and acceptable polishing results have a gloss value of 60-70 GU.[21] Polishing with a one-step diamond disc has a gloss value close to 60 GU. Polishing with a one-step system diamond disc produced better values than multi-step system aluminum oxide. These findings suggest that polishing with a one-step system diamond disc is better than multi-step system aluminum oxide in producing a smooth and glossy surface.

In this study, both polishing systems significantly decreased surface roughness and increased gloss of bis-acryl before and after polishing. Hence, the first null hypothesis was rejected. Polishing under diamond one-step system disc on bis-acryl showed a higher gloss value than aluminum multi-step system. Therefore, the second null hypothesis was also rejected.

The limitations of this in vitro study are the inability to replicate the dynamic oral environment, where additional factors may influence the surface roughness of the polished restorations. More research is needed to establish which polishing material is most suggested under a clinical need where polishing access and material is limited.

CONCLUSION

Diamond one-step systems produced a smoother bis-acryl surface, characterized by a lower average surface roughness (Ra) and higher gloss score compared to aluminum oxide multi-step systems. Since a smoother bis-acryl surface correlates with a higher gloss score, these findings suggest that the diamond one-step is more efficient than the aluminum oxide multi-step system in achieving both smoothness and gloss. The implications of this study indicate that using diamond discs can enhance aesthetics, improve patient comfort, and reduce plaque accumulation—ultimately lowering the risk of gum irritation. Therefore, in clinical practice, dentists may consider diamond discs as a more optimal and time-efficient option.

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