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Flexural and Tensile Strength of Acrylic Resin Denture Base Materials Processed by Three Different Methods.

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ABSTRACT

This contemplate was conducted to both evaluate and compare the flexural and tensile fatigue strength of denture base resins polymerized by the conventional heat cured, microwave, and thermo-press acrylic resin denture base materials. A total number of 60 specimens were fabricated; 20 for each group. In each group 10 specimens were ready to test flexural strength, and 10 for calibrating the tensile strength. The Flexural strength of the microwave-cured resin had the highest flexural strength with a mean value of 1.9400MPa, followed by heat-cured acrylic resin, with a mean value of 1.8390MPa and the lowest value was 1.3800MPa for the injection mold technique. For tensile strength the highest value was for the microwave cured acrylic resin with mean value of 1.94Mpa, followed by injection mold thermo-press curing with mean value 1.322Mpa, and the lowest value was 1.126Mpa for the heat-cured acrylic resin. Thermoplastic resin materials have superior properties, features and provide prime esthetic and biocompatible treatment options.
Keywords: Acrylic resin, Microwaved cured, Thermo-press, Flexural and Tensile strength.

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INTRODUCTION

Acrylic resin polymers have been introduced as denture base materials and the majority of denture bases are fabricated employing poly methyl methacrylate (PMMA). These materials have optimal physical properties and prime esthetics with relatively minimal toxicity compared to other plastic denture bases [1]. Compression molding with heat activation in a water bath for resin polymerization is the conventional method to process dentures [2]. However, shrinkage and dimensional change of denture bases during resin polymerization is unavoidable and has been well documented [1]. Mechanical behavior of the denture base, including flexural strength, depends on the type of the material and even on processing techniques [3].

Therefore, acrylic resins and processing methods have been modified to ameliorate both physical and chemical properties of denture bases. The introduction of injection-molding technique and Microwaved cured acrylic resin to overcome the adverse effects of conventional heat cured acrylic resin [3,4].

In spite of the merits provided by heat-cured acrylic resin like the ease, simplicity and cost-effectiveness, a major demerit is the long processing time required. The microwave polymerization technique produced denture bases with comparable physical and mechanical properties minimal porosity and superior dimensional accuracy when compared to the conventional heat cured once [4,5].

Polyoxymethylene, also known as Acetal resin, has been utilized as an alternative denture base and clasp material since 1986 and was promoted, primarily, for superior esthetics [6]. Acetal resins are formed by the polymerization of formaldehyde [7]. The homopolymer is a chain of alternating methyl groups linked by an oxygen molecule [7]. Due to its biocompatibility, it was considered as a RPD (removable partial denture) framework material for subjects with allergic reactions to Co-Cr (Cobalt chromium) alloys [6]. It has been reported for having a sufficiently lofty resilience and modulus of elasticity to promote utilizing it in the manufacture of retentive clasps, connectors, and support elements for RPDs [6,7].

The most clinically remarkable cause for denture fracture is fatigue under masticatory loads due to the repetitive flexing of the denture bases [8]. Kelly accounted many factors for influencing flexural fatigue strength such as; frenum notches, surface irregularities, and foreign body inclusions [9]. Both porosities and residual monomer content have been proved as important factors influencing the flexural fatigue strength. The processing technique utilized to polymerize the denture base resin has been found to be an important factor, which can induce stress into the denture base during processing and finally lead to fatigue failure.

Abundant properties, [10-12] such as impact strength, transverse strength, porosity, residual monomer content, and dimensional accuracy have been evaluated extensively, very few studies have reported ponder of the flexural fatigue strength [13] of denture base resins. Furthermore, flexural fatigue strength of denture base resins polymerized by both microwave and injection mold techniques have not been evaluated. Therefore, it was essential to evaluate and compare the flexural and tensile fatigue strength of denture base resins polymerized by the conventional heat cured, microwave, and thermo-press acrylic resin denture base materials.

MATERIALS AND METHODS

A total number of 60 specimens were fabricated for this consideration; 20 for each bundle. In each party 10 specimens were fabricated to test flexural strength, and 10 for the tensile strength.

Table 1: The factorial design of this study.

Test	Conventional heat cured acrylic resin	Thermoplastic cures acrylic resin	Microwave cured acrylic resin	Total number
Flexural strength	10	10	10	30
Tensile strength	10	10	10	30
Total	20	20	20	60

The specimens were constructed according to ADA specification NO.12, and Astem D256, (1985, 1988), and BS specification NO. 2482. The Rectangular shaped metal pattern of (65mm. X 10mm. X 2.5mm.) in length, width, and thickness respectively was constructed to test flexural strength. While the Dumbbell-shaped metal pattern of (65mm. X 12.5mm. X 2.5mm.) in length, width, thickness respectively was constructed to test the tensile strength.

The resins were mixed according to the manufacturer's instructions for each type. Polymerization of the specimens was carried out utilizing a standard processing cycle. The specimens were rinsed and stored in sterile distilled water for 24 hours before use. All tests were performed at National Research Center.

Table 2: The materials used, their trade name and manufacturer

Trade name	Description	Manufacture
Acrostone	**Conventional heat cured acrylic resin**	**Acrostone dental factory - industrial zone -Salam city A.R.E- WHW Plastic England**
Eco-cryl M	**Specially designed microwave cured acrylic resin**	**Eco-Cryl M, Protechno, Spain.Polígono Empordà Internacional17469 VILAMALLA, GIRONA , SPAIN ISO 1567 type:5**
Thermo-press	**Injection molded conventional thermoplastic acrylic resin**	**Thermopress 400, Bredent-From Gmbh & Co.KG, Germany.**

Flexural strength

The prepared specimens of 65mm length, 10mm width and 3 mm thickness were tested under static loading using universal testing machine (Universal testing machine, Model LRX plus, Lloyd, Ametec instruments. Fareham, England.).

The specimens were positioned in three point bending apparatus with 7.5 KN full scale load and each specimen was subjected to progressive load. Each specimen was placed on two parallel stainless steel rods located 50 mm apart. A central load was applied through a cylindrical stainless steel rod of 10 mm in diameter at a crosshead speed of 5 mm/min. The load was applied allowing specimens deflection until fracture occurred.

The maximum force [N] upon fracture was recorded. The values of the flexural strength were calculated by the formula:

$$S=3PL/2bd^2$$

S = Flexural strength (N/mm2).
P = Maximum force exerted on specimen (N).
L = Distance between jig supports (mm).
b = Specimen width (mm).
d = Specimen thickness (mm).

Tensile strength

Dumbbell- shaped acrylic resin specimens of (65mm X 12.5mm X 2.5mm) length, width and thickness respectively were used using universal testing machine (maximum load 2000 kg, maximum speed 25-500 cycle/ minute and accuracy 0.03%) which equipped with grips suitable for holding the test specimen.

Set at cross head speed of 0.5mm/min with a chart speed 20 mm/minute. A tensile load cell measured loads with a maximum capacity (100kg). The recorded force at failure was measured (kg) which were converted into (N). The values of tensile strength were calculated by the following formula:

$$T.S=F/A$$

T.S. = Tensile strength (N/mm2).
F = Tensile force at failure (N).
A = Area of cross section at failure (mm).

RESULTS

This contemplate was classified as case-control study and was performed to evaluate the strength properties of different denture base materials (Heat cured acrylic resin, Thermo-press and Microwave cured acrylic resin).

Data were logarithmically transformed for better visualization and assessing further comparisons and testing of significance.

Flexural Strength

Table (3) demonstrated a descriptive consideration of the flexural and Tensile strength measurements between the different denture base materials plotted as means and standard deviations.

Table 3: Descriptive study of the log $_{10}$ of measurements between different denture base materials:

Log $_{10}$		N	M	SD
Flexural	Heat	10	1.8390	.02183
	Thermo	10	1.3800	.05653
	Microwave	10	1.9400	.05657

N; Number M; Mean SD; Standard deviation

Table (4) and figure (1) revealed utilizing one-way ANOVA test as there was a remarkable difference between the measurements of the three different denture base materials, as (P-value < 0.05).

Table (4): Comparative study of the flexural strength measurements between different denture base materials:

		df	F	P-value
Flexural	Between Groups	2	385.912	.00**
	Within Groups	27		
	Total	29		

df; Degree of Freedom F; variable
P; Probability Level
****Highly significant difference**

While table (5) showed that by using Tukey`s post hoc test for multiple comparisons of measurements change between each pair of different denture base materials, there was significant difference between each both types as (P-value <0.05).

Table 5: Multiple comparisons between the three groups regarding flexural strength measurements:

		Tukey`s Rank
Flexural	Heat	A
	Thermo	B
	Microwave	C

Different letters in Tukey`s rank demonstrated significant difference

Tensile Strength

Table (6) demonstrated a descriptive consideration of the tensile strength measurements between the different denture base materials plotted as means and standard deviations.

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Table 6: Descriptive study of the log $_{10}$ of measurements between different denture base materials

Log $_{10}$		N	M	SD
Tensile	Heat	10	1.126	.05985
	Thermo	10	1.322	.05051
	Microwave	10	1.94	.09967

N; Number M; Mean SD; Standard deviation

Table (7) and figure (2) revealed using one-way ANOVA test as there was a remarkable difference between the measurements of the three different denture base materials, as (P-value < 0.05).

Table 7: Comparative study of the tensile strength measurements between different denture base materials:

		df	F	P-value
Flexural	Between Groups	2	183.652	.00**
	Within Groups	27		
	Total	29		

df; Degree of Freedom F: variable
P: Probability Level
****Highly significant difference**

While table (8) showed that by using Tukey`s post hoc test for multiple comparisons of measurements change between each pair of different denture base materials, there was significant difference between each both types as (P-value <0.05).

Table (8): Multiple comparisons between the three groups regarding tensile strength measurements

		Tukey`s Rank
Tensile	Heat	A
	Thermo	B
	Microwave	C

Different letters in Tukey`s rank demonstrated significant difference

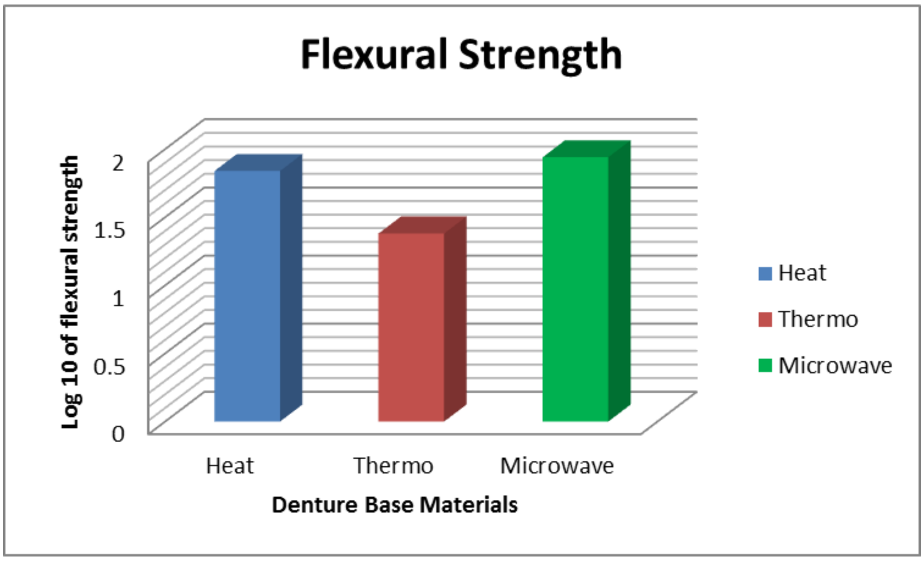

Figure 1: Comparative studies of the flexural strength measurements between different denture base materials.

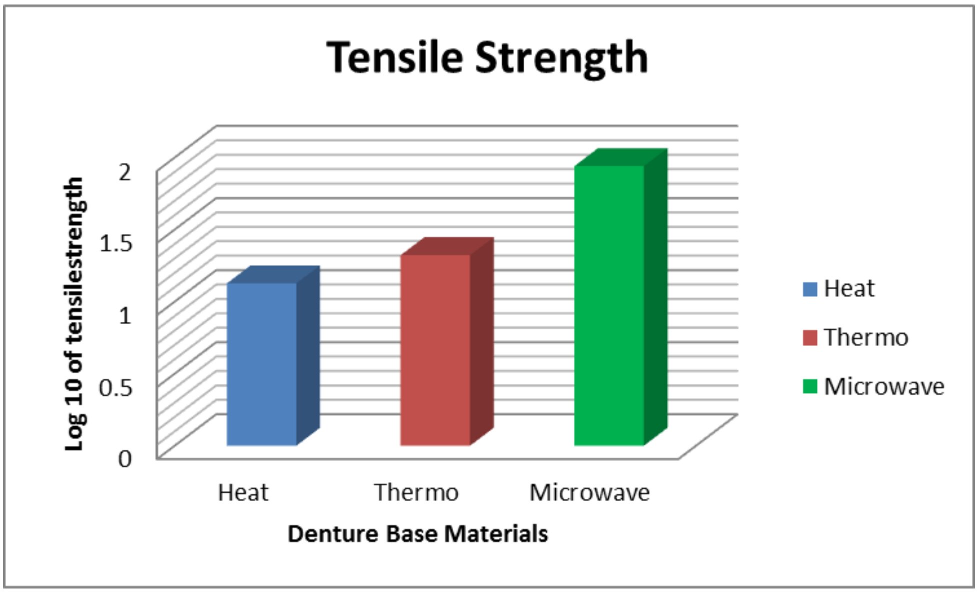

Figure 2: Comparative studies of the tensile strength measurements between different denture base materials.

DISCUSSION

As all in vitro considerations, the present research has limitations. Although this work compared different methods of polymerization, one of the limitations of this contemplate is the employing of resins of different commercial brands and compositions. However, the methods can be utilized safely for comparisons, once it agrees with the studies cited previously [14,15].

During the last few years, curing processes have been modified in order to enhance both the physical and mechanical properties of the materials. This ponder assessed the flexural and tensile strength of water bath, microwaved, and injection mold curing methods. It was found in test groups that microwave-cured resin had the highest flexural strength with a mean value of 1.9400MPa, followed by heat-cured acrylic resin, with a mean value of 1.8390MPa and the lowest value was 1.3800MPa for the injection mold technique.

For tensile strength the lofty value was for the microwave cured acrylic resin with mean value of 1.94Mpa, followed by the injection mold thermo-press curing with mean value 1.322Mpa, and the lowest value was 1.126Mpa for the heat-cured acrylic resin.

The water-bath processing technique has been the most widely used due to its ease of handling and cost effectiveness, but the residual monomer content [16] and porosities produced have been suggested as the most significant reasons for the declined flexural fatigue strength [17] This has been accounted to the unfavorable thermal gradient produced during the processing technique [18]. The residual monomer content and porosities in denture base resins might be the reasons behind such a drop.

The evaporation of the residual monomer leaves porosities in the denture base resin and these imperfections lead to formation of stress and cause propagation of cracks within the acrylic which makes the denture base prone to fatigue failure [19]. Thus, residual monomer content can be directly related to the flexural fatigue strength of acrylic resins.

In Microwaved cured technique electromagnetic waves produced in the microwave oven are used to generate heat inside the resin. During the polymerization, the methyl methacrylate molecules orient themselves in the electromagnetic field of the microwave and their direction changes nearly 5 billion times in a second. The numerous collisions that occur cause rapid heating, and therefore, a less time-consuming procedure is required. As the heat required to break the benzoyl peroxide molecules into free radicals is created inside the resin, the temperature outside the flask remains cool. As a consequence of this rapid reaction, the polymerization heat is dissipated more effectively and the polymerization has lesser risk of porosity.

Moreover, as the temperature increases, the number of monomer molecules decline and the residual monomer content is reduced to minimum. Therefore, it is suggested that the favorable thermal gradient and reduced residual monomer content, and thereby porosities, seem to be the reasons for the highest flexural and tensile strength with this polymerization technique [20,21].

In the injection mold technique there were many problems encountered as that happened with metal alloy castings. Two types of casting defect were encountered: shrinkage-type porosity, manifests as voids in the center specimens, and edge defects, also it requires firm and quick application of the pressure for proper flow of the resin through sprues into the mold. If pressure is not applied quickly, material will not flow properly into the mold and results in incomplete fabrication of the prosthesis [20].

Injection molded resin generally require greater monomer content to improve flow characteristics and facilitating filling of the mold cavity. This often results in additional unreacted monomer within polymerized resin. In turn unreacted polymer may serve as plasticizer, there by increasing the resiliency of polymerized denture base. Further research is needed to evaluate these results under conditions that simulate a clinical situation like thermal cycling and/or cyclic loading.

CONCLUSION

- Thermoplastic resins have been employed in dentistry for over 50 years. During that time the applications have continued to grow and the interest in these materials by both the profession and the public have escalated.
- The materials have superior properties and characteristics and provide excellent esthetic and biocompatible treatment options.
- With the development of new properties, elastomers and copolymer alloys, there are certain to be additional new applications for thermoplastic resins in the future, to aid patients with damaged or missing teeth.

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