Research Article

Effect of adding date palm seed oil on surface roughness, hardness, wettability, and thermal conductivity of soft denture lining material

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Abstract Background: Date Palm Seed Oil (DPSO) contains antifungal properties and health benefits due to the presence of essential minerals, nutrients, and antioxidants. Consequently, it has the ability to provide distinct characteristics when combined with Soft Denture Liner Material (SDLM); however, it may have an impact on the latter's physical and mechanical properties. Thus, the current study aimed to show how DPSO [Saudi (SA) or Pakistani (PK)] integration affects the roughness, hardness, wettability (contact angle), and thermal conductivity of SDLM. Materials and Methods: Two hundred SDLM specimens were manufactured and separated into five groups with varied (vol. %) DPSO concentrations depending on each test (n=40) for roughness, hardness, wettability, and thermal conductivity. The SDLM specimens were separated into five categories: Group A (0% pure control) with no DPSO integration, Group B 2.5%, Group C 5% (DPSO) [Saudi (SA)], Group D 2.5%, and Group E 5% (DPSO) [Pakistani (PK)]. All the synthesized samples were analyzed using Scanning Electron Microscope (SEM). The ANOVA test was employed to demonstrate considerable variance among all of the sample data. Results: Findings indicated substantial differences ($P \leq 0.05$) in roughness, hardness, and thermal conductivity testing. There was a significant difference in wettability test results ($P < 0.001$) across all samples studied. Conclusions: Incorporating DPSO improved SDLM's roughness, hardness, wettability, and thermal conductivity, resulting in more distinctive SDLM. The 5% (DPSO) [SA or PK] produced an optimal proportion that enhanced the SDLM characteristics.

Keywords: Date palm seed oil, hardness, roughness, soft denture lining, thermal conductivity, wettability.

Introduction

Soft denture lining material (SDLM) is commonly used in prosthodontics due to its viscoelastic properties, which act as insulation while promoting oral comfort and masticatory performance [(1)]. There are several issues that must be addressed, including low hardness, increased roughness, decreased thermal conductivity, and poor bond strength between the SDLM and polymer denture bases. This can lead to Candida Albicans (*C. Albicans*) colonization, which raises the possibility of denture stomatitis[(2-4)].

Recently, there has been an updated interest in the use of herbal oils in a number of dental therapies. Combining medicinal oils with SDLM reduces *C. albicans* adherence while improving denture qualities such as hardness, roughness, wettability, and thermal conductivity [(2, 5)].

Relining materials are divided into three categories: hard lining materials, tissue conditioners, and soft lining components [1, 6]. Soft denture lining materials are classified into two types: silicone and acrylic. Both types of SDLMs can be utilized with either auto-curing or heat-curing system [6, 7]. The SDLMs were subjected to modifications during function due to leaching away some components, such as the plasticizer, which over time resulted in changes to the materials' mechanical and physical properties in the patients' mouths [6, 8]. The leaching of the plasticizer reduces resilience and alters the viscoelastic properties of SDLM [9], therefore, it loses its bonding strength properties. Hardness is an essential component of a resilient liner and should be steady for a long period of time [10] to enable the substance to perform its functions as intended [11, 12]. As a result, SDLM can be used to provide the patient with the optimal level of hardness [5, 12]. The significance of roughness in previous research has been questioned because operator skill [5], polishing technique [13], and the material's inherent qualities [14] mostly determine how rough a material is, which varies depending on modifications in the techniques used. The roughness and hardness of the material have a significant impact on how structures interact with their environment [15, 16].

The SDLM can provide the best thermal conductivity or level of comfort for the patient; therefore, it is an essential factor of a resilient liner that must be consistent throughout time in order for the material to function properly [6]. Ideally , SDLMs should have specific qualities that provide maximum benefits for denture wearers. For instance biocompatibility, resilience, wettability, bonding strength against the supporting denture base, and the ability to inhibit or limit microbial proliferation [5]. Herbal plant remedies, on the other hand, are viable substitutes for treating oral fungal infections with little or no adverse effects [10]. This creates a global trend of researching them in order to find physiologically sustainable medicinal products with powerful antifungal capabilities [8, 17]. One of these natural medications is plant-extracted oils [18, 19]. Recently, many investigations have been carried out to assess the antifungal activity of various types of oil against *C. Albicans*. According to the researchers, plant oils [20, 21] are considered a viable therapy option with efficient antifungal benefits for treating prompted denture stomatitis [5, 22]. Date Palm Seed Oil (DPSO) is extracted from the seeds of the date palm tree [23]. DPSO is high in the two types of fatty acids, with lauric and oleic acids being the most common, which include tocopherols, tocotrienols, phytosterols, and phenolic compounds, thus offering value for numerous uses [18, 22], such as pharmaceutical [5, 6] and cosmetic applications [24, 25].

Accordingly, the current study has been recognized as an outstanding contribution to research because of its evaluation of the impact of incorporating DPSO [Saudi (SA) or Pakistani (PK)] into the SDLM for estimating how different vol. % of DPSO affected the roughness, hardness, wettability, and thermal conductivity characteristics of SDLM. The null hypothesis claimed that incorporating DPSO [(SA) or (PK)] into the SDLM would result in no difference in roughness, hardness wettability, and thermal conductivity, as evidenced by interim soft lining denture bases.

Materials and Methods

In this investigation, 200 specimens were manufactured using auto-curing soft denture liner material (SDLM) (EZ-Soft, Korea). Two varieties of DPSO [Saudi (SA) or Pakistani (PK)] were used: Violet Flower from Saudi Arabia (SA) and Hemani from Pakistan (PK). The SDLM of the test group was divided into five primary groups based on roughness, hardness, wettability, and thermal conductivity (n=40) per test [11] in consort with DPSO different (vol. %). Specimens included: Group A, the pure control without DPSO integration (0%), group B, with 2.5%. DPSO (SA), group C with 5% DPSO (SA), group D, with 2.5% DPSO (PK), and group E, with 5% DPSO (PK). The particular volume percentages (vol. %) of DPSO employed in this study were chosen according to previous research done by Naser and Abdul-Ameer [19].

Fabrication of the specimens

The sample pattern was designed using a CNC machine (SZS Co., Ltd, China) to produce plastic disk models to assess roughness (µm), hardness (shore A), wettability (contact angle), and thermal conductivity (w/m.⁰C) of SDLM specimens. A plastic pattern was established using AutoCAD 2023 (Autodesk) and processed for 10 minutes [19]. Each sample was prepared in a disk-like structure with a thickness of 3mm and a diameter of 30mm, in accordance with ISO-SDLM standards [19, 26]. The SDLM (powder and liquid) were combined in a beaker container with a lid to avoid the monomer from vaporizing, as instructed by the manufacturer. To prevent SDLM from adhering to the stone, separating media were placed to the upper part and bottom of the flask. When the mixture reached dough-like consistency, it was molded with one hand and placed in the stone's moulds area. All the techniques used were conducted using the constructing procedures mentioned in the previous research done by Naser and Abdul-Ameer [19].

Incorporation of Date Palm Seeds Oil (DPSO) into soft denture liner material (SDLM)

The amount of DPSO (0.000, 0.062, and 0.125ml) and SDLM (monomer) (2.500, 2.437, and 2.375ml) were measured with a micropipette (DRAGON lab, China) according to proportionate volume quantities (0, 2.5, and 5 vol.%) for producing [DPSO (SA or PK)/SDLM] samples. The SDLM (monomer) and DPSO (solution) were mixed using a magnetic stirrer 78-1 device (Changzhou, China) with a rotation regulator (RPM), then added immediately to the SDLM powder (3.5g) to avoid DPSO separation from the SDLM liquid, and the amount of DPSO was decreased from the SDLM liquid to maintain the identical manufacturing ratio of Powder/Liquid [19, 27]. An electrically balancing equipment (accurateness of 0.001) (KERN, Germany) was applied to weigh the powder of SDLM (g), and a micropipette (Biobase, China) functioned to measure the amount of monomer [19, 28].

Packing, curing and finishing

Following achieving the dough stage, the SDLM was manipulated by hand and placed into the mould. The lid was attached to the polyethylene-coated top part (JIAO JIE, China). Dental laboratory hydraulic press (EPI 1, EA, China) was utilised for applying 100 kg/cm^2 constant pressure in order to remove excess material and evenly spread the SDLM in the mould. Following the press, the flask was unsealed utilising a wax knife (Fahnenstock, China), the polyethylene film was peeled, superfluous substance was eliminated, and the surface of the stone was recoated before curing [10, 19]. The flask was then moved to the Ivomat equipment to complete the curing process. The dental laboratory polymerizer Ivomat (IP3 Ivoclar Vivadent, Germany) was used to cure the SDLM specimens according to the company's guidelines of the auto-curing system at temperature (70-75⁰C) for 30 minutes and pressure (1.5-2 bars). Following the curing stage, the metal flask was removed from the Ivomat device and permitted to cool steadily at ambient temperature for one hour. The flask was unlocked, and the SDLM specimens were carefully detached from the moulds. After that, all SDLM specimens were finished with a finishing sandpaper bur to remove any excess material before being polished with a silicon polishing bur. Finally, all samples were stored in distal water for two days at 37°C beforehand testing [10, 19].

Specimen's tests

Surface roughness test

Surface roughness was measured using a portable digital profilometer (time 3200/TR200) with an accuracy of 0.001µm. The instrument is fitted with a sensor needle (surface analyzer) that detects surface roughness. The device must be adjusted to make sure the stylus only touches the surface of the sample and moves along the 11mm in three different spots to obtain three measurements from each specimen. The roughness test value is calculated by taking the average of three readings [3].

Surface hardness (Shore A) test

The surface hardness (Shore A) test was performed via a durometer (TH200). The testing device consists of a spring-loaded indenter (0.8mm in diameter) coupled to a digital scale with an array of 0 to 100 units. The standard method is to press the indenter and record the reading. Each sample has been analyzed three times (once at each end and once in the middle). The average of the three readings was determined [3, 11].

Wettability (contact angle) test

The wettability (contact angle) (°) test was measured using the static sessile drop technique. An aside view of a liquid drop on a solid substrate with a horizontal flat base was acquired and analyzed using an optical subsystem. The contact angles of SDLM samples were determined at ambient temperature using the sessile drop method with 2µl of distilled water droplets in optical tensiometer equipment (Germany). Five sessile drops from each SDLM sample were analyzed to obtain an average mean [7, 11].

Thermal conductivity test

The thermal conductivity of SDLM specimens was evaluated using a thermal conductivity machine (Lee disc) that contained three copper discs (A, B, and C), each with a hole transferring temperature [27, 29]. The specimen was positioned between copper discs A and B, with the 60-watt electrical plate heater sandwiched among discs B and C. When the clamp screw that held all of the discs together was tightened, the power to the heater was turned on. A transformer was used to measure the 0.25 amp current at 6 volts provided to the heater at 18°C. When the heater was switched on, the temperature in discs C and B rose faster than in disc A, owing to the presence of an isolator. After stabilizing at equilibrium for 30 minutes, calculate heat conductivity using the formulae [27, 29].

Scanning Electron Microscope (SEM) analysis

A Scanning Electron Microscope (SEM) (Axia ChemiSEM System, Portugal) was used to evaluate the qualitative assessment of surface topographies of produced [DPSO (SA or PK)/SDLM] samples with different DPSO (vol. %) (2.5, 5 SA) as well as (2.5, 5 PK) compared to the surface structures of the pure control samples without DPSO (0%). Additionally, SEM evaluated the qualitative analysis of DPSO molecule dispersion in the produced [DPSO (SA or PK)/SDLM] samples. All samples were dried and mounted to stubs, and then they were sputtered with golds, and the surface images of reflected SEM emissions were evaluated using an accelerating voltage was 30.00 kV, 4000x mag., 13.8mm WD, and scale bar 30µm to provide surface images of reflected SEM emissions.

Statistical analysis

The findings were analyzed and appraised applying statistical analysis (mean, standard error, maximum, and minimum values for all tests). The Analysis of Variance (ANOVA) test and the Post HOC-Tukey test (HSD) were used to demonstrate significant difference across the experimental groups. Microsoft Excel 2013 was used to create the graphical representation, together with IBM SPSS Statistical Services for Windows V21.

Results:

This study compared the mean roughness (µm), hardness (Shore A), wettability (contact angle) (°), and thermal conductivity (w/m.^{0}C) of all investigated samples after incorporating DPSO [Saudi (SA) or Pakistani (PK)] at different (vol.%) concentrations into SDLM as presented in Figures (1 a, b, c, and d). Figure (1, a) displays the roughness (µm) test results. The pure control (0%) group showed the highest mean roughness (0.27μm), whereas the 5% DPSO (SA) group had the lowest (0.10μm). The SDLM groups with 5% DPSO [(SA) and (PK)] had the lowest mean roughness (0.03μm and 0.05μm). These findings demonstrated significant variations ($P < 0.05$) among subcategories analyzed with one-way ANOVA. The Post HOC-Tukey test (HSD) revealed significant differences ($P \leq 0.05$) in roughness (μm) among the investigation groups (Figure 1, a).

Figure (1, b) displays the descriptive outcomes of the hardness (Shore A) test. Control group had the lowest mean value (66.6), whereas DPSO 2.5% (SA) had the highest mean value (92.1), followed by DPSO 5% (SA) (92.8), and then by 2.5% and 5% DPSO (PK). These findings indicated a significant difference ($P < 0.05$) among subcategories in hardness among all investigated groups.

Furthermore, Figure (1, c) presents the descriptive outcomes of the wettability (contact angle (◦) test. The mean value for 5% DPSO (SA) (47.20) was the lowest, followed by 2.5% DPSO (SA) (51.27), then 5% DPSO (PK) (54.36), and finally 2.5% DPSO (PK) (58.70). Whereas the control group with 0% DPSO had the highest mean value (61.81).These outcomes showed a significant difference ($P < 0.001$) among all analyzed groups.

In addition, Figure (1, d) reveals the descriptive results of the thermal conductivity (w/m.^{0}C) test. 5% DPSO (SA) had the highest mean value (0.44), followed by 5% DPSO (PK) (0.41), and then 2.5% DPSO (SA) (0.37) as well as 2.5% DPSO (PK) (0.36). Whereas the control group with 0% DPSO had the lowest mean value (0.35). These outcomes displayed a significant difference ($P < 0.05$) among subcategories analyzed with one-way ANOVA (refer to Figure 1, d). The Post HOC-Tukey test (HSD) shown substantial differences ($P \leq 0.05$) in thermal conductivity among all tested groups.

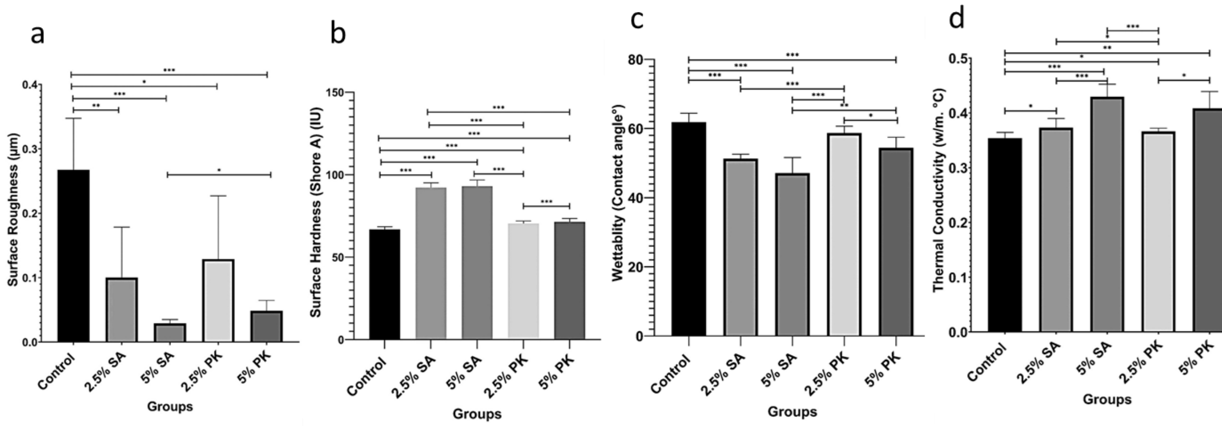

Figure 1: Statistical data with error bars (SD) for pure control and manufactured [DPSO (SA or PK)/SDLM] experimental groups a) Surface roughness (μm), b) Surface hardness (shore A), c) Wettability (contact angle) (◦), and d) Thermal conductivity (w/m.^{0}C) testing among control (0%), 2.5% SA, 5% SA, 2.5%PK, and 5% PK groups.

** Sig. P-value ≤ 0.05; ***High Sig. P-value < 0.001.

Scanning Electron Microscope (SEM) analysis

The SEM investigation of the SDLM specimen (0% pure control) revealed an uneven structure with a notably rough surface, as shown in Figure (2, a). The SEM analysis suggested closed all porosity of SDLM with smooth surface, and the SEM of SDLM with integration of DPSO 2.5% [SA or PK], the DPSO presented more regular distribution of DPSO molecules inside the SDLM matrices, as illustrated in Figures (2, b, and c). Furthermore, the SEM analysis of SDLM containing 5% DPSO [SA or PK] demonstrated a regular and smooth distribution of DPSO molecules inside the SDLM matrices, as indicated in Figures (2, d, and e).

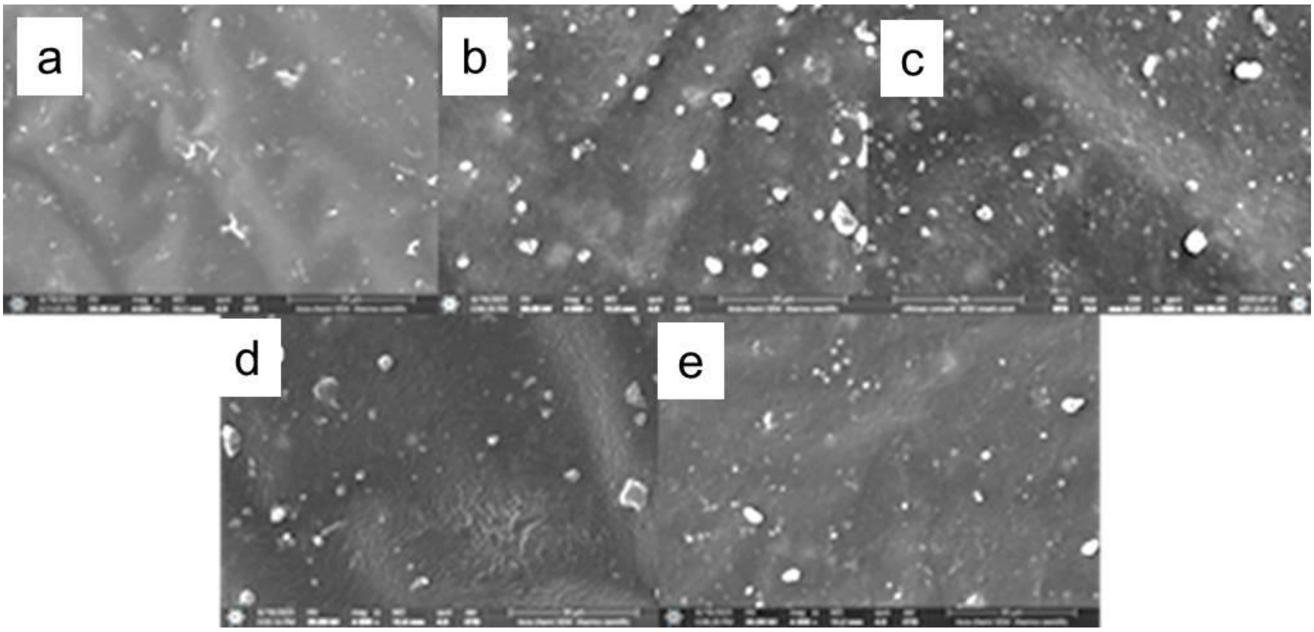

Figure 2: The SEM microphotographs of manufactured [DPSO (SA or PK)/SDLM] samples: a) Pure control group 0%, b) 2.5% SA, c) 2.5% PK, d) 5% PK, and e) 5% SA. The images illustrated the surface textures of the tested samples, scale bars are 30µm.

Discussion

The SDLM has been used as a crucial component in removable denture therapy because they improve patients' comfort, achieve more even force allocation, and reduce localized pressure [3, 6, 30]. Other downsides of using SDLM were loss of hardness, poor tearing strength, and loss of smoothness. As a result, numerous studies has been done in attempt to identify approaches for enhancing the chemical, biological, mechanical, and physical features [9, 11, 19, 31]. The SDLM were defined as soft polymers that can adhere to mucosal surface of the denture base [6, 16, 17]. It plays a crucial role in denture bases because of its capacity to provide a cushioned effect for preserving the health of the traumatised mucosa by absorption and uniform distribution of stresses throughout the entire region covered by the denture bases [12, 19, 32]. This study evaluated the influence of incorporating various volumes (vol. %) of DPSO (SA or PK) into SDLM matrices for testing roughness (µm), hardness (Shore A), wettability (contact angle), and thermal conductivity (w/m.ºC).

Roughness is an important feature of SDLM since it influences the adherence of pathogenic organisms that cause diseases for instance denture stomatitis [5, 11, 16]. The assessed group 5% DPSO (SA) additive (0.03µm) had the lowest mean value, whereas the control sample 0% had the greatest mean value (0.27µm). This reduction in roughness value could be attributed to polymerization accelerations, which encouraged further organization and supplementing of polymer chains, resulting in a fine smooth surface [5, 15]. This outcome could possibly be related to the chemical interactions between DPSO molecules and SDLM, which improve polymer chains bonding and result in smaller fragments chipping away from the surface during deflasking and grinding, perhaps attributing to an overall decreased in roughness. This result coincided with outcome of Muttagi and Subramanya, who figured out that adding seed oils of C anthelminticum and O sanctum to SDLM greatly reduced its roughness [7]. While this study's outcomes contradicted those of Godil et al., they discovered that adding Ocimum sanctum oil to SDLMs had no effect on the roughness of the SDLM[20]. This idea was consistent with a study conducted by (Muttagi and Subranany), they indicated that incorporating the seed oils of C anthelminticum and O sanctum to the SDLM considerably reduced roughness [7].

Hardness is an essential characteristic of resilient polymeric materials to specify the material's resistance to permanent indentation and is a quick way to calculate its elastic modulus (10, 33). The study's findings revealed that the DPSO 5% (SA) group exhibited the highest average hardness rating (92.8). The control 0% group (66.6) had the lowest mean hardness of all the experimental groups. This outcome was in contrast to result of a study conducted by Godil et al., who reported that the incorporation of Ocimum sanctum oil to SDLM had no influence on the measure of hardness presented by that substance (20). Based on Mese and Guzel, as compared to the other materials, the SDLM had the highest hardness after being held in water for one day at 37°C (34).

Wettability is a basic criterion for denture bases because it has a significant impact on denture base retention and it helps saliva to move efficiently and quickly throughout the denture base surface retention. Furthermore, it has a role in reducing *C. Albicans* accumulation on the denture surface by washing action; the higher the wettability, the better the clean ability (7, 11, 35). It also increases patient comfort by generating a lubricating coating on the denture surface, which can substantially alter their contact with the surrounding tissues and fluids (7, 11, 20). Figure (1, c) illustrated the descriptive statistics of wettability for each test group. The study's findings revealed that the DPSO 5% (SA) group had the lowest average rating (47.20). While the control group, 0% (61.81), had the highest average rating of any experimental group. These improvment of wettability for experimental groups due to the differences between chemical structures of two types of DPSO (SA or PK). Therefore, when DPSO is added to SDLM, it creates a more hydrophilic structure while having no negative impact on the wettability of SDLM. This outcome coincided with result conducted by (Muttagi and Subranany), who found that incorporating the C anthelmintic and O sanctum seed oils to the SDLM significantly improved wettability (7).

Thermal conductivity is the measurement of how much heat given volume of material can transport through a specific area in a given amount of time. Low thermal conductivity makes using a prosthetic material made from polymer materials difficult for the patient. Additionally, this material weakens the tissues supporting the prosthesis (15). It is important to consider thermal conductivity in terms of the size and ratio of thermal-conducting nanoparticles in the base denture powder (27, 29). Figure (1, d) demonstrated the descriptive statistics of thermal conductivity (w/m.ºC) for each test group. The study's findings revealed that the DPSO 5% (SA) group had the highest average thermal conductivity rating (0.44) followed by 5% DPSO (PK) (0.41), and then 2.5% DPSO (SA) (0.37) as well as 2.5% DPSO (PK) (0.36). Whereas the pure control group, 0% (0.35), had the lowest mean thermal conductivity of any experimental group. This finding could be attributed to speculation that DPSO could replace plasticizers in the polymer materials industry because it consists mainly of medium chain fatty acids, which can act as plasticizers while also creating energy conductive pathways, albeit in trace amounts, by increasing polymer chain elasticity and decreasing material viscosity, as a result it can improve the thermal properties of SDLMs. The finding of this study was consistent with the outcomes of research done by Noori and Jaber, who utilized Neem or Aloe Vera as well as Mohammed and Jaber, who employed virgin coconut oil. Both of their outcomes found out that incorporating different herbal extract ingredients to SDLM enhanced the thermal conductivity of the SDLMs (27, 29). When DPSO is mixed with SDLM, it fills the pores, forming a heat conducting pathway that aids in the rapid and smooth transfer of heat from one aspect of the specimen to the other, reducing the percentage of polymer thermal insulation (27, 29).

Complementary SEM investigations are required to discover differences in surface topography among all synthesised [DPSO (SA or PK)/SDLM] samples. The DPSO components were efficiently dispersed in areas between the SDLM components, resulting in uniformly aligned DPSO/SDLM composite matrixes, despite the fact that the various volumes of DPSO had diverse crystallographic forms and designs. The polymerized SDLM matrix filled the spaces between the DPSO molecules, and there were no air or hollow spaces. Thus, the SEM results revealed that the manufactured [DPSO (SA or PK)/SDLM] samples had a smooth and homogenous surface, as shown in (Figures 2, b, c, d, and e).

Overall, all experimental samples showed statistically significant improvement as a result of chemical structural alterations between two kinds of DPSO (SA or PK). The type of SDLM manufacturer, the method of producing the DPSOs [Saudi Arabia (SA) or Pakistan (PK)], the volume percentage of oil addition, and the chemical structure of each type of oil (SA or PK) based on the manufacturing company were all factors that contributed to the outcome of this one-of-a-kind study.The null hypothesis proposed in this investigation was rejected since there was a difference in roughness, hardness wettability (contact angle), thermal conductivity, and surface properties after incorporating of DPSO [SA or PK] into the SDLM matrices, as proven by an interim soft relining denture base.

This study is unique and original contribution because no other studies have conducted this type of research. However, the current study has certain limitations, for example, only one type of SDLM (EZ-Soft, Korea) was used. Besides no biological assessments (antifungal and antibacterial activities) were proven for DPSO (SA or PK)/SDLM samples. As a result, this study may include additional surface and structure analyses, such as X-ray diffraction (XRD), Fourier Transform Infrared (FTIR) spectroscopy, and Energy Dispersive Spectroscopy (EDS) to assess the chemical and physical interactions between SDLM and DPSO ingredients. Furthermore, additional research into the use of multiple SDLMs with varying DPSO volume percentages was required.

Conclusions

Given the constraints of this study, the following conclusions were reached:

The addition of different concentrations of DPSO (SA or PK) to SDLM matrices improved the roughness, hardness, wettability, thermal conductivity, and surface characteristics of all [DPSO (SA or PK)/SDLM] samples. When (2.5 and 5%) DPSO (SA or PK) was added to the manufactured [DPSO (SA or PK)/SDLM] samples, the surface and structure properties testing results were consistently superior to the pure control (0% DPSO additive) samples. Furthermore, it enhances SDLM while maintaining its structural and physical properties. Based on the results from 5% DPSO (SA) or (PK), the most optimal oil can be chosen and successfully included into SDLM matrices. As a result, DPSO (SA or PK) can be preferred as an additive for SDLMs.

Conflict of interest

None.

Authors' contributions

NHA prepared the materials, collected the data, and analyzed them. The first draft of the manuscript was authored by NHA and ShFA. While ShFA, SSBQ, and FHM provided feedback on prior versions. All authors helped to conceptualize and plan the study, as well as evaluate and approve the final paper.

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Informed consent

Consent for participating in this type of study does not involve formal consent.

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تأثير إضافة زيت بذور النخيل على خشونة السطح، والصلابة، وقابلية البلل، والتوصيل الحراري لمادة بطانة الأسنان اللينة

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المستخلص:

الخلفية: يحتوي زيت بذور النخيل (DPSO) على خصائص مضادة للفطريات وفوائد صحية بسبب وجود المعادن الأساسية والمغذيات ومضادات الأكسدة. ونتيجة لذلك، لديه القدرة على توفير خصائص مميزة عند دمجه مع مادة بطانة الأسنان الناعمة (SDLM)؛ ومع ذلك، قد يكون له تأثير على الخصائص الفيزيائية والميكانيكية للأخيرة. ونتيجة لذلك، تهدف الدراسة الحالية إلى إظهار كيف يؤثر تكامل DPSO [سعودي (SA) أو باكستاني (PK)] على خشونة وصلابة وقابلية البلل (زاوية التلامس) والتوصيل الحراري لـ SDLM. المواد والطرق: تم تصنيع مائتي عينة SDLM وفصلها إلى خمس مجموعات بتركيزات DPSO متفاوتة (الحجم٪) اعتمادًا على كل اختبار (ن = 40) للخشونة والصلابة وقابلية البلل والتوصيل الحراري. تم فصل عينات SDLM إلى خمس فئات: المجموعة أ (0٪ تحكم نقي) بدون تكامل DPSO، المجموعة ب 2.5٪، المجموعة ج 5٪ (DPSO) [سعودي (SA)]، المجموعة د 2.5٪، والمجموعة هـ 5٪ (DPSO) [باكستاني (PK)]. تم تحليل جميع العينات المصنعة باستخدام المجهر الإلكتروني الماسح (SEM). تم استخدام اختبار ANOVA لإظهار تباين كبير بين جميع بيانات العينة. النتائج: أشارت النتائج إلى وجود اختلافات كبيرة ($P \leq 0.05$) في اختبار الخشونة والصلابة والتوصيل الحراري. كان هناك فرق كبير في نتائج اختبار قابلية البلل ($P < 0.001$) عبر جميع العينات المدروسة. الاستنتاجات: أدى دمج DPSO إلى تحسين خشونة SDLM وصلابتها وقابليتها للبلل والتوصيل الحراري، مما أدى إلى SDLM أكثر تميزًا. أنتجت نسبة 5٪ [(SA) أو (PK)]DPSO نسبة مثالية عززت خصائص SDLM.