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Original article

The influence of the polishing duration on the surface roughness and gloss of nanohybrid composites using a blood cockle shell polishing paste

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ABSTRACT

Background: *The polishing procedure is an important stage in producing a successful restoration. Polishing involves the use of abrasive materials, and blood cockle shells contain these natural components, such as calcium carbonate, which can be used as a polishing paste. One of the factors that influences the polishing quality is the polishing duration.* ***Purpose:*** *This study evaluated the polishability of a nanohybrid composite using blood cockle shell polishing paste by measuring the surface roughness and gloss value, and by observing the surface qualities based on different polishing times.* ***Methods:*** *Ninety samples of maxillary premolars were immersed in artificial saliva in an incubator at 37°C for 24 h. A total of 45 samples were subjected to a profilometer to observe surface roughness, and the rest were subjected to a glossmeter to observe the composite resin gloss. These included blood cockle shell paste, Prisma Gloss polishing paste, and without paste for 30, 60, and 90 seconds. The data were statistically analyzed using repeated measures ANOVA and post hoc least significant difference (LSD).* ***Results:*** *It showed that the group of 90 seconds had the highest gloss and the lowest surface roughness in the blood cockle shells. The difference was statistically significant ($p>0.05$). The results of the surface roughness test of the blood cockle shells with a duration of 30 and 60 seconds were found to be not significant ($p<0.05$).* ***Conclusion:*** *There were significant differences by adding the polishing duration, which decreased the surface roughness and increased the surface gloss, in which the lowest roughness and highest glossiness was found with a polishing time of 90 seconds. The polishability of composite resin restorations in this study obtained the best gloss and smoothest surface results from the longest polishing time duration of 90 seconds with the blood cockle shell polishing paste.*

Keywords: *microporosity; nanohybrid composite; surface gloss; surface roughness*
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INTRODUCTION

Finishing and polishing are one of the most crucial steps in achieving a successful restoration.[1,2] Polishing is a process carried out to reduce roughness and scratches caused by finishing instruments to obtain a smooth restoration surface. Therefore, a smooth restoration surface has clinical resistance, a good aesthetic appearance, and a shiny surface, and it plays a role in the color stability of the composite resin. Abrasive materials that are often used in polishing composite resins are aluminum oxide, carbide compounds, diamonds, and zirconium oxide.[3] A final polishing is initiated after the correct contours and surface texture have been achieved, and this is accomplished with rubber or silicone polishing instruments, diamond-impregnated polishers, polishing discs, and polishing paste. Polishing with a diamond paste seems to be a good option to polish the surface of both direct and indirect composite resin because the diamond paste produces better results in terms of decreasing biofilm formation and improving the surface property.[4]

Polishing techniques can be divided into two types: One-step and multi-step. The one-step polishing system uses only one polishing instrument, while multi-step polishing uses several types of polishing instruments and requires a longer duration.[5,6] Various studies concluded that multi-step has shown a smoother and glossier surface

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finish in composite resin restoration polishing systems. One of the abrasive materials used in the multi-step polishing system process is the polishing paste.[7,8]

Polishing using loose abrasives in dental applications causes wear on the micro and nanometer scale during the polishing process.[1] Many factors can affect the loose abrasive effectiveness. The shape, direction, and size of the abrasive particles, and the length of polishing material application, can affect the results of the restoration's physical properties and durability.[3] The decrease in the surface roughness value of the dental restorative materials due to repeated erosion, friction, and cutting, alongside a longer polishing duration, will result in complete fragmentation. This means the protrusions formed can be separated from the specimen surface evenly so the surface becomes smoother.[9] The duration of polishing material application can affect the restoration's physical properties and durability.[10] One of the restoration's physical properties that is affected is its smooth and glossy surface.[7]

Ultra-fine aluminum oxide and diamond paste are typically used to make a polishing paste. The foundation of both diamond particles and prophylaxis paste for aluminum oxide is glycerin. The size of the diamond particle paste is larger, ranging from 10 μm to smaller than 1 μm, but the size of the aluminum oxide particle distribution is 1 m or smaller to improve surface smoothness.[11] One of the disadvantages of diamond polishing paste is that it should be avoided when combined with an oxidizing agent and should be stored at or below 30°C and if used excessively can cause acute oral toxicity.[12]

The utilization of blood cockle shells, which are marine waste, has become one of the ideas for developing a natural-based composite resin polishing material. The development of natural resource materials, such as plant and animal waste, caused biodegradable raw materials to be economical and environmentally friendly.[13] The blood cockle shell contains calcium carbonate as abrasive particles, which can be used to make toothpaste because of its remineralizing and the ability to clean the surface of the teeth. Calcium carbonate in blood cockle shells has also been shown to have osteogenic properties and act as a substrate where new osteoblasts can grow bone formation.[12,14] Currently, no commercially available composite resin polishing paste has the dual capability of being both a polishing agent and a tooth remineralization agent. The aim of this study was to determine the polishability of nanohybrid composite using blood cockle shell polishing paste by measuring the surface roughness and gloss value (GU), and by observing the surface qualities based on different polishing times.

MATERIALS AND METHODS

The blood cockle shells were collected from Tanjung Balai, Asahan, and the blood cockle shell sample has been identified as the *Anadara Granosa* species by the Aquatic Environment Laboratory, Universitas Sumatera Utara, Medan, through letter number 01/LLP/MSP/USU/2021. One kilogram of blood cockle shells was washed using water and then boiled in a 500 mL vinegar solution for 1 h at 100°C. They were washed again, dried in the sun for two days, and then grounded using a stone mortar and crushed using a blender. The blood cockle shells' powder was sieved using a 400-mesh laboratory sieve, and the powder was then put into a ball mill at 500 rpm for 8 h to produce a 10μm blood cockle shell powder particle.

A Scanning Electron Microscope-Energy Dispersive X-ray Spectroscopy (SEM-EDS) analysis was conducted at Physics Laboratory, Universitas Negeri Medan. The type of SEM-EDS used was the EVO MA by Carl Zeis in Germany. The SEM magnification used was 5000x. The blood cockle shell powder was pulverized using a ball mill, and an SEM test was conducted to investigate the particle size of the blood cockle shell powder. The SEM-EDS was used to determine the blood cockle shell content.

The blood cockle shell paste (BCSP) was prepared by mixing the blood cockle shell powder with a base paste containing Carboxymethyl Cellulose Sodium powder and glycerine. This paste is mixed well until a homogeneous paste is formed.[12]

Experimental laboratory research was conducted in this study using a posttest-only control group design. The research sample used was 90 extracted maxillary first premolars with no caries, calculus, or stains obtained from dentists. The sample of 90 maxillary first premolars was divided into two groups — surface roughness and gloss measurement. Samples were prepared in the outline form of Class V, drawn using a pencil, with dimensions of 4 mm x 4 mm x 2mm, measured with a caliper. The mesiodistal width was 4 mm, the occlusal gingival height 4mm, and the axial depth 2mm, with a 0.5 mm bevel at the enamel edge. The position of the cavity was on the buccal side. The sample was restored using a nanohybrid composite resin (3M ESPE Filtek Z250 XT, USA).

The sample underwent finishing procedures and was polished thereafter using a multi-stage technique that used polishing paste as the final phase. The samples were randomly divided into three groups, namely the blood cockle shell polishing paste, the commercial polishing paste (Prisma Gloss Dental Sirona, Germany), and without (WO) paste, where each group was given three treatments with polishing times of 30, 60, and 90 seconds.[9] The three groups were subjected to the same polishing action using a non-abrasive rubber cup. The 90 samples were divided into 45 profilometer test samples and 45 glossmeter test samples. In Group I, the polishing was carried out using a polishing paste made from blood cockle shells at 0.2 g per sample, which was applied using a silicone bur to the entire surface of the restoration, with a polishing time of 30 seconds on five samples, 60 seconds on five samples, and 90 seconds on five samples. A stopwatch was used to calculate the polishing time. In Group II, the polishing was carried out using a commercial polishing paste of 0.2 g per sample, which was applied using a silicone bur on the

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entire surface of the restoration, with a polishing time of 30 seconds on five samples, 60 seconds on five samples, and 90 seconds on five samples. In Group III, the polishing was carried out without using commercial polishing paste, with a polishing time of 30 seconds on five samples, 60 seconds on five samples, and 90 seconds on five samples.

To determine surface roughness, a total of 45 samples were soaked in artificial saliva for 24 h and stored in an incubator at 37±2°C to simulate the condition of the oral cavity and then tested using a profilometer (Mitutoyo Surfest SJ-210-Portable Surface Roughness Tester, Japan). The unit of measure was expressed in roughness average (Ra). Meanwhile, the rest of the group tested by using a gloss meter (ETB-0686, China) to determine the surface gloss. The unit of measure is expressed in gloss units (GU). A repeated measures ANOVA was used to ascertain the significance of the relationship between the polishing time in each sample group, while one-way ANOVA was used to establish the significance of the relationship between the type of polishing paste used and the post hoc LSD test.

RESULTS

Figure 1 shows the blood cockle shell powder that was ball-milled, and the EDS analysis is summarized in Table 1. The figure shows several sizes of blood cockle shell powder, including 4.502µm, 5.098µm, and 5.636µm, that have been mashed using a ball mill.

The mean and standard deviation of Ra and GU are listed in Table 2. The longer the polishing time, the lower the value of surface roughness, and the surface gloss increases. Table 2 shows the value of the standard deviation and the mean of the surface roughness and gloss test results. Based on the repeated measures ANOVA test results, there were significant changes in the surface roughness and gloss surface of the nanohybrid composite resin after polishing with the BCSP, the Prisma Gloss paste (PG), and WO paste at 30, 60, and 90 seconds ($p<0.05$). The one-way ANOVA test results showed a significant change in the surface roughness and surface gloss of the nanohybrid composite resin after polishing for 30, 60, and 90 seconds in the BCSP

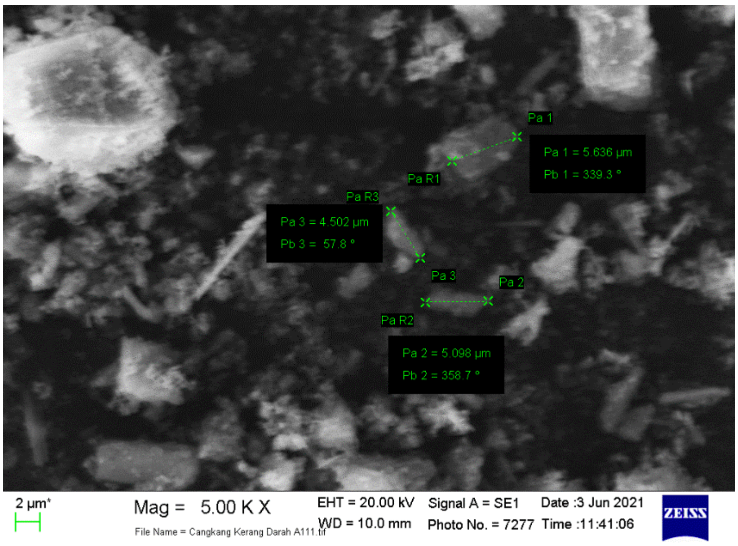

Figure 1. SEM image of blood cockle shells powder with 5.00 K X magnification, ball-milled at 500 rpm for 8 h.

Table 1. Elements contained in blood cockle shells

No.	Element	Symbol	% Mass	% Atom
1	Oxygen	O	50.39	75.92
2	Calcium	Ca	33.8	20.08
3	Stibium	Sb	15.31	3.03
4	Natrium	Na	0.92	0.97
5	Carbon	C	0.00	0.00

Table 2. Mean and standard deviation of surface roughness and gloss value

Time (seconds)	BCSP		PG		WP	
	Ra	GU	Ra	GU	Ra	GU
30	1.88±0.07	29.44±0.11	2.40±0.17	16.62±0.05	3.16±0.23	10.36±0.16
60	1.44±0.11	35.78±0.6	2.00±0.11	23.32±0.52	2.58±0.12	11.42±0.15
90	0.62±0.04	41.06±0.15	1.02±0.10	27.44±0.53	2.24±0.15	11.50±0.11

Repeated measures ANOVA test $p<0.05$: Significant; One-way ANOVA test $p<0.05$: Significant;
*BCSP: Blood cockle shell paste; PG: Prisma Gloss; WP: Without Paste

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Table 3. LSD results for each handling group

Handling	Duration	Comparison	p-value	
			Roughness	Gloss
Blood cockle shell polishing paste	30 sec	60 sec	0.054	0.000*
		90 sec	0.000*	0.000*
	60 sec	90 sec	0.002*	0.000*
Prisma Gloss paste	30 sec	60 sec	0.028*	0.000*
		90 sec	0.000*	0.000*
	60 sec	90 sec	0.000*	0.006*
Without paste	30 sec	60 sec	0.069	0.002*
		90 sec	0.022*	0.003*
	60 sec	90 sec	0.072	0.744

*Post-hoc LSD test p<0.05: Significant

group, the PG, and WO paste (p<0.05). The LSD results test showed that the difference in surface roughness and in the gloss of nanohybrid composite resin restorations after polishing with the BCSP, PG, and WO paste was between 30, 60, and 90 seconds, as shown in Table 3.

The results of the LSD statistical analysis showed there was a difference in the effect of the length of time in each handling group, but between the 30 and 60 seconds of polishing time with blood cockle shell-based polishing paste, there was no significant difference. Between 30 seconds of polishing time and 60 seconds without the polishing paste and between 60 seconds and 90 seconds of polishing time, no significant difference was found. The results of the statistical analysis of the LSD test showed there was a difference in the effect of the length of time in each treatment group. However, between the 60 seconds of polishing time and 90 seconds without polishing paste, no significant difference was found.

DISCUSSION

Proper finishing and polishing are important procedures in enhancing the aesthetics and longevity of composite resin restorations.[11] There are several variables that affect their surface quality, one of which is the polishing time. This has a significant effect on the surface roughness and surface gloss. The statistical analysis with repeated ANOVA test in Table 2 shows that there is a significant difference in the effect of the polishing time on the surface roughness of the nanohybrid composite resins in each treatment group, namely the blood cockle shell polishing paste, the PG paste, and WO paste. The Ra of a clinically acceptable restoration is 0.2 m, in which the surface of the restoration is smooth to reduce plaque accumulation, reduce the risk of secondary caries, and increase the aesthetic value of the restoration.[8] The lowest Ra is found at a polishing time of 90 seconds compared to polishing times of 30 and 60 seconds. This is because the longer polishing time results in more mechanical surface contact with the composite resin and causes erosion of the loose and unnecessary filler due to the use of abrasive materials, resulting in a highly smooth and shining surface.

The results of this study align with previous research, which stated that polishing times of 30, 60, and 90 seconds with the polishing paste can reduce the surface roughness of nanofiller composite resins, with a polishing time of 90 seconds having the greatest effect.[7] The polishing time of 90 seconds in this study reached a clinically acceptable Ra value of 0.2 m. The results of this study are also in agreement with those reported by Kaminedi et al., who reported that the surface roughness of the composite resin decreases with an increased polishing time.[7]

The statistical analysis with the repeated ANOVA test in Table 3 also shows that there is a significant difference in the effect of time on the surface gloss of the nanohybrid composite resin in each treatment group, namely the blood cockle shell polishing paste, the PG polishing paste, and WO paste. The clinically acceptable GU for producing a shiny tooth surface is 40 GU.[15] A rough surface will cause a decrease in the aesthetic appearance of the composite resin restoration. An uneven surface of the restoration will disperse the incident light so it reduces the gloss of the restoration, while the incident light on a flat surface will reflect light regularly so that the surface looks shiny. The surface GU of the nanohybrid composite resin restoration was the highest, with a polishing time of 90 seconds compared to polishing times of 30 and 60 seconds. This is also influenced by the length of polishing time, which is based on previous research that the length of the polishing time has a significant effect on surface roughness and surface gloss.[13]

The results of the LSD surface roughness test on the BCSP on polishing times between 30 and 60 seconds did not show a difference. This is due to changes in the roughness value that occurred in the application of a long duration.[5,9] Ninety seconds does not show a difference in the surface roughness value and GU. This is due to the absence of polishing time only. This difference is because of a very smooth surface obtained by applying another layer on top of the abrasive.[15,16]

Loose abrasive polishing paste is a nonbonded abrasive mainly used in the final polishing stage. To apply the loose abrasive polishing paste, non-abrasive materials, such as felt, leather, rubber, and synthetic foam are used.[9] Loose abrasive polishing paste contains abrasive materials, such as calcium carbonate, that come from Tanjung Balai, Asahan Regency, Indonesia, which are used as the base material for a polishing paste containing chemical elements, namely Ca, O, and C, as shown in Table 1. In the previous study,

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it was stated that the mineral composition of blood cockle shells from the West Coast of Peninsula Malaysia was 98.7% $CaCO_3$, 0.05% Mg, 0.9% Na, 0.02% P, and 2% other. The $CaCO_3$ contained in blood cockle shells is an abrasive used in dentistry, which can produce a smooth and shiny surface.[17] $CaCO_3$ is also found in eggshells as indicated by research on the content of $CaCO_3$ in eggshells (70.84%). If crushed, it has abrasive properties that can polish the surface of acrylic resin denture bases. Calcite in $CaCO_3$ makes eggshells abrasive and can polish the surface of acrylic resin denture bases with a surface roughness of less than 0.2 m, which is clinically accepted in dentistry.[18] Thus, it proves that CaCO3 can abrade the surface used as a polishing material, so the development of blood cockle shell polishing paste is possible.

Based on previous studies, the application of blood cockle shells has begun to be developed, such as their biomedical use in bone and tissue engineering. Blood cockle shells can also remineralize teeth because the $CaCO_3$ they contain is isolated from CaO, and this compound can be further processed into hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$), which is the main inorganic substance in bones and teeth. This material is added to toothpaste as a remineralization material to form hydroxyapatite crystals so that the tooth enamel can be stable, strong, and caries resistant.[19] Blood cockle shells are being developed into a natural base for polishing paste. This polishing paste has good abrasive properties on composite resins. Blood cockle shell polishing paste has an effect on increasing the gloss, surface smoothness, and color stability of composite resin.

In this study, surface roughness was decreased in the composite resin group using polishing paste compared to the control group (without paste). Whereas the composite resin group polished with blood cockle shell paste looks smoother compared to using the diamond paste group (PG). The lowest roughness value was in the blood cockle shell polishing paste group, with a duration of 30 seconds. The blood cockle shell polishing paste with a polishing time of 60 seconds also showed the lowest roughness value, which was compared to PG paste and without polishing paste. The blood cockle shell polishing paste with a polishing time of 90 seconds also showed the lowest roughness value compared to a PG paste of 90 seconds, and without polishing paste with a duration of 90 seconds. In addition to the length of polishing time, which affects the low Ra value in this study, the surface roughness is also influenced by the abrasive content of the polishing paste, which also affects the quality of a restoration surface. In this study, the lowest value of Ra in each group was 30, 60 and 90 s with a blood cockle shell polishing paste of (Table 2).

The results of the studies showed the PG polishing paste with a polishing time of 60 seconds, and without polishing paste with a long time of 60 seconds showed the lowest gloss (GU) value. The blood cockle shell-based polishing paste with a polishing time of 90 seconds also showed the highest gloss (GU) value compared to the PG paste with a polishing time of 90 seconds, and without polishing paste with a duration of 90 seconds showed the lowest gloss (GU) value (Table 2). In addition to the long polishing time, which affects the high-GU in this study, the surface gloss is also influenced by the abrasive content of the polishing paste, which also affects the quality of a restoration surface. In this study, the lowest GU in each group was 30, 60, and 90 seconds, namely with a blood cockle shell-based polishing paste.

Based on previous studies, the gloss of composite resin restorations after polishing with blood cockle shell-based polishing paste was higher (20,750 GU) compared to PG (15,830 GU). The increase in the gloss of the composite resin is a positive effect of a smooth restoration after polishing.[6] This aligns line with the results of the one-way ANOVA test in this study, where the clinically acceptable GU was the polishing time of 90 seconds in the polishing paste group made from blood cockle shells. The results of this study indicate that the content of $CaCO_3$ in blood cockle shells has abrasive properties that can polish the surface of the composite resin so that the restoration surface is smooth and shiny.[20] From this research, when applying the paste, it still splashes due to the consistency of the material. Therefore, further research is needed regarding the best concentration of abrasive material to get the best consistency. In previous studies, calcium from the shell of blood cockles has the ability to remineralize teeth by forming hydroxyapatite crystals. Therefore, in future studies, the ability of blood cockle shell polishing paste will be seen as an abrasive that can remineralize the tooth surface around the restoration area.[21] In this study, applying the paste produces a splash due to the consistency material. Hence, the best concentration of abrasive material should be applied.

The results of this research show that the lowest roughness values and the highest glossiness are found in composite resin restorations polished using blood cockle shell polishing paste with a polishing time of 90 seconds. It shows that the longer the polishing time with a polishing paste made from blood cockle shells, the smoother and shinier the surface results of the nanohybrid composite resin.

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