Effect of die lubricants on the compressive strength and surface hardness of a die stone.

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Abstract

Objective: The aim of this study was to determine the effect of 5 liquids used as die lubricants: microfilm, silicone oil, palm oil, slurry water and water on the compressive strength and surface hardness of a die stone.

Materials and methods: Five liquids; microfilm, silicone oil, palm oil, slurry water and water, were applied on the die stone as die lubricants and die stone without lubrication was served as control. Ten specimens of the die stone for each test of compressive strength and surface hardness were prepared. The specimens were stored at room temperature for 24 hours and then soaked in each liquid for 1 minute. The compressive strength test at speed 5 KN/min was preformed. The hardness specimens were indented by Vicker hardness tester with 1 KgF load for 20 sec. Scanning electron microscope was used for study of surface topography and the penetration of the liquids into the bulk of the stone.

Results: Silicone oil and palm oil did not affect both compressive strength and surface hardness of the die stone compared with control ($p > 0.05$). While the commercial die lubricant (microfilm®) affected the compressive strength of the die stone compared with control ($p<0.05$). In contrast, the slurry water and water affected both the compressive strength and surface hardness of the die stone compared with control ($p < 0.05$). There were some oily character left moderately to less on the surface of die stone lubricated with silicone oil, palm oil and microfilm respectively. The specimen treated with distilled water demonstrated the most far liquid penetration into the center of the specimen, followed by the slurry water and microfilm, respectively. On the contrary, silicone oil and palm oil did not show any liquid penetration into the specimen, only wet on the specimen surface.

Conclusion: Silicone oil, palm oil did not affect both compressive strength and surface hardness of die stone, while slurry water and water decreased both properties of die stone.

Key words: compressive strength, die lubricant, die stone, surface hardness, silicone oil, palm oil, slurry water

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Introduction

Dental improved stone (Type 4 gypsum products according to ISO 6873; 2013) are commonly used as die material for dental prosthesis construction. The routine work in the laboratory for the fabrication of crown and bridge has been using the internal relief, paint-on die spacers on the wall, together with the lubricant at the margin, as the die-wax separator[1]. The trouble shooting is the scratch or abraded surface of the die from cutting or carving instruments. Unfortunately, the surface hardness and the abrasion resistance of the materials were regarded as intermediate and low in comparison with resin and metal dies[2]. The surface properties of die stone then influence its ability to tolerate all type of forces during the construction of a restoration. The study done by Harris et al [3] indicated that the use of die hardener or die coating reduced the surface hardness of the gypsum materials. Microfilm® has been used to coat dies as a die-wax separator. This liquid has been imported and rather expensive. Therefore, alternative die-wax separators such as cooking oil, silicone oil, slurry water[4] or water are used for coating. Thus, the effect on compressive strength, which is the standard property of gypsum materials, and surface hardness of coated die stone with the commercial lubricant and the alternative liquids needs more investigation. Therefore the aim of this study was to determine the effect of one commercial and four alternative liquids utilized as die lubricant on compressive strength and surface hardness of a die stone.

Materials and methods

The materials used in the study are shown in Table 1. Four experimental lubricants (silicone oil, palm oil, slurry water and distilled water) were selected to evaluate in this study. The commercially available die-wax separator (microfilm®, Kerr Corporation., CA, USA) was used as positive control. The die without lubricant served as negative control. The improved die stone (Vel-Mix®, Kerr Corporation., CA, USA) was mixed with distilled water at a powder-liquid ratio of 0.23 by hand mixing for 10-15 seconds then machine-mixed in an automatic vacuum mixer (Vacuret-S, REITEL Feinwerktechnik GmbH, Germany) at 150 rpm under 13 psi of vacuum for 30 seconds. The mixed die stone were poured under gentle vibration into a cylindrical mold, size 20 mm in diameter and 40 mm in length for compressive strength test and into 20 mm^3 cubic block for surface hardness testing following the ISO standard (ISO 6873/2013 Dental gypsum products)[5]. The specimens were left for initial setting for 1 hour then separated from the mold. After separation, the specimens were stored at room temperature for 24 hours before being treated with lubricants. Ten samples for each test and each lubricant including the control were prepared.

The specimens' surface were painted with lubricant using a brush and then soaked

Table 1 Materials used in the study

No	Materials	Composition	Manufacturer / batch
1	Silicone oil	Poly(dimethylsiloxane)	Down Conning, USA / lot 436905
2	Palm oil	Vegetable oil from palm	Morakot industry, Thailand
3	Microfilm	Denatured Ethyl Alcohol, Octyl Alcohol	Kerr corporation, USA / lot 0-3173
4	Slurry water	Saturated solution of calcium sulfate	Self-prepared, Mahidol University
5	Distilled water	Pure water	Self-prepared, Mahidol University
6	die stone (Vel-Mix®)	Calcium sulfate hemihydrate	Kerr Corporation., USA / lot 0-24013

in each lubricant for 1 minute except the control. After soaking, the specimens were then picked up from the lubricant, wiped the excess lubricant off by wiped paper until no liquid droplet was seen and left at room temperature for 5 minutes before testing.

The compressive strength tests were performed with a universal testing machine (Instron model 8516, Buckinghamshire, UK) at a loading rate of 5±2 KN/min.

For surface hardness, nine indentations on one surface of each sample were made with Vicker microhardness tester (Mitutoyo MVK-G3, Japan) using 1 Kgf load for 20 seconds. The Vicker hardness number (VHN) was obtained.

The compressive strength and surface hardness data were statistical analyzed by one-way MANOVA and then post hoc multiple comparisons by Tukey's test at 5% significance level (α=0.05).

Scanning electron microscope study

The surface characteristics of control and treated die stone with various lubricants were studied using the scanning electron microscope (JSM-5410LV, JEOL LTD, Tokyo, Japan) at x500 magnification. The penetration of various liquids into the bulk of specimens was also observed at x50 magnification.

Results

The compressive strength and surface hardness of the specimens are shown in Table 2. The statistical analysis found that silicone oil and palm oil did not affect both compressive strength and surface hardness of the die stone compared with control ($p>0.05$). While the commercial die lubricant (microfilm®) decreased the compressive strength of the die stone compared with control ($p<0.05$). In contrast, the slurry water and water affected both compressive strength and surface hardness of the die stone compared with control ($p<0.05$). Scanning electron micrographs of die stone treated with various liquids are shown in Fig. 1. There were no any different in crystal structure, only some oily character left moderately to less on the stone surface treated with silicone oil, palm oil and microfilm respectively.

The observation on the penetration of liquids revealed that distilled water penetrated into the specimen most far to the center of the specimen, followed by the slurry water and microfilm, respectively. Silicone oil and palm oil did not penetrate into the specimen, only wet on the specimen surface. (Fig. 2).

Discussion

Microfilm is the mixture of 20-30% denatured ethyl alcohol and octyl alcohol[6]. It has been used in commercial laboratories for a long time. The problem with this liquid is sticking of wax to the die after several corrections of wax pattern and also the coated die is easy to scratch with the sharp carving instrument. In this study, microfilm exhibited statistically lower compressive strength but not the surface hardness property.

Table 2 Compressive strength and surface hardness of die stone after treated with various lubricants.

Materials	Control	Silicone oil	Palm oil	Microfilm	Slurry water	Distilled water
Compressive strength; MPa (SD)	52.07^{a} (2.66)	56.37^{a} (3.37)	53.47^{a} (4.15)	44.00^{b} (3.26)	42.92^{b} (3.63)	39.87^{b} (3.54)
Surfaces hardness; VHN (SD)	18.84^{A} (1.56)	19.76^{A} (2.04)	19.01^{A} (2.33)	16.66^{A} (1.00)	9.99^{B} (1.11)	8.79^{B} (0.69)

The values with the same superscript letter were not statistical different ($p>0.05$)

Silicone oil has been used in various industries and utilized as the mold releasing agent in dentistry. Palm oil is easily obtained as a cooking product. Both liquids have an oily characteristic. This study proved that these two liquids did not harm the compressive strength and surface hardness properties of the die. However, the slurry water (water with saturated calcium sulfate) and distilled water should not be used as a die lubricant due to their effect of lowering the properties of the stone materials. This may be due to the higher watery contained composition. From Fig. 2, it shows that distilled water is

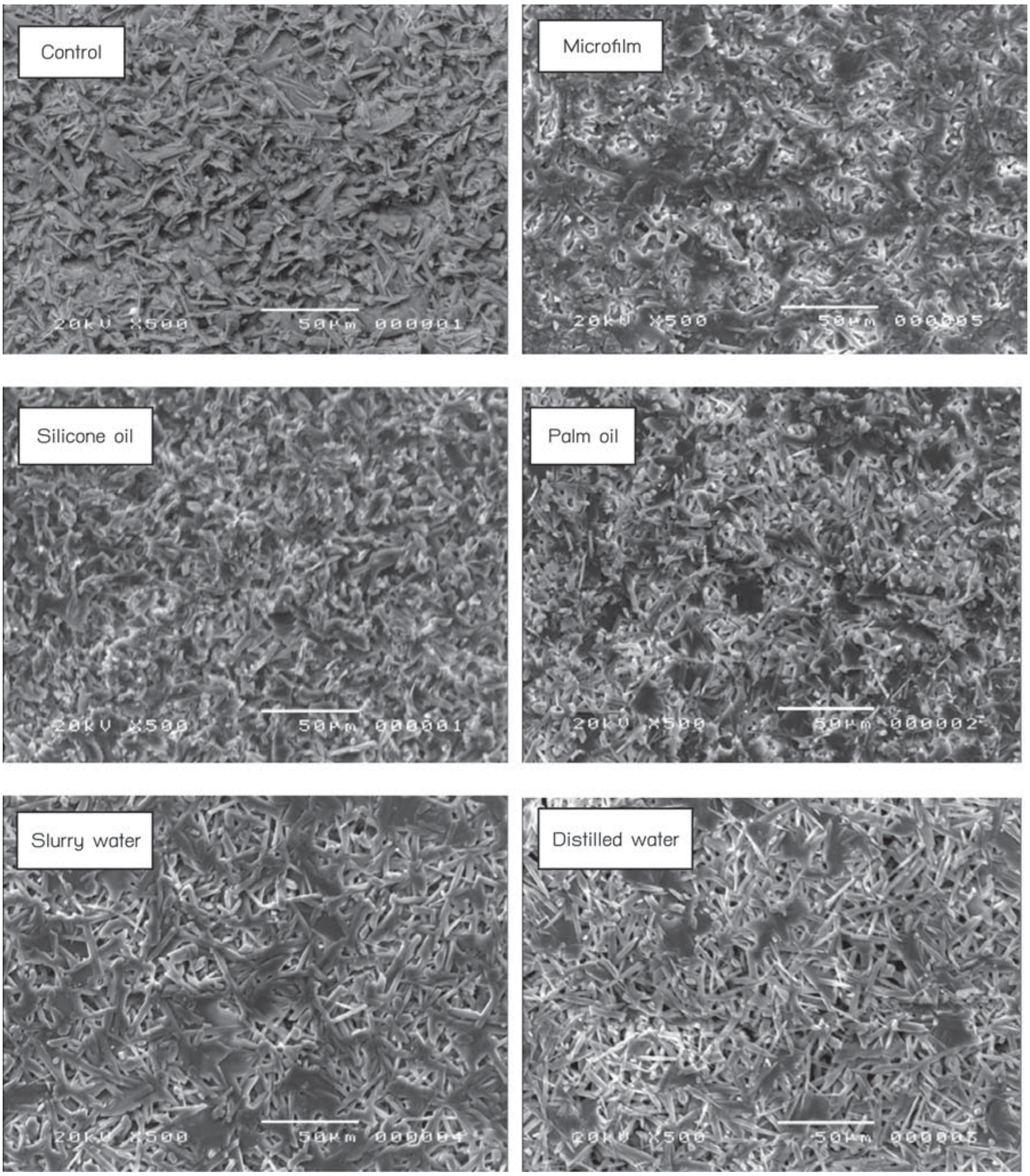

Fig. 1 Scanning electron micrographs of control and die stone after being treated with various liquids, There were no any different in crystal structure, only some oily character left moderately to less on the stone surface treated with silicone oil, palm oil and microfilm respectively.

the most far diffused into the center of the gypsum specimen, followed by slurry water and microfilm, respectively. In contrast, the silicone oil and palm oil, which have an oily characteristic, did not show any diffusion of the liquid into the specimen. The higher liquid diffusion into the specimen, the lower in properties of the specimen. This study agreed with some study [3,7].

The observation of the surface changes gave a clue that the surface treated with silicone oil was relatively smoother and still felt of oily substance at the surface while palm oil was not different from microfilm. The results of the compression test were also benefit to determine the bulk change of the die stone. This was more benefit when a small die was painted on with the lubricant because greater risk of developing a weak point to the die might occur. Regarding the surface hardness test, the authors agreed with Duke et al[8] that surface hardness was not a good measure of the abrasion performance of die stone. However, the validity of the surface hardness in this study helps us to gain more understanding on the effect of various liquids on the die stone. Therefore slurry water and water should be prohibited to use as a die lubricant at all time. It is possible that the silicone oil and palm oil in this study can be used as the die-wax pattern separator, or a lubricant as well as microfilm. However, due to higher viscosity of silicone oil and oily character left at the surface, this liquid should be used as an alternative only.

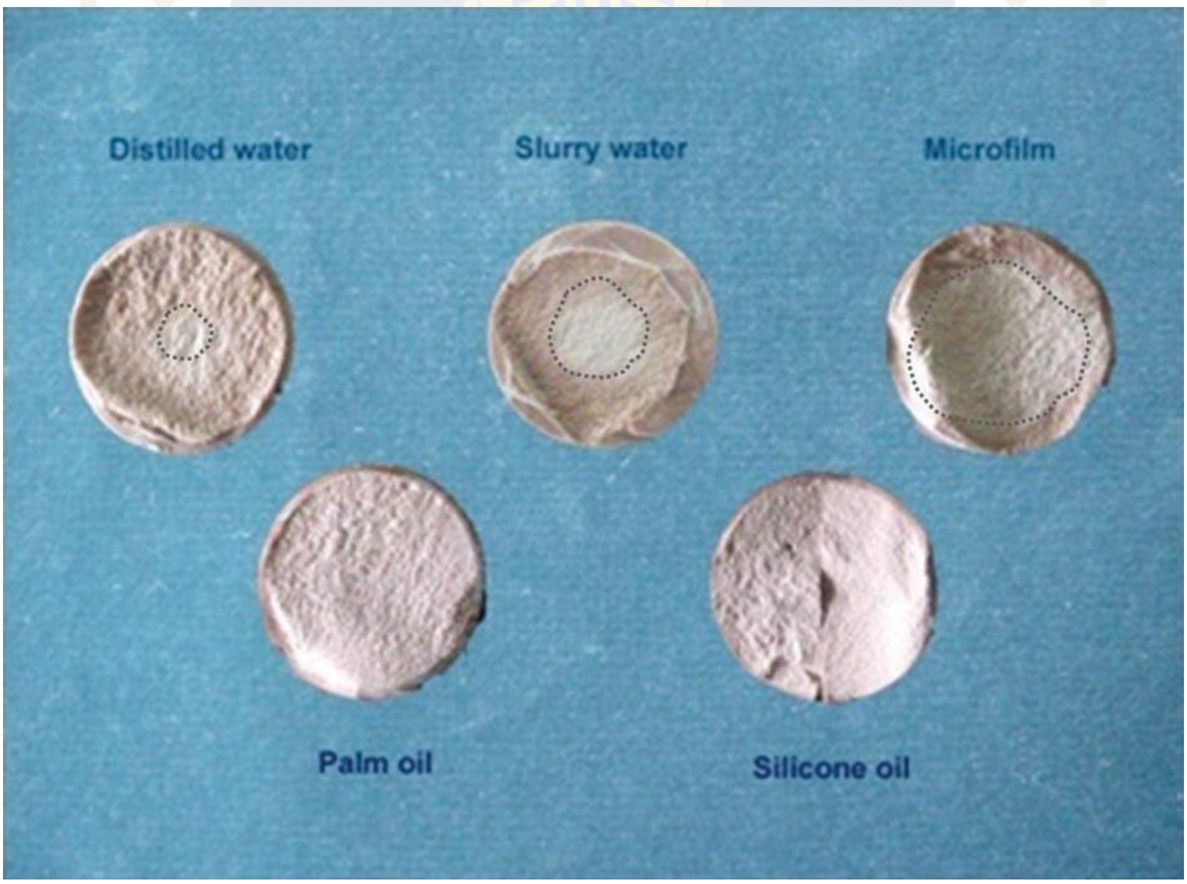

Fig. 2 The penetration of the liquid into the specimens. The dot line indicate the boundary of the diffusion of liquid into the center.

In conclusions: silicone oil, palm oil did not affect both compressive strength and surface hardness of die stone, while slurry water and water decreased both properties of die stone.

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