*Research Article*

# Surface roughness and surface hardness of acrylic resins exposed to cuttle bone powder polishing agents

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**Abstract**: Background: Preserving oral health for denture wearers is of high priority. It can be significantly affected by the degree of surface roughness of the dentures. So, it is essential to refine the dentures properly before delivering to the patient. The abrasive materials should offer a smoother surface without affecting the properties of denture bases. This study aimed to evaluate the impact of various abrasive agents on both surface roughness and surface hardness of acrylic resin denture base material. The abrasive agents selected for this study were pumice and cuttlebone Materials and Methods: A total of 60 heat-polymerized polymethylmethacrylate specimens (65x10 x2.5 mm) were constructed and grouped into control (n=10) finished with pumice size (120 µm) and experimental (n=20) finished with cuttlebone powder sizes (150 µm) and (120 µm). Then they were divided into two groups: 30 specimens were subjected to profilometer surface roughness analysis and 30 specimens were subjected to Shore D hardness tester. Polished of acrylic resin surfaces specimens were assessed by scanning electron microscopy and Atomic Force microscopy. Results: The acrylic resin specimens finished with cuttlebone powder (experimental)size 150 µm and 120 µm showed the least surface roughness in comparison with specimens finished with pumice (control). ANOVA and LSD tests showed significant differences ($p<0.001$) between the control and experimental groups. In surface hardness test, ANOVA - test revealed non- significant differences at the ($p > 0.05$) level between control and experimental groups. Conclusion: This study demonstrated that cuttlebone powder has successfully reduced the surface roughness of denture base material. Moreover, surface hardness was not affected by the cuttlebone polishing agent which suggests the successful applicability of the tested particle size for dental practitioners.

**Keywords:** Surface Roughness, Hardness, Abrasive, Cuttlebone powder, Pumice

## Introduction

Dental plaque formation on rough surfaces in the oral cavity is a major issue that affects the oral health. This is particularly applicable in case of the prosthesis, which is supposed to be worn in the oral cavity for a long time [(1)]. Surface roughness is a crucial issue, which affects dentures through the accumulation of stains and bacterial plaque, leading to adverse effect on oral health and leading to difficult oral health management by the professionals [(2,3,4)]. Surface roughness describes the micro irregularities and geometrical imperfection of the solid material surface. This could at some point increase the incidence of biofilm formation when the material is placed in biological environment. Biofilm is a thin layer of colonies of microbes that grow on any surface [(5)]. Rough denture surface can be considered as a target for plaque aggregation as well as increase the adherence of *Candida albicans* [(3,6)]. To minimize this issue dentures should be properly finished and polished before being worn by the patient [(1)]. The polishing procedure includes the step-by-step elimination of rough surface areas. This procedure may affect some physical properties of acrylic resin [7]. There has been limited information and studies regarding acrylic resin surface roughness evaluation based on polishing agent and their impact on biofilm formation [8]. Conventionally, acrylic resin is polished by mechanical process using abrasive agents since it produces a smoother base surface. Pumice is one of the most common well dental abrasive materials used in dentistry. Pumice is the powdered form of volcanic rock that has a holey texture [9]. It consists of 7-8% sodium oxide-potassium oxide, 60-67% silica, 13-17% alumina, and a minimal amount of titanium dioxide, iron oxide and calcium oxide [10]. Other alternative abrasive materials that can be used as polishing agent are toothpaste, eggshell and cuttlebone. Cuttlebone is a type of highly preamble and ultra-lightweight material; these characteristics allow the cuttle fish to survive in very deep water and gives it the ability of buoyancy. The resilience of the strong cuttlebone is an important factor in the protection of vital organs of cuttlefish. The cuttlebone consists of two parts; the dorsal shield on the outer surface which is a tough and dense material for protection and the lamellar matrix which is very Porous and consists mainly of calcium carbonate in crystalline form. [11]. It consists of an inorganic and organic composite framework. The organic component includes protein and chitin (constituting 1% - 2% by weight), influencing its physical properties and crystal size regulation [12]. Meanwhile, the inorganic fraction comprises calcium carbonate and calcium phosphate [13]. Importantly, cuttlebone is a natural substance devoid of toxins or contaminants [14,15]. The microstructure of cuttlebone demonstrates multifunctional properties such as compressive strength, high porosity and flexural stiffness, exemplifying nature's optimization in cellular structure design. Historically, cuttlebones were utilized to produce polishing powder, which was incorporated into toothpaste to enhance its whiteness. [16]. Cuttlebones powder offers a favorable sustainable alternative to traditional pumice for finishing acrylic resin in dental implementation. It offers surface quality, comparable, contributing to dental prosthetics, functional and esthetics excellence. Moreover, its environmental and economic advantages make it an attractive choice for dental practices committed to sustainability. This study aims to assess the impact of two distinct polishing agents on the sur face roughness and surface hardness of heat-activated acrylic resin.

**Materials and Method**

Samples groups

The total number of specimens is 60, which are two main groups according to the test be used, 30 specimens for the surface roughness test and 30 specimens for the surface hardness test. Each group was subdivided into three subdivisions according to the polishing agents:

10 samples for the control (group A): polished by pumice (120 μm)
10 samples for the experimental (group B): polished by cuttle bone powder (120 μm)
10 samples for the experimental (group C): polished by cuttle bone powder (150 μm)

Specimens prepared with dimensions of 10 mm × 2mm ×65 mm width, depth and length [ADA Specification No.12 1999]. Acrylic specimens were prepared using plastic patterns, which were produced by designing in an STL file and produced plastic patterns by 3D printer into the desired form and dimension.

Samples preparation

A conventional flasking procedure was done for mold preparation, Firstly, a separating medium was applied to the plastic patterns and left to dry. Type IV hard dental stone (Germany) mixed according to the manufacturer's specifications in the ratio (powder/water 100 g/31 mL) was poured into the lower part of the metal flask. The metal patterns were inserted into the stone when the investing stone was set after 30–45 min. It was opened, separated, layered with (separating medium) and let to dry, then the flask's top was attached to the invested one and filled with stone on the vibrator, after the stone was entirely set, the 2 parts of the flask were carefully separated, the patterns were removed from the mold. To prepare for packing with acrylic dough, the two halves of the flask were coated with the separating medium (17).

Heat cure acrylic resin (Vertex /Netherlands) was mixed in proportion (3:1) (powder-monomer ratio) according to the manufacturer instructions. The packing of acrylic resin began when reached the dough stage. The acrylic dough was rolled, put into the molds, and then the two parts of the flask were sealed together after establishing metal-to-metal contact under pressure by a hydraulic press (20 bar for five minutes) (11) clamped the flask and transferred to the water bath for a half-hour at 74° C before being heated to boiling point for 30 min. The metal flask was allowed to cool at room temperature, then de-flasking and finally removing the acrylic specimens from the mold (18).

Acrylic bur was used to remove the remaining acrylic and flash in all specimen surfaces, then tungsten carbide burs (extra coarse grits) were used to finish all surfaces at 15,000 rpm for 60 seconds. After that all specimens were finished using silicon carbide waterproof papers (Carborundum universal) of grit size coarse then medium and fine (19).

Cuttlefish bones (Australia / Sydney beaches) were acquired from the local market. These samples were all in properly good state with minimal external damage. Cuttlebone was vigorously rinsed by water in order to remove impurities and remains. After that, the cleaned bones were dried under sunlight for three days. (20) Bones were crushed in an electric grinder (SILVER-CREST_ powder grinder SC_1880). It was designed for grinding limestone and stone objects, then sieved into 150 (21) and 120 µm particles using (sieve vibrator_FRITSCH) and finally stored in a glass bottle.

Sixty specimens were prepared and categorized into three groups, each containing ten specimens (n=10) treated with different abrasive powders. The groups included a control group using pumice powder (120 µm) and two experimental groups using cuttlebone powder of sizes 120 µm and 150 µm, correspondingly. The slurry of each abrasive powder was made by mixing 30 gm of powder with 5 ml of water (22). Specimens were polished on a dental lathe (QD-England) using a rag wheel and bristle brush (Vertex) for 2 minutes at 1500 rpm (23). All specimens were kept in distilled water for 2 days at 37 °C (24).

Surface roughness test

A surface profile-measuring device (TR:220/ Germany) was used. The specimen surfaces were positioned flat against a horizontal base of the profilometer. A profilometer stylus was then moved across each specimen surface, covering a distance of 11 mm. Each specimen was given three readings in µm. The final value of the surface will be determined by averaging these readings according to the apparatus design. The roughness average (Ra) of each specimen (25,26).

Surface hardness

In this study, a shore D hardness tester (Shore D, HT-6510A, BYQTER, China) was employed to measure the hardness or indentation of the specimens. The shore D hardness apparatus was situated vertically above a flat specimen on a level, firm platform. The recording was obtained from the reading scale D directly. The distance among the specimen surface and the hardness tester's indenter was (five) and (twelve) mm. The load was around (5 N). On each specimen, three spots with a (six mm) spacing between them were marked, and the hardness value was calculated by means of the average of these three readings with scale D. The reading was taking directly from the scale and calculated [25, 26].

SEM examination

The morphologic characterization of polished specimens was exposed to SEM examination (Inspect F50/FEI Company Netherlands) at a magnification of 500X and 1000X.

Surface roughness was analyzed with an Atomic Force Microscopy (AFM) controlled by Nano Scope (9.0) software (WORKSHOP, USA).AFM scan the surface of substrate using sharp tip attached to cantilever type NCLR -50 scanning probe microscopy (SPM) with silicon SPM senser.

One specimen was used in this test from each group. Scans were performed over 30µm x30 µm areas at a scan rate of 1Hz, producing 3D images. For each specimen, three randomly selected regions were measured, and both two-dimensional (2D) and three-dimensional (3D) AFM images were obtained. The microscope worked in non-contact mode, had a nominal tip radius of 5-10nm.

Statistical analysis

In this study, SPSS (Statistical Package for the Social Sciences) v 20 was used for the analysis. One-way ANOVA and LSD tests were utilised for comparison.

**Results:**

Surface Roughness Test

In table (1) Illustrates that surface roughness mean value was highest for the control group in comparison to the experimental groups. ANOVA - test revealed that significant difference between the control group and experimental groups (120 um , 150um).

**Table 1:** Descriptive statistics for surface roughness test.

| Studied groups | Groups | Mean | SD | Std. Error | Min. | Max. | ANOVA sig. |
|---|---|---|---|---|---|---|---|
| **Pumice (control)** | **Group A** | 0.628 | 0.1648 | 0.0521 | 0.422 | 0.944 | <0.01 |
| **cuttlebone size 120 µm** | **Group B** | 0.364 | 0.077 | 0.0243 | 0.204 | 0.443 | |
| **cuttlebone size 150 µm** | **Group C** | 0.266 | 0.068 | 0.021 | 0.190 | 0.363 | |

**Table 2:** LSD test for multiple comparisons of the surface roughness among the different surface treatments of each group.

| Groups | | Mean Difference (I-J) | P-Value |
|---|---|---|---|
| **Group A** | **B** | 0.263430* | <0.01 |
| | **C** | 0.361650* | <0.01 |
| **Group B** | **C** | 0.098220 | 0.06 |

Hardness Test

The hardness test showed that the lowest mean value was obtained in the control group while the highest value was obtained in the experimental group (150um) (Table 3).

**Table 3**: Descriptive statistics for surface hardness test.

| Studied groups | Groups | Mean | SD | Std. Error | Min. | Max. | ANOVA sig. |
|---|---|---|---|---|---|---|---|
| **Pumice (control)** | **Group A** | 88.04 | 1.965 | 0.622 | 83.03 | 89.67 | 0.309 |
| **cuttlebone size 120 µm** | **Group B** | 89.08 | 1.814 | 0.573 | 85.83 | 91.67 | |
| **cuttlebone size 150 µm** | **Group C** | 89.20 | 1.694 | 0.536 | 86.67 | 91.17 | |

Scanning Electron Microscope

SEM showed the surface irregularities, highest roughness cracks and pores was found in the specimens polished with pumice under a magnification power of 500X and1000X. (Fig. 1 A and B). For specimens polished with bone powder under the same magnification power for both sizes (120 µm and 150 µm ) is clearly appeared less irregularities, voids and cracks .(Fig. 1 C and D) and ( Fig. 1 E and F).

Atomic Force Microscopy (AFM)

The 3D topographical images of AFM of all groups are presented in (Fig 2). we can see that the experimental group (120 µm) was the more surface roughness and the experimental group (150 µm) was the less roughness as compared with control group. The mean values of AFM average surface roughness Sa (nm) of all groups are presented in bar charts. (Fig 3).

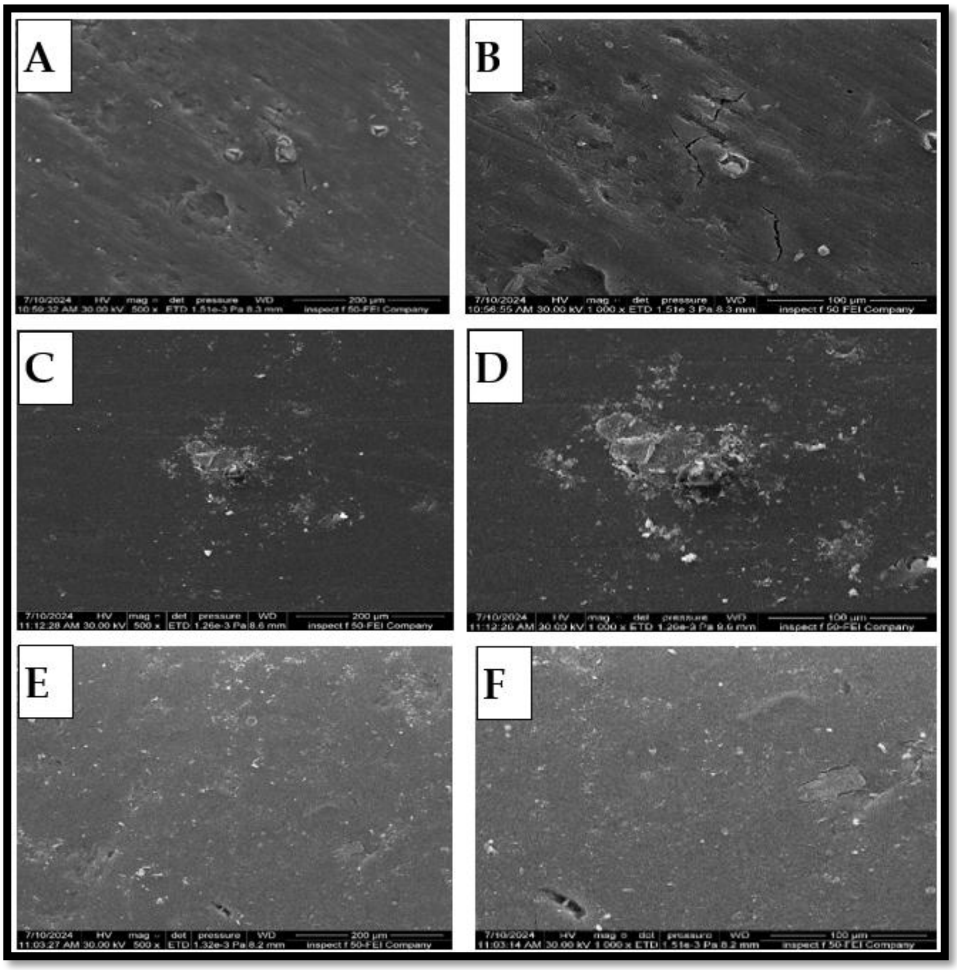


**Figure 1:** A: SEM image specimen after polishing with pumice (500 X) ;B: SEM image specimen after polishing with (1000 X); C: image specimen after polishing with bone powder 120 μm (500 X) ;D: image specimen after polishing with bone powder 120 μm (1000X); E: ): image specimen after polishing with bone powder 150 μm (500 X); F: image specimen after polishing with bone powder 150 μm (1000 X).

**Discussion**

Dentures are rigid surfaces prone to attracting food debris and developing plaque and calculus if not properly polished (27,28). Ensuring a smooth surface on denture base acrylics is crucial to prevent plaque buildup and avoid denture-induced stomatitis (29,30). For surface roughness reduction, acrylic dentures are submitted to various finishing and polishing procedures using several materials and techniques. These step-by-step procedures begin on modifying rough to smooth denture surfaces by mechanical means (31). The pumice polishing technique, employed by lathes, involves using a mixture of pumice and water to create a slurry that effectively finishes and polishes denture base acrylic resins. Therefore, it was selected as the control laboratory polishing technique for this study (31,32).

This current study assessed the efficacy of cuttlebone powder as abrasive agents in comparison with pumice. The lowest surface roughness mean value was obtained from cuttlebone powder size 150 μm and 120 μm. This due to the bone powder composed of calcium carbonate and calcium phosphate which aids in an abrasive activity. They excess the abrasion amount and smoothness of dentures (33).

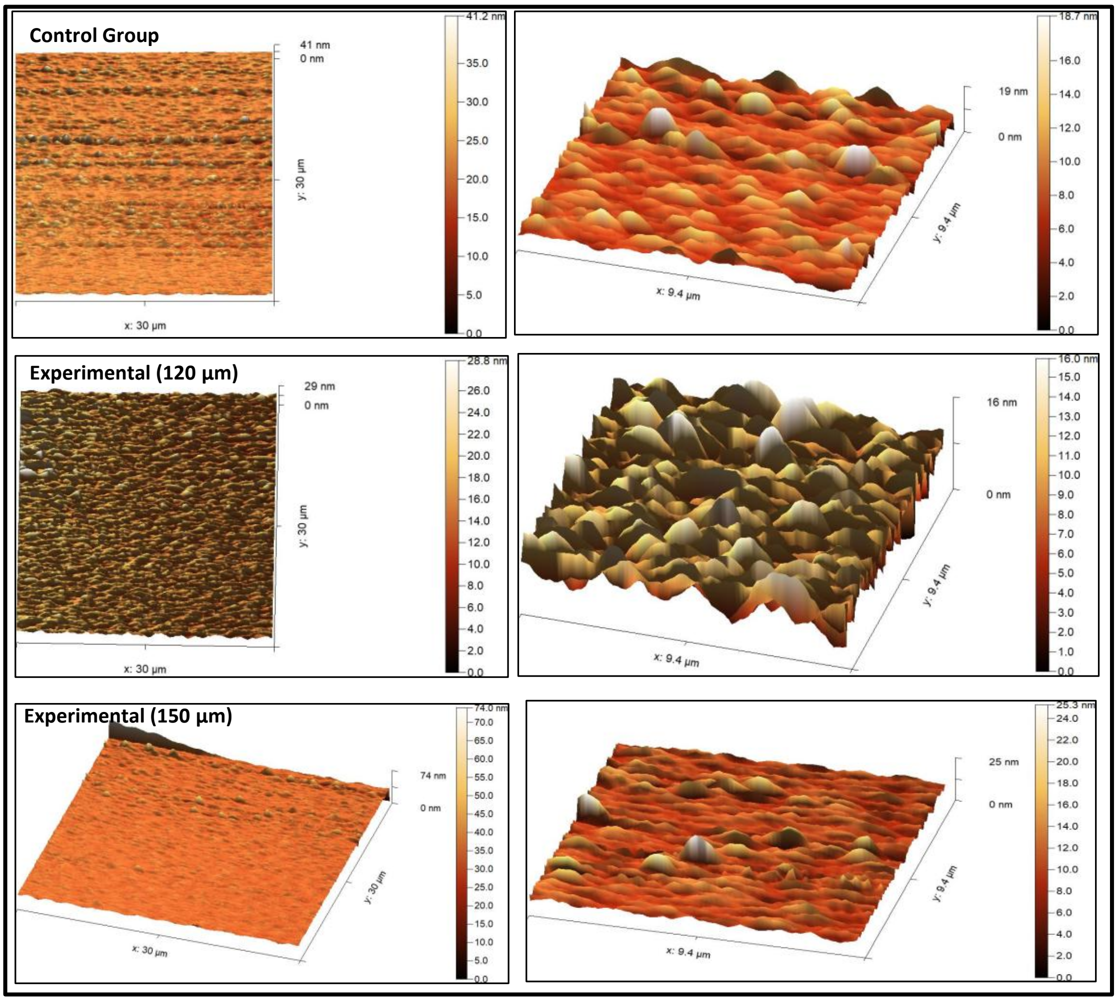


**Figure 2:** AFM 3D topographical images of control and experimental group.

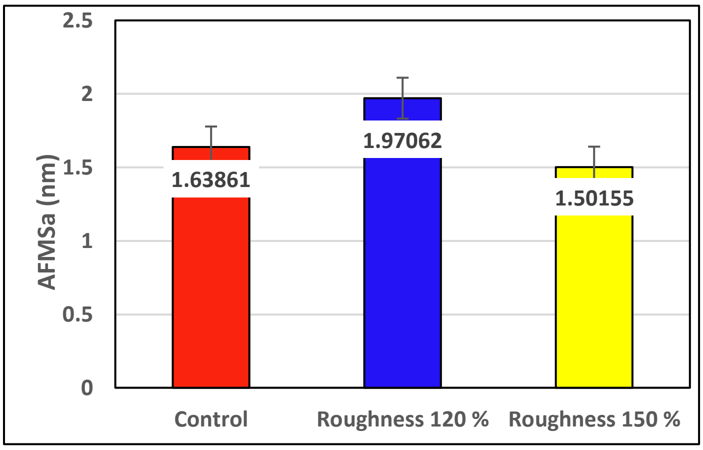


**Figure 3:** Bar charts of mean values of AFM Sa (nm).

The cause for this can be referred to the hydrophilic nature of calcite ($CaCO_3$) covering existing on the cuttlebone that assistances to become direct slurry with water to increase abrasive property [3,34]. It has been confirmed by several studies that cuttlebone polishing procedure produce surface erosion through eliminated superficial stains. Therefore, it is hypothesized that this biomaterial could produce smoother acrylic resin surface [31, 35]. The visual comparison of SEM images with mean values presented that after polishing, specimens polished using bone powder exhibits surface smoothness when compared to the surface structures of samples polished by pumice.The results of this study were in the line with previous study which suggested that abrasive powder obtained from egg shell enhanced smoother acrylic resin surface using cuttlebone polishing material [3] and study that concluded the experimental mollusk shell-based paste compact the surface roughness values on the surfaces of dental resins [36]. Furthermore, the measurement of surface roughness is essential method for assessing surface alterations, especially in dental research [37]. AFM has acquired estimation as a useful tool for this goal as it offers numerous advantages over other methods, including higher resolution measurements at the nanoscale, the capacity to generate 3D images, and more proportionality for evaluating restorative dental materials and tissues [38]. Moreover, AFM facilitates the evaluation method as it does not require additional fixation or coating of specimen [39]. In this study, the AFM findings were not identical to the profilometer readings and this is in line with previous research that justified this incompatibility of the readings to be due to the low sensitivity of the stylus profilometer as compared to AFM. The radius of the stylus tip limits the ability of the stylus to detect measurements smaller than the tip radius and so it cannot detect the nano roughness [40]. The stylus profilometer measured major area pro-vided input in micro (μm), while the AFM survey a smaller area with high resolution, supplying data at Nano scale which can't be revealed by profilometer [41]. The roughness values found in the present study indicate that the PMMA surfaces polished with the experimental bone powder and pumice were within the acceptable range of surface roughness in the oral cavity (0.2 μm) [39]. Therefore, it can be supposed that this new cuttle-bone powder could be used in dentistry because itis effective in reducing the surface roughness of acrylic resins.

On the other hand, surface hardness is well-defined as the material's resistance to abrasion or indentation [42,43]. In this study, the surface hardness of acrylic resins was evaluated using a Shore D hardness tester. Surface hardness is affected by various influences, including surface roughness, regardless of the polishing method or type of polishing powder utilized [19]. According to this study, it has been demonstrated that the difference in polishing agent did not significantly affect the surface hardness of the acrylic resin in a negative manner. This finding is of great importance since the surface roughness of high priority to be reduced of the denture base external surface at the same time preserving the surface hardness of the material.

The smooth surface achieved with cuttlebone powder enhances the durability and wear resistance of acrylic resin prosthetics. A smoother surface is less prone to scratches and microbial colonization, thereby extending the functional life of the prosthesis [44]. This improved quality directly translates to fewer adjustments and repairs, saving time and resources for both dental professionals and patients [9].

Since that the rate of polishing time and pressure applied on the specimens were consistent in the study, this may probably clarify the statistically similar effects. As the surface gloss and smoothness levels are considered reliant on material hardness, the consequences observed in the current study followed the same design in relative to this acrylic property. In other words, fewer roughness showed greater hardness and improved gloss values [45].

The main limitation of this study is the lack of control over the force exerted during the acrylic polishing process, as well as the absence of a device to measure this force. To mitigate this, specific criteria were implemented: a single operator performed all polishing tasks, and short breaks were taken after every five acrylic samples to prevent operator fatigue.

## Conclusion

This study demonstrated that cuttlebone powder has successfully reduced the surface roughness of denture base material. Moreover, surface hardness was not affected by the cuttlebone polishing agent which suggests the successful applicability of the tested particle size for dental practitioners.

## Conflict of interest

The authors have declared no conflicts of interest.

## Author contributions

I.M.H. perceived of the presented idea, wrote the manuscript, completed the analysis, drafted the manuscript I.N.Y designed the figures and tables. M.S.M. carried out the laboratory procedure. G.G.F. supervised the findings of this work. All authors discussed the results and contributed to the final manuscript. The research was improved by all authors, who also offered constructive criticism

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## Informed consent

Informed consent was obtained from all individuals, or their guardians included in this study.

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**خشونه وصلابه سطح الاكريل المستخدم في قاعده اطقم الاسنان المعرض الى سحوق عظم الحباركماده منعمه**

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**المستخلص:**
تهدف هذه الدراسة إلى معرفة تأثير مسحوق عظم الحبار كماده منعمه على خشونه وصلابه سطح الاكريل المستخدم في قاعده اطقم الاسنان .
تم تصنيع 60 عينه من ماده الاكريل المطبوخ حراريا .تم تقسيم العينات الى مجموعتين كل مجموعه تحتوي 30 عينه لقياس خشونه السطح وصلابه السطح بعد تنعيم العينات وتقسيمها الى 3 مجاميع :المجموعه الاولى تم تنعيمها بمسحوق ماده البومس المعروفه بتنعيم سطح الاطقم المتحركه ,المجموعه الثانيه:تم تنعيمها بواسطه مسحوق عظم الحبار (نوع سيبيا) بعد تنظيفه وطحنه الى حجم,120 مايكروميتر والمجموعه الثالثه : تم تنعيمها بمسحوق عظم الحبار الى 150 مايكروميتر.تم قياس خشونه سطح جميع العينات بواسطه جهاز البروفيلوميتر وصلابه السطح بواسطه جهاز **Shore D** كما تم فحص ثلاث عينات من كل مجموعه تحت المجهر الالكتروني وثلاث عينات اضافيه تحت مجهر القوه الذريه.
اظهرت النتائج ان العينات التي تم تنعيمها بواسطه مسحوق عظم الحبارنعومه واضحه وسطح املس مقارنه بالعينات التي تم تنعيمها بواسطه مسحوق البومس كما اظهرت النتائج ان صلابه السطح لم تتاثربالتنعيم بمسحوق عظم الحبار.
نستنتج من ذلك ان مسحوق عظم الحبار يمكن استخدامه كماده بديله البومس وبتكلفه واطئه.