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An Evaluation of the Influence of Surface Hardness on Phosphate-Bonded Investment Hardening by Dental Waxes

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Abstract
Background An investment can be defined as a ceramic material that is appropriate to form a mold into which an alloy or a metal is cast. The mold-forming operation can be described as an investment, which means a process of covering or surrounding material, such as a denture, wax form, crown, or other objects. The phosphate-bonded investment results in a brittle-cast model with the surface of a pore. The hardening agents of the dental surface are then used in materials of refractory investment to improve their properties. The problem of Statements: The phosphate-bonded investment results in a brittle-cast model with the surface of a pore. **Objectives** was to compare and evaluate the effectiveness of various hardening agents (Bee wax, paraffin wax, and soy wax) on surface hardness. **Materials and Methods** 28 specimens were created using «phosphate-bonded investment» materials. Each group had seven samples: group A (control without immersion), group B (immersion in soy wax), group C (immersion in paraffin wax), and group D (immersion in beeswax). After being immersed in wax, the hardness value of each specimen was determined. **Results** The results indicated that after immersion in various waxes, the surface hardness value increased for all specimens. **Conclusion** The immersion technique with a hardening agent considerably enhanced the surface hardness of the refractory investment materials.

Keywords: Phosphate bonded investment material; beeswax; soy wax; paraffin wax; hardness test.

Introduction

Dental waxes come in several types, each designed for a specific function, such as Baseplate wax, Occlusal registration wax, indicator wax, sticky wax, utility wax, inlay wax, boxing wax, and corrective wax. (Okorie et al, 2019). The qualities of dental waxes vary in terms of hardness, ductility, and melting point. Dental waxes have a wide range of physical qualities, but they all have several features, such as a range of melting temperatures, the ability to flow, the ability to hold residual stresses, and the largest thermal expansion of all dental materials (Okorie et al, 2019). Many types of natural waxes, which are used in dipping methods to harden agents, differ in their origins and may be of animal origin, such as beeswax, or plant origin, such as soy wax, or synthetic waxes, such as paraffin wax (Ribas Garriga, 2019). The Apis genus of honey bees generates natural bee wax in beehives. It is mostly made up of a fatty acid ester and several long-chain alcohols (Zbigniew et al, 2019). Paraffin wax is classified as a natural wax in the petroleum wax category. Beeswax is mostly derived from the high boiling point fraction of petroleum. It is mostly made up of a hydrocarbon combination. (Okorie et al, 2019). Soy wax is a natural wax made of biodegradable and renewable resources and is environmentally friendly. The wax is derived from soybeans, which are farmed by North American soybean farmers. (Rezaei et al, 2002). The mechanical properties of waxes play a critical role in dental procedures as they determine the strength and toughness of patterns used in impression making, casting, and waxing up of restorations. Dental waxes must be sufficiently resistant to avoid breaking during assembly and to preserve dimensional specifications without distortion. Therefore, compared to other materials, dental waxes have lower mechanical properties that are strongly dependent on temperature (Zhang, 2004). Phosphate-bonded investments are one type of investment material that is an important part of dental restoratives. We can use casting processes with high melting temperatures (850–1100 °C) for alloys like cobalt chromium, which is the substance used to produce the refractory model by reproduction of a master cast (Prakhar et al, 2020). To get a harder surface and suitable qualities, models of refractory materials are submerged in dental hardening wax. Aljubori and Aljafery, 2020, reported that the hardening waxes have a low melting point, so they can easily be melted and vaporised during the burnout process. The hardening process is essential as it improves the compatibility of the wax pattern with the refractory model, leading to the creation of accurate dental restorations. Additionally, the use of hardening agents enhances the durability and strength of the refractory models, ensuring their ability to withstand the wax pattern process (Dotchev and Soe, 2006). The impact of the hardening agents on the refractory models extends beyond their surface, improving the mechanical properties of the dental restorations and resulting in strong and durable restorations. Overall, the dipping procedure with hardening agents is a critical step in the production of high-quality dental restorations (Virmani et al, 2018; Rathi et al, 2019). Hardening agents improve the mechanical properties of phosphate material, such as surface roughness, hardness, and resistance to abrasion and scratching. The roughness test plays an important role in the success of dental restorations; a rough surface reduces the material›s durability, which may be due to friction between coarse surfaces or the occurrence of pores on the material›s surface (Emsley, 2011; Vyas et al, 2020). The purpose of this study is to compare and evaluate the efficiency of several hardening agents (Bee wax, paraffin wax, and soy wax) on the hardness of Phosphate-bonded investments.

Materials and Methods

Mold preparation for the surface hardness test

A rectangular-shaped mold with a measurement of (5x2x1cms) was used to invest specimens for surface hardness tests (Saji et al, 2017). As illustrated in Figure (1), the molds were made from modelling wax and then reproduced with silicon material for pouring specimens with phosphate-bonded investment materials (Virmani et al, 2018).

Mixing procedure

The refractory phosphate-bonded investment material powder: the liquid ratio was combined by the manufacturer›s corporate specifications (Protechno Dentistry) (100 g:26 ml). The powder was added to the liquid and fully mixed by hand for 15-20 seconds to achieve a perfectly homogenous and wet mass before passing through a mechanical vacuum mixer for 60 seconds. Following the conclusion of the mixing period, the mixture was poured into the silicon mold for 10–15 seconds using a vibrating device.

for preventing air bubble trapping. After waiting for 60 min, the specimen was separated from the silicon mold and then placed in an oven for hardening treatment at 200ºC for 15 minutes to ensure their drying and deriving moisture to obtain dense surfaces (Virmani et al, 2018).

Immersion procedures

Immediately immersed the specimens in the melted wax when they were removed from the oven. The dental hardening waxes are melted in a thermostatically controlled wax pot, as shown in Figure (2). After 10 minutes, the wax softens and becomes liquid, allowing us to immerse the sample in a thermosetting device with an average melting range of about 78ºC. It takes about 15 minutes to obtain a high-viscosity liquid, in addition to the immersion process is done only once (Hummudi, 2021). This study utilised a total of 28 specimens, which were divided into four groups, each containing 7 specimens. Group (A): (Control group) 7 specimens not immersed. Group (B): immersion 7 specimens in soy wax for 10-15 seconds.The melting point of soy wax at 40-75ºC (Shaharuddin et al, 2023). Group (C): Immersion of 7 specimens in soy wax for 10-15 seconds. The melting point of paraffin wax is 40-70ºC (Ragunathan et al, 2020; Okorie et al, 2019). Group (D): Immersion of 7 specimens in beeswax for 10-15 seconds. The melting point of bee wax is 60-64 °C (Bogdanov, 2009). Each specimen is submerged for 10-15 seconds in molten wax until the whole surface is coated, closing all holes on the surface (Heikkinen et al, 2020; Abdelfattah, 2019; Hummudi, 2021). Following the immersion technique, all specimens were placed on paper for one minute to dry before being stored in a box at room temperature 25 ± 1ºC (Hummudi, 2021).

Surface hardness testing procedure

The hardness test in this study was performed using a durometer hardness device (type Shore-D scale) by (ASTM D2240). The testing loads were set to 50 N, and the specimens were placed under the indenter area with a measurement time of 10 seconds. The digital (shore D) device has an indenter with a diameter of 0.8 mm, tapering to a cylinder with a diameter of 1.6 mm. After a firm pressing down on the indenter, the reading was recorded on the digital scale. The specimens were tested in three faces (right, middle, and left) at room temperature 25±1ºC and average readings were measured for each specimen. Each result value was recorded between (0-100) hardness number on the hardness scale. The higher values indicated harder materials (Oleiwi and Hamad, 2018). Figure (4) shows the ultimate surface hardness value for immersion specimen surfaces.

Results

Surface Hardness Test

Descriptive statistics are shown in Table (1) and Figure (5) for the surface hardness tests including (minimum, maximum values, mean and SD) after immersion. The result showed that the highest mean value of the hardness test was (83.0714) following immersion in beeswax, whereas the lowest mean value of the hardness test was (36.2857) not immersed (Control Group). The one-way ANOVA test was performed to find the significant differences among groups. The test's results revealed highly significant differences between groups, as shown in Table (2). Table (3): Multiple comparisons found a highly significant difference between waxes, except for a substantial difference between paraffin wax and beeswax.

Table (1): Descriptive Statistics of the surface hardness test for different process techniques of studied groups.

Groups	N	Mean	Std. Deviation	Minimum	Maximum
Control Group (A)	7	36.2857	1.035	34.5	37.5
Soy wax (B)	7	72.5714	2.206	70	76
Paraffin wax (C)	7	79.8571	2.656	75	83
Bees wax (D)	7	83.0714	3.690	79.5	89.5
Total	28				

Table (2): One–way ANOVA to compare surface hardness.

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9760.955	3	3253.652	488.921	0.000 (HS)
Within Groups	159.714	24	6.655		
Total	9920.670	27			

Table (3): Multiple comparisons between groups by LSD test.

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	P-Value	Sig.
Control Group (A)	Soy wax	-36.28571*	1.37890	.000	HS
	Paraffin wax	-43.57143*	1.37890	.000	HS
	Bees wax	-46.78571*	1.37890	.000	HS
Soy wax (B)	Paraffin wax	-7.28571*	1.37890	.000	HS
	Bees wax	-10.50000*	1.37890	.000	HS
Paraffin wax (C)	Bees wax	-3.21429*	1.37890	.028	S

* The mean difference is significant at the 0.05 level.

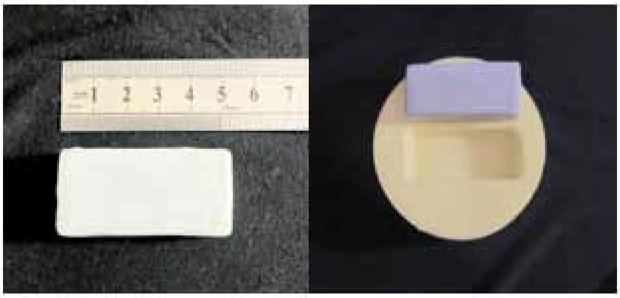

Figure (1): Mold preparation.

Figure (2): Dipping procedures.

Figure (3): Specimens after dipping in Besswax.

Figure (4): The specimen under surface hardness (shore D) testing unit.

Discussion

The hardness test is a commonly used method for evaluating a material›s ability to withstand mechanical stress or wear. It can also be used to assess the effectiveness of a particular treatment or process applied to the material (Wojda and Sajewicz, 2019; Emsley, 2011). Because the phosphate-bonded investment is brittle and thin, a replicated master model with a roughened surface and porosity is created (Hummudi, 2021). It is challenging to retain the surface details of the refractory cast model while creating wax patterns (Rathi et al, 2019). The surface specimen was covered with melting liquid wax and then tested surface hardness after dipping. Our study revealed that the mean value of the surface hardness test of all specimens increased following dipping in dental agents as in figure (5). This indicates the addition of another substance to it, leading to an increase in its strength and mass. Therefore, the hardness was improved. Hardening agents basically are natural waxes which contain natural elements such as calcium, sodium, carbon, magnesium, oxygen, nitrogen and iron. In case of adding the elements to another solid material, then its strength and weight will increase. If the material strength increases, its hardness property will be enhanced. This result was in agreement with the study by Saji et al, (2017). Who employed two commercially available refractory materials and three dental hardener agents (Paraffin wax, Bees wax, and Okodur cold hardener), and discovered that these agents had an impact on enhancing the surface hardness of specimens, increasing the rate of hardness. Furthermore, Jain et al, (2020) found that the hardness value of refractory investment material increased after treatment with dental hardening agents, implying that the hardening treatment was effective in improving the surface hardness of phosphate-bonded refractory investment materials. Aljbori et al, (2020), conducted research that emphasise the relevance of dental gypsum, which is often used as an investing and moulding material in prosthodontic restorations, having appropriate hardness to withstand any deformation produced by external pressures. The authors also emphasised the importance of material hardness in producing the needed strength and perfect replication of tiny features in difficult prosthodontic procedures. This result agreed with the study by Hummudi, (2021), who concluded the Hardening gents are natural waxes that contain natural elements, if they are added to another material they increase its strength, therefore hardness improves and the liquid wax covers the entire surface of the specimen and closed all the pores on its surface, thus the surface became smoother, solid, and with good working properties.

Conclusions

1. The immersion of specimens in the hardening agent influenced the surface hardness of a refractory investment material specimen.
2. The surface hardness value is enhanced when immersion in hardener waxes.

Referances

ABDELFATTAH, M. Y. 2019. Clinical and laboratory evaluation of the fit accuracy of metal frameworks of removable partial denture fabricated from two different pattern materials. Oral Health Dent Manag, 18, 1-4. https://doi:10.35248/2247-2452.19.18.1065

ALJUBORI, O. M. & ALJAFERY, A. M. A. 2020. Evaluation of the Linear Dimensional Changes and Hardness of Gypsum Product/Stone Type -after Adding Silica Nanoparticles. Nano Biomedicine and Engineering, 12, 227-231. https://doi: 10.5101/nbe.v12i3.p227-231

BOGDANOV, S. 2009. Beeswax: uses and trade. The Beeswax Book, 1-16.

DOTCHEV, K. & SOE, S. 2006. Rapid manufacturing of patterns for investment casting: improvement of quality and success rate. Rapid Prototyping Journal, 12, 156-164. https://doi: 10.1108/13552540610670735

EMSLEY, J. 2011. Nature›s building blocks: an AZ guide to the elements, Oxford University Press, USA.

HEIKKINEN, V., NYSTEN, J., BYMAN, V., HEMMING, B. & LASSILA, A. 2020. Multi-sensor optical profilometer for measurement of large freeforms at nm-level uncertainty. Surface Topography: Metrology and Properties, 8, 045030. https://doi:10.1088/2051-672X/abd293

HUMMUDI, I. M. 2021. Determination of Surface Hardness of Refractory Cast Investment Materials Before and After Dipping in Wax Hardening Agents. Iraqi Dental Journal, 43.

JAIN, A., NASIR, R. M., CHEE, L. W., XIN, L. H., YEIH, L. Z., UGRAPPA, S. & MARIMUTHU, K. 2020. To Evaluate and Compare the Effect of Commercially Available Model Hardening Agent on Surface Hardness and Surface Roughness of Refractory Investment Materials: An In-Vitro Study. Indian Journal of Public HealthResearch &Development11,11-18.

OKORIE, P. C., EMAIMO, J., ALEKE, C. O., OKORONKWO, S. C., NWANGWU, G., OKEKE, K. N., OKONKWO, C. S. & OBIANO, E. C. 2019. Production of Dental Inlay Wax Using Locally Sourced Materials in Enugu, Nigeria. International Journal of Dental Medicine, 5, 1-8. https://doi: 10.11648/j.ijdm.20190501.11

OLEIWI, J. K. & HAMAD, Q. A. 2018. Studying the mechanical properties of denture base materials fabricated from polymer composite materials. Al-Khwarizmi Engineering Journal, 14, 100-111. https://doi.org/10.22153/kej.2018.01.006

PRAKHAR, K., SINGHAL, R., AGARWAL, S., MAHESHWARI, R., JAVED, B. & KALPANA, K. 2020. Investment materials: A review. European Journal of Pharmaceutical and Medical Research, 7, 457-461.

RAGUNATHAN, T., HUSIN, H. & WOOD, C. D. 2020. Wax formation mechanisms, wax chemical inhibitors and factors affecting chemical inhibition. Applied sciences, 10, 479.

RATHI, A., PANDE, N., RADKE, U., DESHPANDE, S. & CHANDAK, A. 2019. Comparative evaluation of diametral tensile strength of phosphate-bonded investment (ringless) material by using air-drying method, conventional hot air oven, microwave oven, and combination of microwave and conventional oven: An in vitro study. The Journal of the Indian Prosthodontic Society, 19, 248. https://doi: 10.4103/jips.jips_45_19

REZAEI, K., WANG, T. & JOHNSON, L. A. 2002. Combustion characteristics of candles made from hydrogenated soybean oil. Journal of the American Oil Chemists› Society, 79, 803-808.

RIBAS GARRIGA, M. 2019. Ribas Garriga M. Evaluation of natural wax for green packaging applications [Internet] [Dissertation]. 2019.

SAJI, P., MOHAMED, R., NOUFAL, P., REDDY, P. S., JAIN, A. R. & GOUNDER, R. 2017. Comparative evaluation of the influence of cast hardening agents on surface abrasion, surface hardness and surface detail reproduction properties of refractory investment materials. Biomedical and Pharmacology Journal, 10, 1517-1524. https://dx.doi.org/10.13005/bpj/1261

SHAHARUDDIN, S. I. S., MANSOR, M. A., RASHID, M. A., SHAFFIAR, N. & AHMAD, Z. 2023. The Effects of Beeswax Additions on the Structural, Thermal, Mechanical and Mass Loss Properties of Soy Wax Blends. Journal of Mechanical Engineering (1823-5514), 20. https://doi.org/10.24191/jmeche.v20i1.21079

VIRMANI, R., PATIL, A. G., PATIL, R. & KARNI, P. A. 2018. Comparative evaluation of the dimensional accuracy of cast partial denture frameworks fabricated by conventional technique and light-cure wax technique: An: in vitro: study. Indian Journal of Health Sciences and Biomedical

Research kleu, 11, 155-159. https://doi: 10.4103/kleuhsj.kleuhsj_245_17

VYAS, A., PANDYA, M. & SUTARIA, M. Effect of mixing proportion and mixing time on primary slurry retention and surface roughness of investment casting shells. IOP Conference Series: Materials Science and Engineering, 2020. IOP Publishing, 012094. https://doi:10.1088/1757-899X/872/1/012094

WOJDA, S. & SAJEWICZ, E. 2019. Influence of dental materials on hardness and Young's modulus of the surface layers of tooth enamel formed as a result of friction. Acta of Bioengineering and Biomechanics, 21, 129-139. https://doi: 10.5277/ABB-01222-2018-02

ZBIGNIEW, R., AGNIESZKA, N., JOANNA, W. & DANUTA, N. 2019. Effect of Different Paraffin's and Microcrystalline Waxes on the Mechanical Properties of Base Plate Dental Waxes. Saudi Journal of Oral and Dental Research, 2.

ZHANG, K. 2004. Rheological characterization of dental waxes.