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Original article

Evaluating the Surface Properties of Prosthodontic Polymer Impression Materials

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ABSTRACT

Surface properties of prosthodontic polymer impression materials, such as hardness, roughness, and accuracy, are crucial for the accurate replication of oral structures in restorative dentistry. To evaluate the surface properties by using different types of polymer impression materials commonly used in dentistry and analyze their surface characteristics. Materials and methods: Forty -five samples of materials were used, including alginate (irreversible hydrocolloid), condensation silicone (putty) and addition silicone (putty), study was conducted at the advanced medical polymer group in the Libyan Polymer Research Center to evaluate the surface properties of prosthodontic polymer impression materials. Three evaluation methods were used: Shore hardness testing, surface roughness testing, and dimensional accuracy measurements. Data analysis included mean, standard deviation, and One-way ANOVA calculations. Alginate has a lower hardness compared to addition silicone (putty) and condensation silicone (putty). The ANOVA test for surface roughness showed no significant differences among the materials, with a p-value of 0.027. For shore hardness, there were no significant differences among the materials, with a p-value of 0.000. The ANOVA test for dimensional accuracy showed no significant differences among the different periods for alginate, condensation silicone (putty) and addition silicone (putty), with p-values of 0.000 respectively. The study concluded that alginate had the lowest hardness and roughness compared to condensation silicone (putty) and addition silicone (putty). There are no significant differences among the material surface properties (Shore hardness and surface roughness) but not in dimensional accuracy among the materials. This information provides valuable insights for dental professionals working with impression material.

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INTRODUCTION

In dentistry, an impression is crucial for accurate tooth and orofacial replacement, impressing both professionals and patients. A precise impression is a dimensionally stable "negative copy" that can fill in as a cast shape. Every impression material must meet essential requirements, but recording minute details of oral cavity tissues is hard due to factors like

salivation, blood flow, and sulcular fluid. This is especially important for recording finish lines for fixed restorations, especially when edges lay intracellularly. The success of impression materials is attributed to their properties, such as tear strength and dimensional stability, resulting in excellent surface detail reproduction [1].
Surface properties of impression materials play an important role in producing an accurate replica of the oral structures, which is a prerequisite for high-quality restorative dentistry [2]. Inaccuracies during impressions inevitably lead to laboratory errors resulting in a lack of precision and misfit of prostheses. Many factors affect the accuracy of impression materials, such as: impression material selection, impression material manipulation impression material thickness, impression technique and impression removal, storage condition [3]. In the meanwhile, maintaining a smooth and moist surface for tooth imprints is crucial [4]. Additionally, the prosthesis's fit and acceptance may be impacted by surface roughness (Ra) on the tissue surface. When a material undergoes a disinfection process, its characteristics change, which can lead to surface defects or irregularities. Inappropriate method use is mostly to blame for these changes [5]. The surface hardness test is crucial since the results could have an impact on a material's surface characteristics [6]. The ability of a material to resist surface indentation or penetration is called its hardness. The hardness also changes with time for some materials [7]. To achieve dimensional accuracy, impression materials must possess certain properties. For instance, they should have low shrinkage upon setting, meaning they should maintain their shape and size once they have been removed from the oral cavity. Additionally, they need to have good flow and wetting properties to ensure optimal surface contact with the oral tissues, capturing intricate details and contours accurately. The surface properties of impression materials are closely tied to their dimensional accuracy and are crucial considerations in selecting the appropriate material for a specific dental procedure [8].
This study aims to investigate to assess the surface properties of commonly used prosthodontic polymer impression materials in dentistry. The study was involved the analysis of characteristics various types of impression materials alginate (irreversible hydrocolloid), condensation silicone (putty) and addition silicone (putty) to evaluate their surface.

METHODS

Materials

Dental polymer impression materials are manufactured by different companies, the material is supplied in the form of alginate (irreversible hydrocolloid), condensation silicone (putty) and addition silicone (putty).

Samples preparation

These dental polymer impression materials were made in three different routes (Alginate, condensation silicone (putty) and addition silicone (putty)) according to the manufacturer's instructions.
Forty-five samples were divided into three groups based on their manufacturing technique (Alginate (tropical), Zeta plus condensation silicone (putty) (Zhermack indurent gel “catalyst) and addition silicone (putty) (Zhermack Hydrorise Putty (base) and catalyst), with five samples assigned to each test. The surface properties of the samples were tested using a roughness test, shore hardness test, and dimensional accuracy test. Samples were prepared in cylinder Teflon with the following diameter dimension (2 x 0.5) mm.

Testing procedure

Surface roughness test

The (SR) test was done using a surface roughness meter (Surface Roughness tester STR-6210). It is made up of a stylus that was mechanically moved across the surface of the specimen by the drive unit. It also moves in the vertical direction up to the specimen surface as it ascends or descends over the irregularities of the specimen. This movement was converted to a corresponding electrical signal. A high cut-off value was selected to measure all micro- and macro irregularities. Three (SR) measurements were carried out for each specimen, and mean average (Ra) values were utilized for the statistical analysis. Five (Ra) readings on different areas with similar positions on each polished surface of the specimens were taken and the average was calculated. the data collected and the mean of five polymer impression material samples of each test group were measured calculated and analyzed using suitable statistical methods.

Dimensional accuracy test

After samples were constructed, the initial weight for each was measured using an electronic balance (OHAUS, PIONEER). Then we weigh the samples for zero hours, one hour, and after 24 hours. Then all samples were kept in a tissue moistened with distilled water at room temperature Change in percentage weight for each specimen calculated.
Shore hardness test

Shore Hardening A was used to measure the surface hardness, the indenter was attached to a digital scale that graduated from 0 to 100 units the usual method was to press down firmly and quickly on the indenter and record the maximum reading as the shore A hardness measurement was taken directly from the digital scale reading. Hardness results are average for each sample out of 15 samples for each alginate, condensation silicone (putty) and addition silicone (putty). measurements taken from different batches using a Durometer (Ray-Ran Machain, Model RR/B550, United Kingdom) by ASTM D2240, ISO 868. the test was carried at room temperature. Five replicates were tested for each sample, and the average values were calculated using;

Average Hardness = 1St+2Nd +3Rd+4Fr+5Fif / 5(Shores).

Statistical analysis

Parametric tests such as analysis of variance (ANOVA) were potentially used Since the study was designed to look at the impact of only one independent variable on the selected dependable variables, the one-way analysis of variance was selected due to its similarity to the t-test; where there was a significant mean difference among more than two groups on a continuous (metric) - selected dependent variable. The Siegel–Tukey test was used to determine if one of the two groups of data tends to have more widely dispersed values than the other.

RESULTS

This section This was designed to evaluate of surface properties of prosthodontic polymer impression materials. Materials with different consistencies (alginate, condensation silicone (putty) and addition silicone (putty) impression materials) were investigated. The tested null hypothesis was the fact that there would be no significant differences in surface properties among these impression materials.

Surface roughness results

The mean value for the condition of the alginate is 2.41, the mean for the condition of the condensation silicone (putty) is 2.13 and the mean for condition of the addition silicone (putty) is 1.66 The standard deviation for alginate is 0.268, condensation silicone (putty) is 0.450 and addition silicone (putty) is 0.399. The number of cases in each condition (N) is 5 in Table (1) more clarifications about the result of differences.

Table 1. One-way ANOVA Comparison of Surface Roughness Test (µm) of the tested polymer impression materials at p = 0.027

Material	Mean ±Std	df*	F
Alginate	2.41± 0.268	2	4.975
Condensation silicone (putty)	2.13 ± 0.450	14	
Addition silicone (putty)	1.66± 0.399		

Dimensional accuracy results

The mean value for condition of the alginate at zero hours, the mean weight was 3. 696, After 1 hour, the mean weight was 4.46 while After 24 hours, the mean weight was 4.566. The mean for the condition of the condensation silicone (putty) at zero hour, the mean weight was 3. 326, After 1 hour, the mean weight was 3.280 while After 24 hours, the mean weight 3.17. and addition silicone (putty) at zero hours the mean weight was 2. 861, After 1 hour, the mean weight was 2.818 while After 24 hours the mean weight 2.78. The standard deviation for alginate at zero hours, the mean weight was 0. 176, After 1 hour, the mean weight was 0.340 while After 24 hours the mean weight was 0.168. The mean for condition of the condensation silicone (putty) at zero hour the mean weight was 0. 093, After 1 hour, the mean weight was 0.090 while After 24 hours, the mean weight 0.127. and addition silicone (putty) at zero hour the mean weight was 0. 257, After 1 hour, the mean weight was 0.258 while After 24 hours the mean weight was 0.334. The number of cases in each condition (N) is 5 in Table (2) more clarifications about the result of differences.

Table 2. One-way ANOVA Comparison of Dimensional Accuracy result (g) of the tested polymer impression materials at p = 0.000

Material		Mean ±Std	df*	F
Alginate	**Zero hour**	3.696± 0.176	2	Zero hour 24.431
	After 1 hour	4.466± 0.340		
	After 24 hours	4.566± 0.168		
Condensation silicone (putty)	**Zero hour**	3.326± 0.093	14	After 1 hour 56.723
	After 1 hour	3.280±0.090		
	After 24 hours	3.17±0.127		
Addition silicone (putty)	**Zero hour**	2.861± 0.257		After 24 hours 15.855
	After 1 hour	2.818± 0.258		
	After 24 hours	2.78±0.334		

Shore hardness results

The mean value for condition of the alginate is 3.186, the mean for the condition of the condensation silicone (putty) is 3.980 and the mean for the condition of the addition silicone (putty) is 6.398 The standard deviation for alginate is 0.343, condensation silicone (putty) is 0.176 and addition silicone (putty) is 0.537. The number of cases in each condition (N) is 5 in Table (3) more clarifications about the result of differences.

Table 3. One-way ANOVA Comparison of Shore Hardness Test of the tested polymer impression materials at p = 0.000

Material	Mean ± Std	df*	F
Alginate	3.186 ± 0.343	2	95.966
Condensation silicone (putty)	3.980 ± 0.176	14	
Addition silicone (putty)	6.398 ± 0.537		

DISCUSSION

The section of the study aimed to compare the results of the shore hardness test, surface roughness measurement, and dimensional accuracy evaluation among three different impression materials: alginate, condensation silicone (putty) and addition silicone (putty) with the results of other similar studies.

In terms of surface roughness, the results indicated that addition silicone (putty) had a higher level of roughness compared to alginate, while condensation silicone (putty) had a similar level of roughness as alginate When comparing the mean values for the three materials with different using (ANOVA) test for analysis, it was found that there were no statistically significant differences (p-value> 0.05) between the tested groups where F = 4.975. These findings are consistent with the study conducted by Leung et al. (2016), which reported higher surface roughness values for silicone compared to alginate [9]. However, this previous study did not include condensation silicone (putty) as a comparison material. Therefore, the current study expands on the existing knowledge by including putty in the comparison and demonstrating its similarity to alginate in terms of surface roughness. Although there was some variation in surface roughness among the three impression materials, the ANOVA analysis did not reveal statistically significant differences. This finding is in line with the results of the study conducted by Wang et al. (2017), which also reported non-significant differences in surface roughness among different impression materials [10]. However, it is important to note that the current study used a different measurement method for surface roughness, which might have contributed to the differences in findings. Furthermore, the analysis of dimensional accuracy based on weight measurements showed that there were no significant differences among the different periods for each impression material. When comparing the mean values for the three materials and time with different using (the ANOVA) test for analysis, it was found that there were no statistically significant differences (p-value> 0.05) between the tested groups where F = (zero hour 24.431, After 1 hour 56.723and After 24 hours 15.855).

Undoubtedly, one of the most important stages of treatment in fixed prosthesis is accurate impression, which determines the success or failure and prognosis of the treatment. Neglecting this stage of treatment will lead to an inaccurate plaster cast and eventually a prosthesis with improper adaptation. In case of inaccuracy, the impression should be repeated, spending costs and time. Therefore, selecting the best and most accurate impression method is essential for successful treatment [11].

These findings support the results of the study conducted by Huang et al. (2015), which also reported no significant differences in dimensional accuracy among different periods for alginate and silicone impression materials [12].

Otherwise, Joshi et al., reported the addition silicone impression materials were superior in accuracy and dimensional stability in comparison to condensation silicone [13]. However, comparable studies specifically examining condensation silicone (putty) were not found in the literature. Therefore, the current study adds new information by including condensation silicone (putty) and demonstrating its consistent dimensional accuracy over time.

Regarding shore hardness, the results showed that alginate had a relatively lower hardness compared to condensation silicone (putty) and addition silicone (putty). When comparing the mean values for the three materials with different using (ANOVA) test for analysis, it was found that there were no statistically significant differences (p-value> 0.05) between the tested groups where F = 95.966. The results found that the hardness of the models was significantly influenced by the type of impression materials used. Alginate, a type of impression material, had a lower hardness compared to addition silicone (putty). The mean hardness for alginate was 304.32 with a standard deviation of 31.235, while for addition silicone (putty), the mean hardness was 468.320 with a standard deviation of 46.70. This indicates that alginate is a softer material than silicone, and the difference in hardness was statistically significant with a p-value of 0.0076 [14]. This finding supports the results of previous studies conducted by Lee et al. (2017) and Chen et al. (2015), which reported similar trends in shore hardness values for alginate and silicone impression materials [15,14]. However, these previous studies did not include condensation silicone (putty) as a comparison material. Therefore, the current study provides additional information regarding condensation silicone (putty) hardness levels of alginate and addition silicone (putty). The ANOVA results confirmed that there were significant differences in surface properties, as measured by shore hardness, among the three impression materials. This finding is consistent with the findings of a previous study conducted by Wang et al. (2017) and Kim et al. (2014), which also reported significant differences in shore hardness values among various impression materials [16,17].

CONCLUSION

With limitations, this study concluded that alginate had a lower hardness compared to addition silicone (putty), while condensation silicone (putty) fell in between alginate and addition silicone (putty) in terms of hardness. There were significant differences in surface properties among the impression materials. Results did not show significant differences in surface properties among the impression materials. Regarding dimensional accuracy, all three impression materials showed no significant differences in dimensional accuracy among different periods. Overall, the study provides valuable insights into the surface properties of dental impression materials and their dimensional accuracy.

The addition silicones have better dimensional accuracy and stability than condensation silicones and Alginate. An dental impression material should be poured as soon as possible.

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Conflicts of Interest

The authors declare no competing interests.

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تقييم الخواص السطحية لمواد طباعة البوليمر للتعويضات السنية

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المستخلص

تعتبر الخصائص السطحية لمواد طباعة البوليمر للتعويضات السنية، مثل الصلابة والخشونة والدقة، ضرورية للتكرار الدقيق للأنسجة والتركيبات الفموية في طب الأسنان الترميمية .الهدف من الدراسة هو تقييم خصائص السطح باستخدام أنواع مختلفة من مواد الطباعة البوليمرية شائعة الاستخدام في طب الأسنان وتحليل خصائص سطحها. تم استخدام خمسة وأربعين عينة من المواد، بما في ذلك الألجينات (غرواني مائي غير قابل للانعكاس)، سيليكون التكثيف (المعجون)، والسيليكون الإضافي (المعجون)، أجريت الدراسة في مجموعة البوليمرات الطبية المتقدمة في مركز أبحاث البوليمرات الليبي. لتقييم مدى فعالية الخصائص السطحية لمواد طبع البوليمر للتعويضات السنية. تم استخدام ثلاث طرق للتقييم: اختبار الصلابة، اختبار خشونة السطح، وايضا اختبار قياسات دقة الأبعاد. وشمل تحليل البيانات المتوسط والانحراف المعياري وحسابات ANOVA أحادية الاتجاه. الألجينات لديها صلابة أقل مقارنة بالسيليكون الإضافي (المعجون) وسيليكون التكثيف (المعجون). أظهر اختبار ANOVA لخشونة السطح عدم وجود فروق ذات دلالة إحصائية بين المواد، بقيمة p تبلغ 0.027. بالنسبة لصلابة، لم تكن هناك فروق ذات دلالة إحصائية بين المواد، بقيمة .0.000 p أظهر اختبار ANOVA لدقة الأبعاد عدم وجود فروق ذات دلالة إحصائية بين الفترات المختلفة للألجينات وسيليكون التكثيف (المعجون) والسيليكون الإضافي (المعجون)، مع قيم p تبلغ 0.000 على التوالي. خلصت الدراسة إلى أن الألجينات كان لديه أقل صلابة وخشونة مقارنة بسيليكون التكثيف (المعجون) وسيليكون الإضافة (المعجون). لا توجد فروق معنوية بين خواص سطح المادة (صلابة وخشونة السطح) ولكن ليس في دقة الأبعاد بين المواد. وتوفر هذه المعلومات رؤى قيمة للعاملين في طب الأسنان والاطباء الذين يعملون مع مواد الطبعات السنية.

الكلمات الدالة. خصائص السطح، مادة الطباعة، طب الأسنان الترميمي.