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RESEARCH ARTICLE – DENTISTRY (MISCELLANEOUS)

Impact of Flexible Material and Processing Techniques on the Tensile Strength of Repaired Polyamide Denture Base Material

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Abstract

Background: Polyamide denture base material is a commonly used material in dentistry for making removable dentures. However, it is prone to fracture and requires repair. The traditional repair methods involve the use of acrylic resins, which can lead to a decrease in the tensile strength of the repaired material.

Objective of study: The goal of this study is to determine the tensile strength of polyamide denture base material that has been rebuilt using flexible material and various processing processes. (manual heating, reinjection and spruing).

Materials and Methods: A total of 50 samples were produced from a total of 50 acrylic resins for this study. Group one contains the positive control consisting of 10 specimens, and negative control group, which were tested for tensile strength 10 with fracture both 20 specimens without addition fusing material. three groups of 10 specimens for each were formed from the thirty specimens that had been repaired by manual heating, reinjection and spruing these groups were treated by surface Russian treatment (evidsum fusing material) after that sample preparation, curing and finishing and polishing process. The tensile strength specimens were tested by instron machine.

Results: The findings of the present study indicated highly significant differences among means of the tensile strength for different Russia's processing techniques. The highest mean value of Tensile Strength was (23.813 ± 3.390 mpa) for C1(control without repairing), and the lowest mean value was (5.657 ± 0.715 mpa), for C2(control with repairing).

Conclusion: The use of flexible material and processing techniques has a significant impact on the tensile strength of repaired polyamide denture base material. The incorporation of flexible materials such as thermoplastic nylon can improve the flexibility and fracture resistance of the repaired denture base. Additionally, re-injection nylon repair (RiNR) processing technique promotes the adhesion and highest value of tensile strength.

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Keywords: Flexible Material; Tensile Strength; Repair; Polyamide Denture.

1. Introduction

The denture base is the component of the denture that is affixed to the teeth and lies on the foundation. Since 700 B.C. dentures have been used to cure edentulism. Among the materials utilized are wood, ivory, and bone [1]. Metal, rubber, and a variety of other materials were used to make dentures. Poly methyl methacrylate (PMMA) was introduced as a denture base material by Walter Wright in 1937, and it immediately rose to prominence as the superior material to all previous denture base materials. It gained popularity in the 1940s due to its attractive properties, ease of clinical and laboratory manipulation, and low cost [2]. Denture foundation materials with superior properties have been created. However, none of the accessible materials satisfy all of the requirements. As a result, any material that meets a high proportion of all standards is the ideal option [3]. The polyamide nylon foundation is a condensation polymer formed by the reaction of a diamine and a diacid monomer, yielding in a wide range of polyamides depending on the bonding interactions between both the acid and amine groups, they have variable physical and mechanical properties [4]. Using a lightweight denture fabrication material, such as thermoplastic nylon, has recently gained popularity. With the advancement of technology in dental prosthetics, there is a greater need to determine the optimum bonding procedures that may be used for repairing these new materials. The mxaterial's optimal functioning following such repairs is crucial [5]. When thermoplastic resins are created using the injection molding technique, accurate and precise denture bases are produced, resulting in minimal polymerization shrinkage. Creep resistance, greater fatigue resistance, and dimensional stability are some of the advantages of thermoplastic polymers over liquid and powder materials systems [6]. Nylon is a general term for a class of thermoplastic polymers known as polyamides [7]. Resins made of nylon have grown in prominence and are largely regarded as an appropriate choice of denture base materials in clinical practice. Its application is supported by an aesthetically pleasing product, greater flexibility, and sufficient tensile strength compared to traditional heat-polymerizing resins [8]. Furthermore, investigations have shown that the usage of nylon bases results in minimal or no free monomer releaser, making nylon thermoplastic resins a feasible choice for individuals who are hypersensitive to traditional metals, as well as free monomer [9]. To repair the damaged dental prosthesis, a variety of processing heat-polymerized, auto polymerized, and light-polymerized procedures, or microwave polymerized acrylic resins were utilized [10]. However, auto polymerizing resin acrylic is frequently used to repair fractured denture bases and damaged artificial teething terms of surface treatment, a Rocatec® silica-coating was used, After that, silane couplings are used to increase adhesion qualities via sandblasting [11]. Denture base surface treatment with various compounds can enhance adherence between the nylon base and repairing materials. These chemicals damage the denture foundation's surface, altering its chemical and physical properties [12]. The goal of this study was to evaluate the tensile strength of polyamide denture bases material repaired by flexible material and different processing techniques (flexible cartilage, reinjection, and sprue- material) with surface treatment by evidsum fusing material.

2. Materials and Methods

2.1. Sample grouping

Five separate groups of samples, totaling 50 acrylic samples, were used in this study:

- Group 1: 10 specimens were used as the positive control, which tested for tensile strength with fracture 10 specimens without addition fusing material.
- Group 2: 10 specimens were used as the negative control which tested for tensile strength with fracture 10 specimens without addition fusing material.
- Group 3: 10 specimens repaired by Recycled Nylon-manual heating (spruing) (RcNHR), 10 specimens with surface treatment with Russian’s evidsun fusing material.
- Group 4: 10 specimens repaired by Nylon-manual heating (NHR), 10 specimens with surface treatment with Russian’s evidsun fusing material.
- Group 5: 10 specimens repaired by Re-injection nylon (RiNR), 10 specimens with surface treatment with Russian’s evidsun fusing material.

2.2. Sample preparation

The specimens were made by cutting a hard metal disc piece under running water at an angle of 450. The dimensions of the specimens were (65 x10 x 2.5 ± 0.03) mm (length, width, and thickness, respectively) parameters needed for the flexural strength test), according to ADA Specification No.12,1975. As illustrated in Fig. 1. A separating media (Zeisol) was applied over the set stone before placing the top half of the flask on top of the bottom half, which was then filled with stone. When the stone had formed, the flasks' two parts were opened, and hard, elastic models were retrieved. After both parts were dried, a separating substance was applied to them.

Fig. 1. Dimension of specimen

2.3. Flexible polyamide specimen preparation

Three different methods were used for material of fusing (bonding agent repair liquid); the examination for tensile strength was carried out using a device and mold with dimensions (65mm x12.5mm x 2.5± 0.03mm), by placing 4 molds on each flask, using Die Stone, (made in England, type 4). When the stone has hardened, sprue wax of 4 mm and 2 mm is added, then the separating material is placed at the bottom of the flask, the upper part of the flask is placed, and the die stone material is added to it, followed by the stone, solidify the material well, open the flask with a plastic knife, use boiling water to dissolve the sprue wax, clean the flask thoroughly, closed the upper and lower parts of the flask, set the Multipress Eco at 287 ºC for 18 minutes using the flexible capsule (deutflex medium), and apply the special oil to the surface of the capsule (cartridge). When the temperature is reached, it is set in previously, and the device gives a warning that the required temperature has been reached, inject the capsule by pressing the button to release the capsule material in the flask on its device and waiting between 3 and 5 minutes according to manufactural instruction, then pressing the button to empty the flask. Open it and take out the molds.

The specimens cut them from the side of the sprue using a diskbur and brightens by carbidebur and other burs used to make flexible material (valplaste), then put molds of a valplaste in another flask and pour it with plaster material to fix the sample and cut it in the middle according to measurements (1.5 mm) from each side so that the distance between the two pieces becomes 3 mm under running water and at an angle of 45^0 according to the molding device and for every samples [13], then put sprue wax on the void area as shown in Fig. 2 and cover the upper part of the flask with plaster material, and after the material hardens well, the flask is opened by the plastic knife into two parts and washed with hot water, and all the wax on it is melted.

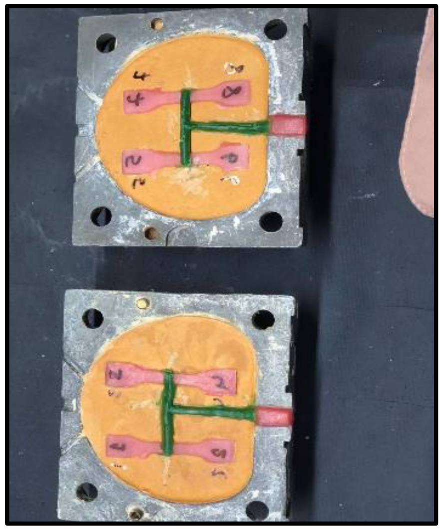

Fig. 2. Sprue wax on the void area

2.4. Repairing polyamide specimens

2.4.1. Reinjection nylon repairing procedure

A bonding agent repair liquid (fusing liquid evidsum) Russian origin which works by creating a chemical bond between the surfaces being bonded. It penetrates into the pores of the material and forms a strong bond that is resistant to water, chemicals, and other environmental factors [14] was placed into the end of halves of specimens and two parts of the flask were closed, and the injection device was set at the same predetermined temperature (287 ºC) and time, and when the required temperature was reached, small cartilage was placed and lubricated in the injection device, waiting for the specified time (18 minutes), the injection was done, and waiting for a period ranging between 3 and 5 minutes, after which the flask was opened, the samples were taken out, and they were brightens by bur designated for the valplast substance mentioned previously. Noted that there was no change in the material and their color for the all samples used for tensile strength test.

2.4.2. Recycling manual heating (spruing) repairing procedure

After pouring the samples into the flask and injecting it with polyamide (flexible), opening the vial, then cutting the sample into two halves, with a distance of (3 mm) (1.5 mm) on each side, and putting the fusing agent (Russian) and using the pre-injection cartridge, then smearing The flexible was brightening bybur and placed in the cutting area of the sample, then the area was welded and cut with a flexible material (Polyamide).

2.4.3. Manual heating nylon (flexible cartilage) repairing procedure

After pouring the samples into the flask and injecting it with polyamide (flexible), opening the vial, then cutting the sample into two halves, with a distance of (3 mm) (1.5 mm) on each side then he took a new, un-injected cartridge, opened it, and took out the material inside it (granules) after placing the Russian fusing agent and using the gun machine, dissolving the granules and placing them in the fracture area, brightening them with the bur used for the flexible material.

2.5. Finishing and polishing

The remaining acrylic was removed from each specimen using a lab engine equipped with an acrylic bur. A stone bur is used first, followed by sandpaper with a grain size of (120) that continuously refreshes the surface (immersed in cold water in rubber bowel). Pumice and a bristle brush (Vertex) were used for polishing. A gloss finish was then achieved by employing POLI-R polishing gel and the rouge wheel in a lathe polishing machine. Low-speed rotation was used by the polishing apparatus (1500 rpm). All specimens had their dimensions checked using an electronic digital caliper to make sure they were all the same size. Constant cooling was used to prevent over heating of specimen, which might lead to deformation, the specimen after polishing shown in Fig. 3 [15].

Fig. 3. Sample after polishing

2.6. Tensile bond strength test

The examination for tensile strength was carried out using a device shown in Fig. 4 Formerly, a 200 kg. (load cell using 0.5 mm/min crosshead speed and 20 mm/min chart speed) tensile bond strength test was presented. Instances were filled up till they fractured. Founded on the load (F) in (N) at fracture and the adhesive surface area (S) in (mm^2), the tensile bond strength was computed and translated to Map for samples [16].

T. S=F/S
(1)

$S= \pi /4. D^2$ (2)

where $\pi = 22/7$

D (diameter) =5 mm,

$S= 19.64\ mm^2$

T. S= Tensile strength (N/mm^2)

F=Force at failure

S= area of cross section

Fig. 4. A sample of acrylic that was placed into a tensile strength test

2.7. Statistical analysis

The SPSS program (version 20). after that determined the minimum values, the maximum values, the means, the standard deviation, and the standard error were calculated. After examination the normal distribution by using Shapiro–Wilk test, which is a specific test for normality and after checking the homogeneity by using Levene's test, which evaluates the homogeneity assumption. P-value ≤ 0.05 was reflected statistically significant. The Dunnett C method is a statistical test used for post hoc comparisons in experimental designs. It is often used when comparing several treatments to a control group. The method compares the means of each treatment group to the mean of the control group while controlling for the overall type I error rate. If there are significant differences between groups, similar letters are used to indicate which groups are statistically significant.

3. Results

The findings of the present study indicated highly significant differences (F=73.809, p-value <0.0001) among means of the tensile strength for different Russia's processing techniques: spruing (RcNHR), Nylon-manual heating repair (NHR), and Re-injection nylon repair (RiNR) and both controls; Control/ Nylon Non-repair (C1) and Control/ Nylon Repair (C2). The higher mean ± SD value of Tensile strength was (23.813 ± 3.390 mpa) for C1, and the lowest mean value was (5.657 ± 0.715 mpa) for C2. Comparisons of Post hoc The Dunnett C method was used for post hoc comparisons, and similar letters were statistically significant, the tensile strength was statistically significantly superior in C1 than C2 and all different Russia's processing techniques (RcNHR, NHR and RiNR) (p-value < 0.05), as well as it was statistically significantly higher in RcNHR than NHR (p-value < 0.05), but it was statistically not significant difference for both C2 and RiNR with NHR (p-value > 0.05) as shown in Table 1 and Fig. 5.

Table 1. Comparison of Means for Tensile Strength in different Russia's processing techniques (Recycled Nylon-manual heating repair (RcNHR), Nylon-manual heating repair (NHR), and Re-injection nylon repair (RiNR)) and both studied controls (C1 and C2) using ANOVA statistical test

Processing Techniques	No.	Mean	SD	SE	Min.	Max.	WF-Statistic	P-value	*Post-hoc* analysis ᵠ
C1	10	23.813	3.390	1.072	17.390	28.760			A B
C2	10	5.657	0.715	0.226	4.590	6.962			A
RcNHR (spruing)	10	7.233	1.149	0.363	5.570	9.360	73.809	<0.0001 (HS)	A B
NHR (Manual heating)	10	6.112	1.070	0.338	4.680	7.750			B
RiNR (reinjection)	10	12.570	2.882	0.911	8.470	16.860			A

Tensile strength of tested samples after various Russia processing procedures are shown in a bar chart Fig. 5.

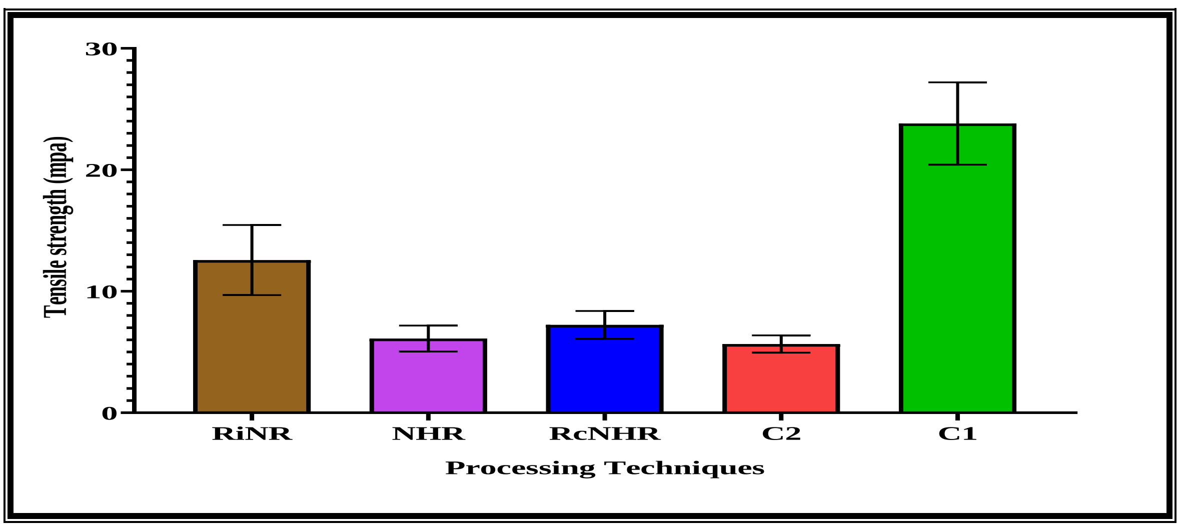

Fig. 5. Bar chart showing the tensile strength of tested samples after different Russia's processing techniques.

4. Discussion

A replacement denture is a costly and time-consuming procedure. As a result, whether as an intermediate or final treatment, mending a denture is a typical management method [17]. The objective is to return the denture's original strength while avoiding potential fracture propagation. Nonetheless, fracture of restored samples occurs commonly rather than in the repair center, at the contact point of the original foundation and restoration materials, where the load is focused [18]. methyl methacrylate is a reliable and effective material for repairing broken denture base surfaces [19]. However, for surface treatment, Acetone, methylene chloride, and chloroform are examples of organic solvents. are examples of organic solvents. have been used. Surface treatment methods, such as chemical and physical treatment have been shown to improve the strength of the link between both the denture base and the repair resin. Air blasted, in which accelerating alumina particles with a silica coating collide. The interaction with the surface causes tiny melt on the treated surface. This method permits the silica-coated alumina particles to permeate the surface and produce an adhesive connection [13]. The adhesive bond's initial strength is acceptable; however, the procedure for aging has showed poor results [20]. Bonding with a Solvent is an excellent approach to attach thermosetting acrylic resins. Polyamides are usually durable and strong as subjected to chemical assaults. A solvent containing amide groups ($^{-}$NHCO^{-}), on the other hand, causes polyamide to absorb water and create hydrogen bonds. Polar molecule traces in solvents produce polyamide matrix plasticization. This plasticization effect can lead to changes in the mechanical properties of the polyamide, such as increased flexibility and decreased strength. The extent of plasticization depends on the concentration of amide groups in the solvent and the temperature of the system. In general, higher concentrations and temperatures lead to greater plasticization. This property of polyamide can be useful in applications where flexibility is desired, such as in textiles or flexible packaging materials [21].

Changes in the strength and number of main (covalent) bonds between the atoms and second (hydrogen) linkages with nearby chains, as well as the lack of a cross-linking with the nylon structure, could explain the breaking [22].

Furthermore, the lower binding strength measurements when contrasted to the standard denture base may be due to variations in the polymerization process, namely condensation polymerization in the nylon base vs. addition polymerization in the restore materials [23]. Nylon particles, the opposite hand, are more densely packed (with fewer intermolecular gaps) and have lower water diffusion in which the polymeric chains do not include side groups. This results agrees with Defonseka [24] who mentioned that when compared to amorphous acrylic resin, Nylon is a chemically resistant material. (low solvent solubility) because of its great degree of crystallinity, it is resistant to heat. The results of the present investigation demonstrated that chemical surface treatments and techniques of repair might enhance the adhesion properties of the nylon denture base polymer for heat.

The current study discovered highly significant differences in tensile strength for various Russian processing techniques, including spuring (RcNHR), Nylon-manual heating repair (NHR), and Re-injection nylon repair (RiNR), as well as both controls, Control/ Nylon Non-repair (C1) and Control/ Nylon Repair (C2) (C2). C1 had a higher mean SD value for tensile strength and a lower mean value for C2 this results agree with Wahyun, et al. 2020 [25] found that significantly results were discovered, and a tensile strength test that demonstrated an impact of blending 60% nylon with 40% recycled nylon on the strength of thermoplastic nylon denture bases. Tensile strength was statistically considerably higher in C1 than C2 and in all different Russia's processing techniques (RcNHR, NHR, and RiNR), as well as in RcNHR than NHR. This finding agrees with Kümbülolu et al. 2019 [26].who found that The repair material improved the tensile strength investigations (P 0.05), however treatment V or G had no effect on POL-relining resin adhesion. There are several reasons why Russia's processing techniques, including spruing (RcNHR), Nylon-manual heating repair (NHR), and Re-injection nylon repair (RiNR), may have resulted in lower tensile strength compared to the control group [27]. Firstly, it is important to note that these techniques involve repairing or modifying nylon materials, which can be a challenging process. Nylon is a thermoplastic material that can be difficult to work with due to its high melting point and tendency to warp or shrink during processing. As a result, any errors or inconsistencies in the processing techniques used could lead to weaker materials with lower tensile strength. Another factor that may have contributed to the lower tensile strength of the processed materials is the use of different materials or additives during the repair process. For example, some of these techniques may involve adding additional layers of nylon or other materials to reinforce weak areas or fill in gaps. However, if these additional layers are not properly bonded or integrated into the original material, they may create weak points that reduce overall tensile strength [28].

Finally, it is possible that variations in processing conditions, such as temperature, pressure, and cooling rates could also impact the final tensile strength of the repaired materials. Even small changes in these parameters could affect how well the material bonds together and how evenly it cools and solidifies [29]. Overall, while Russia's processing techniques may offer some benefits for repairing damaged nylon materials, it is important to carefully consider their potential impact on tensile strength and other mechanical properties before using them in critical applications.

5. Conclusion

The use of flexible material and processing techniques has a significant impact on the tensile strength of repaired polyamide denture base material. The incorporation of flexible materials such as thermoplastic nylon can improve the flexibility and fracture resistance of the repaired denture base. Additionally, Re-injection nylon repair (RiNR) processing technique promotes the adhesion and highest value of tensile strength. These advancements in materials and techniques have led to improved clinical outcomes for patients with repaired polyamide dentures.

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Nomenclature & Symbols			
RcNHR	Recycling Nylon-Manual Heating Repair	SPSS	Statistical Package for the Social Sciences
NHR	Nylon-Manual Heating Repair	ANOVA	Analysis of Variance
RiNR	Re-Injection Nylon Repair	SD	Standard Deviation

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