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Dental Wax and Surface Hardness of Refractory Materials

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Abstract

The purpose of this study was to assess the effect of three different types of natural dental waxes (beeswax, palm wax, and candelilla wax) on the surface hardness of a phosphate-bonded refractory material. Twenty specimens of a phosphate-bonded investment material were made and divided randomly into four groups (n=5). Group 1 received no treatment and served as the control. Groups 2, 3, and 4 were exposed to the surface treatment by dipping in melted beeswax, palm wax, and candelilla wax, respectively. The surface hardness of all samples was measured using a Shore D hardness tester. The results were analyzed by one-way analysis of variance (ANOVA). All three dental waxes showed non-significant differences in surface hardness when compared to the control group. The highest hardness value was determined in the palm wax group (106 ± 4.9), which was significantly higher than that obtained for the other groups. Within the limitations of this experimental in-vitro study, the use of natural dental waxes can be considered as an effective surface-hardness improving technique for phosphate-bonded investment materials. Palm wax was the best enhancement agent, indicating that it could be used as a simple and inexpensive means of improving the quality of investment molds in dental laboratories.

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Introduction

The accuracy of the casting procedure is a key factor for the clinical success of fixed and removable prosthodontic restorations. The precision of final item is based on the content quality of the investment, which in turn relies upon the capabilities to form a fine and exact mold from a wax pattern [1]. Additionally, this material needs to be sufficiently heat-tolerant to survive the high temperatures associated with burnout and casting without processing degradation or loss of structural integrity [2,3]. Phosphate-bonded investments are one of the types of investment materials used for casting high-fusing point alloys, because they have long-term stability in thermal treatment and sufficient expanding properties to adjust for metal shrinkage [4]. But phosphate-bonded investment materials have the disadvantage that the mold surface is porous and fragile. This may cause surface roughness and loss of detail in the final casting, which can impact the fit and serviceability of the dental prosthesis [1,5]. Hardness of the investment mold surface is an important factor; a harder surface may provide better resistance to abrasion and crack during handling and casting procedure [3,6].

In order to overcome the low surface hardness and porosity, a variety of surface treatment methods and hardening agents have been studied. These are intended to produce a smoother, denser, and stronger mold surface [1]. Additives such as the silica gel and other processing methods for improving these surface properties have still been studied [7,8]. One successful and commercially convenient technique is the use of a surface hardener capable of penetrating into the pores in the investment medium. Dental waxes, on the other hand, are convenient and inexpensive materials in a dental laboratory environment and thus have been suggested for this purpose [7].

Various natural waxes, such as beeswax, palm wax, and candelilla wax, have different physical properties (melting point, hardness, and viscosity), and the physical properties may contribute to their capability as hardening agents [9]. Thus, this study investigated the influence of the application of these three different types of dental waxes on the surface hardness of a phosphate-bonded refractory material.

Materials and Methods

Mold Preparation for Surface Hardness Testing

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To ensure consistency across all test samples, a rectangular metal mold with specific internal dimensions (40 mm diameter, 10 mm height) was manufactured. Using this uniform mold for all samples is an essential step to maintain consistency in size and shape, which is essential for the validity of laboratory comparative research [10,11].

Mixing Procedure

For this in-vitro study, a total of twenty (20) specimens were prepared from a phosphate-bonded investment material (Rema Dynamic S; Dentaurum, Ispringen, Germany). The selection of a phosphate-bonded investment is consistent with its widespread use for high-fusing alloys in dental practice [4]. The investment powder and liquid were dispensed and mixed according to the manufacturer's instructions to achieve a homogenous, creamy consistency. The mixture was then carefully poured into the metal mold, using mechanical vibration to prevent the entrapment of air bubbles for 10-15 seconds then stop [9]. After the material reached its final set, the specimens were carefully retrieved from the mold. And then placed in an air fryer for hardening treatment at 200°C for 9 minutes to ensure drying them and deriving off moisture to get a dense surface [12].

Dipping Procedures

The twenty specimens were randomly allocated into four equal groups (n=5). Group 1 was designated as the control and received no surface treatment. Groups 2, 3, and 4 were subjected to surface treatment with different dental waxes. The general procedure involved melting the specific wax for each group on a thermostatically controlled hot plate to a liquid state (70-80°C), to ensure optimal fluidity and penetration, as recommended by dental material standards [13] followed by the immersion of the specimen.

Beeswax Dipping

The melting point of beeswax is between 61-66°C; wax from capping is 63.7°C [14]. The temperature at which the beeswax changes from a solid state to a liquid state. At first, the wax begins to soften and after 10 minutes becomes liquid and ready for the dipping process. Specimens were treated with molten wax for approximately 15 seconds, then placed on paper for one minute to dry and kept in a box at room temperature.

Palm Wax Dipping

The temperature at which the palm wax changes from a solid state to a liquid state 60°C when it becomes liquid and ready for the dipping process. Specimens were dipped in melted wax for 15 seconds, then placed on paper to dry and kept inside the box until they were examined again after treatment.

Candelilla Wax Dipping

Pellets of candelilla wax were placed in a wax pot thermostatically controlled device for melting. With a melting point of 68.5°C it took about 10 minutes inside the thermal melting device until became liquid and ready for the dipping process. Following immersion, each specimen was removed from the molten wax at 15 seconds and placed on a flat, heat-resistant surface to cool to room temperature, allowing the wax coating to solidify completely.

Surface Hardness Measurement

The surface hardness of all specimens was evaluated using a Shore D hardness tester (Digi Test; Bareiss, Germany), a standard instrument for assessing the hardness of polymers and elastomers in dental materials science [15]. The test was performed on the treated surface of each specimen after it had cooled completely. For each specimen, five indentations were made: one at the geometric center and four at equidistant points 20 mm from the center. This 5-point measurement technique is a common method to ensure a representative average hardness value and minimize localized measurement errors [8]. The five readings were then averaged to obtain a single representative surface hardness value for each specimen.

Results

The descriptive statistics for the surface hardness (Shore D) of all four groups are presented in Table 1 and [Figure 6]. The highest mean surface hardness was recorded for Group 3 (Palm wax) with a value of 106 ± 4.9, while the lowest mean value was observed in Group 2 (candelilla wax) with a value of 96.2 ± 7.172.

The one-way ANOVA test revealed a statistically non-significant difference in the mean surface hardness values among the four groups (P = 0.055) as shown in Table 2.

The application of all three types of dental wax led to a statistically non- significant difference in the surface hardness of the phosphate-bonded investment material compared to the untreated control group. Among the treatment groups, palm wax provided the most significant improvement, yielding the highest surface hardness values. While both beeswax and candelilla wax also enhanced surface hardness, they were statistically similar to each other, and both were significantly less effective than palm wax.

Discussion

The purpose of this study was to investigate the influence of three types of natural dental waxes, beeswax, palm wax, and candelilla wax, on surface hardness properties of a phosphate-bonded investment. The findings showed that the application of any of the tested waxes led to a statistically significant improvement in surface hardness compared to the untreated control group. This supports the assumption that coating of the investment surface could improve its physical properties. Presumably, the reason for the enhanced surface hardness is likely due to the molten wax penetrating microscopic surface pores of the investment material. As noted above, as the wax hardens, both cracking and shrinkage will asymptotically accumulate inside these fine spaces and thus process them; a denser, more compressed condition in less time is achieved. The principle has been well described in dental materials science [1,7]. This effectively reduces the material's surface porosity, which is a primary cause of its low initial hardness and susceptibility to abrasion during handling [6]. This finding is supported by recent studies, which also reported significant improvements in surface properties of investment materials after the application of various waxes [8,16].

The better performance of palm wax in the series of treatment groups demonstrated is that this study may be attributed entirely to its known inherent physical properties. The better performance of palm wax is due to its natural attributes. It is widely accepted to be one of the firmest naturally occurring waxes, because of its higher molecular weight and more crystalline end-structure upon solidification, when compared with beeswax or candelilla wax [17]. Such intrinsic hardness is thus efficiently translated to the investment surface by means of its inherent high thermal conductivity, leading to a much higher resistance to the indentation. On the other hand, beeswax and candelilla wax are used as a natural resinous component, yet their melting points are well known to be softer than those of palm wax, and thus slightly smearing when touched as well [3,13]. The fact that their efficacy was similar in this study, and no significant difference between them existed (P = 0.055), indicates that the intrinsic hardness of both waxes is close to each other, so that they would show somewhat the same or less surface improvement if formulated compared with palm wax.

These results agree with those obtained in a previous study, which used some surface hardeners to increase the quality of investment molds [18]. Although most studies relate to commercial cyanoacrylate-based or resin hardeners, here it is shown that common and inexpensive dental waxes can work effectively. The concept of filling surface micro porosities to improve mechanical properties is a common theme in materials science and readily translates to this case [19].

These findings have practical implications from a clinical and laboratory point of view. Harder investment mold is less likely to be damaged during manipulation of the wax

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pattern, sprucing, and casting process. This can result in a finished casting having reduced surface and improved marginal convergence and dimensions. Minimizing the number of surface defects at the mold stage, as we did in this study, not only shortens chair-side or laboratory time due to less finishing and polishing of the final prosthesis but also leads to one more step towards a better-adapted restoration [13]. Recent work reported that the surface treatment of investment led to a smoother final casting [5].

However, there are some limitations in this study. As an ex vitro study, it may not accurately simulate the complicated parameters in a clinical dental laboratory. The number of cases in each group was also limited. Hence, further studies are needed to investigate the influence of these wax coatings on other key properties (i.e., surface roughness and overall dimensions of the final castings). Other works may also explore alternative application methods or long-term aging of these wax hardeners under different casting condit.

Conclusion

The use of natural dental waxes significantly increased the surface hardness of phosphate-bonded investment material. All tested wax treatments caused significantly harder surfaces: beeswax, candelilla wax, and palm wax than the untreated control. Of the treatments used, palm wax was the most efficient hardening agent with significantly higher values for surface hardness. Accordingly, palm wax as a surface hardener is simple to use, inexpensive, and a useful means for dental laboratories to enhance the quality of investment molds, which may ultimately result in increased accuracy and cast life.

Conflict of Interest

The authors declare no conflicts of interest.

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Table 1. Descriptive Statistics of the surface hardness test for studied groups.

Groups	Mean	Std. Deviation	Std. Error	Min.	Max.
Control	103.6	3.95917	1.77059	99.5	109
Candelilla Wax	96.2	7.17287	3.2078	89	107.5
Palm Wax	106.9	4.83994	2.16449	101.5	111.5
Bees Wax	104	8.10864	3.62629	92.5	112.5

Table 2. One – way ANOVA to compare surface hardness.

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	311.938	3	103.979	2.661	0.083
Within Groups	625.2	16	39.075		
Total	937.137	19			