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Assessment the retentive force and XRD analysis on the recycling esthetic thermoplastic acetal clasps

Avaliação da força de retenção e análise de DRX dos grampos de resina estética termoplástica acetal reciclada

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ABSTRACT

Objective: To reduce environmental biohazards, technicians should be educated with safe biological waste disposal procedures and dental material recycling. The present study assesses the retentive force, deformation test and XRD analysis of re-injection acetal resin clasps. **Material and Methods**: specimens were prepared for clasp retention test injection according to the manufacture's instruction for acetal resin. The first group represent control group with (100% New) and other five groups as experimental groups (group II (25% old +75% new), group III (50% old + 50%) new, and group IV (75% old + 25% new) with different percentages between new acetal materials and old acetal materials, while two last groups with several times (group V (100% old) and group VI (re-injection two times)) only used old acetal materials. The X-ray diffraction (XRD) device used to give structural information for the materials to be tested. The study data were analyzed via One-way ANOVA (LSD) at a significant P-value of ($p \leq 0.05$) and a confidence level of 95%. **Results**: After comparing the results, a significant improvement in the retentive force of acetal clasp specimens after re-injection two times there was found high mean value in group re-injection two times and lower mean value recorded in control group. In XRD patterns of there was no diffraction peak refers to crystal structure of acetal resin. **Conclusion**: the present study findings concluded that the recycling of acetal resin enhanced the retentive force of acetal clasp and not affected on the crystal structures of material.

KEYWORDS

Acetal clasp; Esthetic clasp; Recycling; Retentive force; XRD.

RESUMO

Objetivo: Para reduzir os riscos biológicos ambientais, os técnicos devem ser educados com procedimentos seguros de eliminação de resíduos biológicos e reciclagem de material dentário. O presente estudo avalia a força de retenção, teste de deformação e análise de DRX de grampos de resina acetal reinjetada. **Material e Métodos:** as amostras foram preparadas para o teste de retenção dos grampos e a injeção realizada de acordo com as instruções do fabricante para resina de acetal. O primeiro grupo representa o grupo controle com (100% novo) e os outros cinco grupos como grupos experimentais (grupo II (25% antigo + 75% novo), grupo III (50% antigo + 50% novo) e grupo IV (75% antigo + 25% novo) com porcentagens diferentes entre materiais de acetal novos e antigos, enquanto os dois últimos grupos (grupo V (100% antigo) e grupo VI (reinjeção duas vezes)) utilizaram apenas materiais de acetal antigos. O dispositivo de difração de raios X (DRX) foi utilizado para fornecer informações estruturais dos materiais a testados. Os dados do estudo foram analisados por ANOVA um fator (LSD) com um valor P significativo de ($p \leq 0,05$) e um nível de confiança de 95%. **Resultados**: Após a comparação dos resultados, foi encontrada uma melhora significativa na força de retenção das amostras de grampo de acetal após duas reinjeções, além disso, foi registrado um maior valor médio no grupo reinjeção duas vezes e menor valor médio no grupo controle. Nos padrões de DRX não houve pico de difração referente à estrutura cristalina da resina acetal. **Conclusão:** os resultados do presente estudo concluíram que a reciclagem da resina de acetal aumentou a força retentiva do grampo e não afetou as estruturas cristalinas do material.

PALAVRAS-CHAVE

Grampo de acetal; Grampo estético; Reciclagem; Força de retenção; DRX.

INTRODUCTION

The difficulty in the current world is in reducing, reusing, and recycling various resources. Reusing is a phrase used to refer to reusing the materials that can be reused and minimizing material waste, whilst reducing is used to refer to reducing the amount of the earth's resources and utilization should only be when necessary. Since recycling is the second source of oxygen for modern life, attempt to recycle all resource you can to maintain a cleaner, greener world [1]. In order to fulfill both patient aesthetic needs and the requirement for denture retention, a material known as flexible thermoplastic resin was introduced into dentistry [2]. When it comes to replacing missing teeth with the finest possible aesthetics, removable partial dentures (RPDs) are seen to be the best and most practical option. The display of the clasp assemblies was one of the main issues with RPDs. One of the numerous more modern methods used to address this issue involves etching the retainer's arm and covering it with a tooth-colored resin finish. The mechanical qualities of these aesthetic retainers also play a significant part in their success and intraoral use, despite the fact that their outward look is of fundamental importance [3].

Early in the 1990s, acetal resin, along with tooth-colored clasps, was employed to create a complete partial denture framework in dentistry. Formaldehyde is polymerized to create acetal resins. A chain of alternating methyl groups connected by an oxygen molecule makes up the homopolymer poly(oxyethylene) (POM) [4]. The lack of aesthetic appeal of cobalt chromium (CoCr) clasps drives the hunt for thermoplastic resin clasps to solve this issue. In light of this, Polyoxymethylene (POM) has been employed in the creation of RPD retaining and supporting components [5]. The flexibility of the thermoplastic acetal clasp would enable the retainer to be positioned in deeper occlusal rests on the abutment teeth [6]. The surface of the tooth is not scratched by acetal resin clasps, which maintain retention. Acetal resin clasps are attractive and are offered in 16 distinct hues. Using a stereomicroscope for a qualitative investigation, it was discovered that the use of cast Co-Cr and acetal resin clasps caused enamel to develop linear scratches and grooves. The enamel only received minor scratches when an acetal resin clasp was used. Optical profilometry produced statistically significant findings with the Co-Cr clasp. Acetal resin clasps had negligible impact. The retentive force of the cast Co-Cr clasp dropped from 12.4 N to 8.1 N. The acetal resin clasp's retentive force decreased from 5.2 N to 4.03 N at the conclusion of the trial [7]. The molecular and atomic structure of a crystal can be determined using a technique called X-ray diffraction analysis (XRD), in which the crystalline atoms cause an X-ray beam to diffract in a number of distinct directions. The density of the electrons inside the crystal can be visualized in three dimensions by estimating the intensities and angles of these diffracted beams. The average atom locations in the crystal can be calculated from this electron density [8].

The goal of this study was to assess the retentive force and XRD of re-injection acetal resin as esthetic clasp in different percentages or several times.

The null hypothesis stated that the tested characteristics will not be changed by recycling acetal resin as an aesthetic clasp in different percentages or several times.

MATERIAL AND METHODS

Sixty clasp specimens for retentive force test were divided to six groups as Group I: Control group (Group I) with 100% New acetal material, Group II:25% New acetal material + 75% Old acetal material, Group III: 50% New acetal material + 50% Old acetal material, Group IV: 75% New acetal material + 25% Old acetal material, Group V: 100% Old acetal material and Group VI: re-injection for two-time acetal material.

Preparation the percentages for clasp retention test groups

Each flask contains three specimens to ensure the exact percentages for each group and each flask, the weight of the empty capsule is 3 g, according to the pilot study. In this study, it was found that every 12 g of acetal is sufficient to inject a flask containing three samples of acetal. The old material is preparation by acetal sprue is collected and cutting by cutter and re-injection with new acetal resin.

Preparation the study tooth model

A study tooth model was constructed to represent an ideal RPD situation with a standardized undercut. The occlusal rest measurements of a case study model of a zirconia first upper molar in size 34 were the same as those utilized for the Co-Cr clasp. This was a spoon-shaped design with a 1 mm thickness, 3 mm width, and a right angle to the minor connector on the proximal surface, as shown in Figure 1.

Block acrylic resin and clasp design preparation

In rectangular acrylic blocks, tooth was inserted vertically up to the level of the cement-enamel connection. They were created using a wax pattern and the test machine's specifications (30 mm 14 mm 25 mm). Molding processes for the heat-cured PMMA (vertex, Germany) were the same as those used in traditional dentistry laboratories for the compression method of water-bath curing. A 3-D scanner (Swing 3-D dental scanner) (Medit extraoral scanner, Corea) as shown in Figure 2. Software designer program was used to scan the research model. The system depth scale was used to digitally measure the undercut amount as shown in Figure 3. The study tooth model was exported into stereolithography (Stl) file form after surveying so that it could be retrieved and used to construct the acetal clasps [9] .Undercut of 0.25 mm depth was determine with software designer program [10]. According to the most typical traditional design pattern, the clasp was created. Software was used to organize the clasps' design into the disc space. The machine then used wax blank discs to grind these digital patterns into 3D wax clasps. Number of software processing program were used to complete this step [11].

Figure 1 - Preparing the study tooth model design using exocad software.

Clasp injection

Hard dental die stone molding compound (Type IV, Zhermack, Italian) was prepared following the manufacturer's instructions (W/P: 20 ml / 100 g) and used to mold the wax designs. The wax clasp was individually invested utilizing a cylindrical mass of investment material to prevent any undercuts that would influence the final clasp design during the flasking technique. The wax was removed with a wax extraction equipment after flasking and embedding the wax patterns. After that, a hot water and detergent solution was used to clean the mold cavity. A layer of acceptable separating material (Vertex, Germany) for thermo-pressing purposes was then put to the surface of the mold after it had dried for 30 seconds. The mold was then left to dry about 12 hours [11].

The acetal resin (Evidsun, Russian) sample was made according to the manufacturer's instructions. Acetal resin that had been heated and softened was injected into the mold, and it was cured at 220°C for 20 minutes at an injection pressure of 7-8 bar. The samples were deflasked, polished with thermal resin finishing burs after drying, and then polished to a high shine with a swans down mop as shown in Figure 4 [12] .

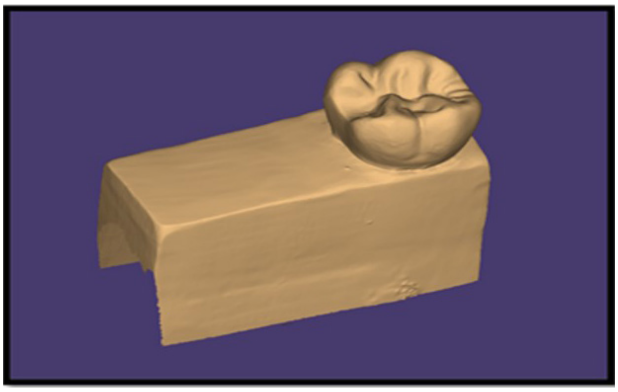

Figure 2 - Scan the studied model by dental scanner after complete the process.

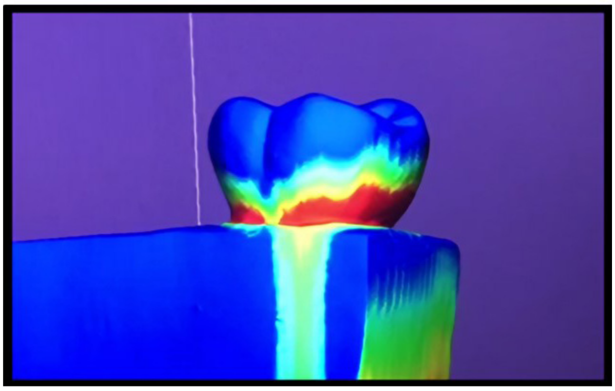

Figure 3 - Digital surveying and measuring the undercut area by using software program.

Clasps retentive force testing

Specimens were fixed to a universal testing device (BOTO, China). Utilizing the cylindrical pin connected (Figure 5), three withdrawal forces were applied to each clasp. The retentive force of this clasp was calculated as the average of the three measurements. Retentive forces were measured in Newton (N) and the specimens were examined at room temperature with a crosshead speed of 0.5 mm/minute. Using a particular attachment in the device, the clasps were fixed to the upper portion of the testing machine, and the acrylic block was fixed to the lower portion. Both of these approaches provided a straight path while cycling and may have reduced or eliminated any torquing possibilities, which may have favorably influenced the results of the experiment. Torquing too much could harm the results of clasps [9].

For clasp deformation, Before and after applying force, the software micrometer was used to measure the distance between the tips of the clasps' reciprocal and retentive arms using digital reference points as illustrated in Figure 6 [9].

X-ray diffraction analysis

The X-ray diffraction (XRD) device (PANalytical, AERIS) used to give structural information for the materials to be tested. It was done on six specimens. One specimen from each six groups.

RESULTS

Retentive force test

The mean of retentive force value and standard deviation for each group are listed in Table I. The smallest retention force values (17.3329±1.632948 N) were found in control group while, the largest values (20.9997±2.419075 N) were in the re-injection two times group. Statistically there is significant difference between the groups are reveal by applying the (ANOVA) test.

The LSD test between groups of retentive force test showed significant difference between control group and all experimental groups except the group IV that show non-significant ($p > 0.05$), and highly significant difference between control group and group re-injection two time ($p < 0.001$) (Table II).

Clasp deformation test

A single group's means for two variables are compared using the Paired-Samples T Test technique. After applying the force, Table III demonstrated a statistically significant (p value 0.05) increase in the separation (mm) between the retentive and reciprocal arms.

X-Ray Diffraction (XRD) analysis

XRD showed the peaks of the specimens of all groups. In XRD patterns of there was no

Figure 5 - Testing procedure of acetal clasp specimen after mounted on a universal testing machine.

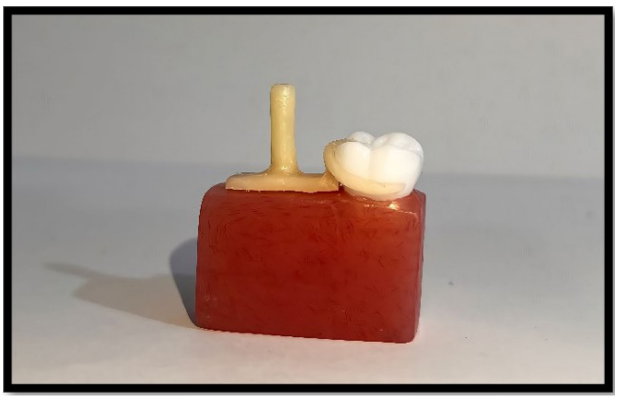

Figure 4 - Acetal clasp specimen after polishing and finishing on the study tooth mold.

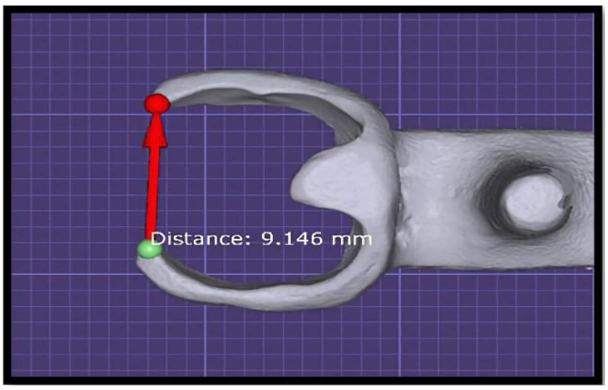

Figure 6 - Aker clasp deformation determined by utilizing a software micrometer to measure the distance between the points of the reciprocating and retentive arms.

Table I - Mean values, standard deviation, standard error, and 95% confidence interval of mean parameters concerning mean values of the retentive force (N) test for the studied group's readings and the two extreme values (min. and max.)

	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	ANOVA test p-value
				Lower Bound	Upper Bound			
Group I (Control)	17.33	1.63	.51	16.16	18.50	15.33	19.33	P=0.001 Sig. P<0.05
Group II (25% Old + 75% New)	19.06	1.91	.61	17.69	20.44	16.00	22.00	
Group III (50% Old + 50% New)	19.07	1.41	.45	18.06	20.08	16.67	21.33	
Group IV (75% Old + 25% New)	18.59	1.76	.56	17.34	19.86	16.67	22.00	
Group V (100% Old)	20.27	2.04	.65	18.81	21.72	17.33	23.33	
Group VI (Re-injection two time)	20.99	2.42	.77	19.27	22.73	18.00	24.67	

Table II - The LSD test between groups of retentive force test mean difference(I-J), standard error and p-value reading of all study groups

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	P-value
Group I (Control)	**Group II (25% Old + 75% New)**	-1.73*	.85	.045
	Group III (50% Old + 50% New)	-1.73*	.85	.045
	Group IV (75% Old + 25% New)	-1.27	.85	.140
	Group V (100% Old)	-2.93*	.85	.001
	Group VI (Re-injection)	-3.67*	.85	.00
Group II (25% Old + 75% New)	**Group III (50% Old + 50% New)**	.00	.85	1.00
	Group IV (75% Old + 25% New)	.47	.85	.58
	Group V (100% Old)	-1.20	.85	.16
	Group VI (Re-injection)	-1.93*	.85	.026
Group III (50% Old + 50% New)	**Group IV (75% Old + 25% New)**	.467	.85	.58
	Group V (100% Old)	-1.20	.85	.16
	Group VI (Re-injection)	-1.93*	.85	.026
Group IV (75% Old + 25% New0	**Group V (100% Old)**	-1.67	.85	.05
	Group VI (Re-injection)	-2.40*	.85	.006
Group V (100% Old)	**Group VI (Re-injection)**	-.733	.84	.39

*The mean difference is significant at the 0.05 level.

Table III - Paired sample T test to compare between groups for clasp deformation test

Groups	Applied Force		T test (P value)
	Before	After	
Group I (Control)	8.017	8.490	2.839 (0.0422^{S})
Group II (25% Old + 75% New)	8.871	9.518	3.992 (0.0023^{HS})
Group III (50% Old + 50% New)	8.784	9.324	2.729 (0.0428^{S})
Group IV (75% Old + 25% New)	8.193	9.002	3.319 (0.0013^{HS})
Group V (100% Old)	8.872	9.376	2.404 (0.0342^{S})
Group VI (Re-injection two time)	8.683	9.146	3.239 (0.0392^{S})

S: Significant difference (p value < 0.05), HS: High significant difference (p value < 0.01).

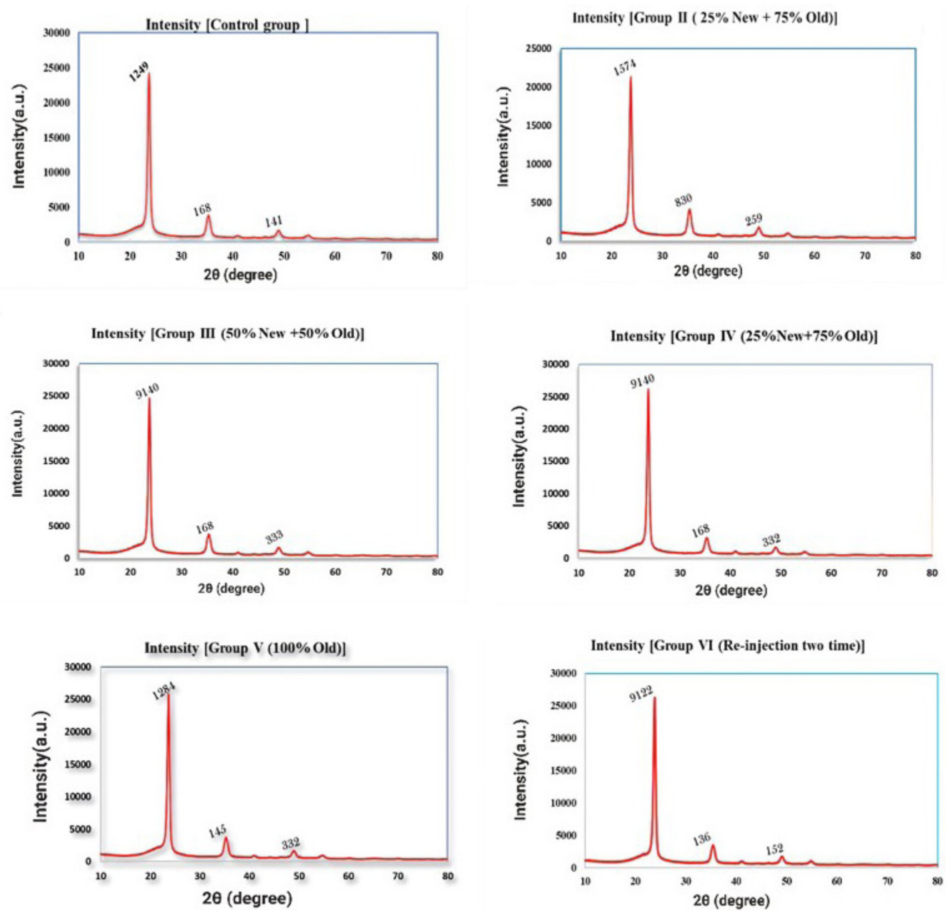

Figure 7 - XRD patterns of all study groups represent the Pos. [°2θ] with horizontal axis and intensity with vertical axis with three peaks of Crystallite Size only [Å].

diffraction peak refers to crystal structure of acetal resin as show in Figure 7.

DISCUSSION

Any dental material's initial mechanical characteristics can be used to predict the main cause of clinical failure and make a choice for a particular application. To enhance the mechanical qualities, new materials for load-bearing areas have recently been proposed. There is not any previous work on the subject because both the material employed in this study and the concept of research for re-injection of the substance are new. As a result, we lacked citations for previous research. Compared to new acetal resin claps, the Aker clasp design, manufactured from re-injected acetal resin material, showed a significantly stronger retention force, according to the data collected during this study. This investigation's goal was to contrast the retentive forces of six different acetal clasp groups. According to Davenport, the clasp's flexibility is influenced by its thickness, section, length and material, and a more flexible clasp offers less retention [10]. In the present study the retention force of re-injection two times clasp shows the higher retentive force that's due to more the acetal material is exposed to heat and injection for several times, the flexibility decreases. Clinically adequate retention for thermoplastic clasps may be achieved at dimensions that are different from Co-Cr clasp; a clasp with increase in thickness may be necessary in order to engage a deep undercut area [13]. Since thermoplastic material is less stiff than metals and alloys, this might be required. It also lessens the chance of traumatic overloading [14, 15].

The distance between two clasp tips (deformation) increased significantly in acetal clasps between the control and experimental groups. This is according to previous studies [9, 16], They found that acetal clasps with greater flexibility deformed more than those with greater stiffness. Co-Cr clasps upon aging and wear. Consequently, the clasps' retentive forces gradually diminish as they undergo plastic deformation, and breaking could happen while using them [11].

CONCLUSION

This study's limitations show that the new acetal clasps with a 0.25mm undercut had the lowest initially retentive force and the maximum initial retentive force were observed in the two-time re-injection acetal clasps. On the other hand, the re-injection of acetal material and reuse had no effect on the crystalline structure whereas the acetal clasps showed a modest increase in the distance between the tips of the clasps after re-injection.

Author's Contributions

RMZ: Methodology, Writing – Original Draft Preparation. NSM: Supervision.

Conflict of Interest

We have no conflicts of interest to disclose regarding this article. The opinions expressed are solely those of the authors and have not been influenced by any financial or personal relationships.

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Regulatory Statement

This article did not involve the use of any hazardous materials, living organisms, or any procedures that could harm the environment. There was no need to comply with any specific regulatory laws or regulations regarding occupational health and safety or the environment. All necessary measures were taken to ensure compliance with ethical research practices and laboratory safety.

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