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Evaluation of Strength of Different Resin Materials Used in Overdenture

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ABSTRACT

Introduction: Finding a suitable material that could be used to restore relatively small inter-arch spaces in which reasonable aesthetics as well as good functional strength could be achieved is a difficult process that requires good understanding of the clinical situation and precise management. Historically Metal used to offer the smallest possible thickness with excellent strength but lacks resiliency with poor aesthetics.

Aim of the study: This In-vitro study was conducted to compare two different aesthetic materials PEEK and ACETAL regarding their mechanical strength when used as Overdenture framework in a relatively small thickness.

Material and Methods: 120 specimens were prepared according to the American Society for Testing and Materials (ASTM) International standards and divided into two main groups according to the material, group (A) PEEK samples and group (B) ACETAL samples. Each group of 60 specimens was subdivided into three different groups (I, II, III) according to three different thicknesses (1, 1.5 and 2 mm). Each group contains 20 identical samples, half of them were subjected to water absorption and the other half were left untouched. Then all specimens were loaded to failure in a Universal Testing Machine (UTM).

Results: Data analyzed using Student's t test for independent samples and showed that any increase in thickness lead to increase in the flexural strength which was proportioned in all Acetal samples in contrast to PEEK samples. All PEEK samples recorded significantly higher flexural strength values on every thickness than Acetal samples. Acetal samples with 2 mm of thickness did not offer enough strength as suggested by the international standards for polymer materials and ISO.

Conclusions: The flexural strength of PEEK samples was 3 times higher than Acetal samples. Acetal thickness should be more than 2mm. water has a significant effect on the strength of Acetal materials

1. INTRODUCTION

Although the absence of teeth minimize the elements that could complicate diagnosis and treatment, other factors such as limited Interarch distance should be considered carefully; as Interarch distance represents the available restorative space, planning a restoration in limited space taking into account the esthetic along with the functional demands will be challenging.[1]

Many attempts have been made and proposed to offer successful management of the problem of restoring limited Interarch space whether, surgically, orthodontically or prosthetically.[2–4]

Overdenture dentures were proven superior to conventional complete dentures in biting force, chewing efficiency, and force discrimination.as a result, patient quality of life is improved. Overdentures are considered a viable treatment modality and conservative one, which offers simple and cost effective solution.[5]

Poly methyl methacrylate (PMMA) is a polymer that is most commonly used in dental practice and laboratories. Due to the acquired properties, such as the ease of processing, acceptable mechanical properties, aesthetics cost-effectiveness, and relatively lower toxicity, PMMA has been used as denture base material. However, PMMA is not an ideal material due to discrepancies in its physical and mechanical characteristics For instance, PMMA absorbs water, which may compromise its physical and mechanical properties.[6]

Poor impact and flexural strength which inversely affect the denture base, as vulnerability to complex forces of mastication, denture base is more prone to permanent deformation or fracture. Consequently, several chemical modifications and mechanical reinforcement techniques using various types of fibers, nanoparticles, and nanotubes have been reported.[6]

Thermoplastic materials have been introduced in dentistry for different removable appliances, they impose wide range of applications due to their good mechanical properties, biocompatibility, chemical stability, excellent esthetic characteristics, good formability, and low cost.[7]

There is no enough evidence to evaluate the impact of the change in thickness on the flexural strength, also no enough data about the minimum possible thickness that could provide acceptable mechanical strength to withstand the masticatory forces without failure.

This in-vitro study was conducted to compare and investigate two different esthetic materials PEEK and ACETAL regarding their mechanical strength when used as Overdenture framework in a relatively small thickness.

2. MATERIAL AND METHODS

120 specimens were prepared according to the American Society for Testing and Materials (ASTM) International standards and divided into two main groups according to the material, group (A) PEEK samples and group (B) ACETAL samples. Each group of 60 specimens was subdivided into three different groups (I, II, III) according to three different thicknesses (1, 1.5 and 2mm). Each group contains 20 identical samples, half of them were subjected to water sorption and the other half were left untouched. Then all specimens were loaded to failure in a Universal Testing Machine (UTM).

A commercial CAD software with a 3D printer were used to fabricate the required castable templates. Then for PEEK samples preparations following the manufacture instructions The casting ring and spruing was prepared for the three different samples thicknesses, so that the single ring will contain the three different sample thicknesses at a time every time. Adding of the special investment material followed by mould heating in a specialized PEEK heating furnace, as the optimum preheating temperature is around 850°C–900°C.

After heating of the mould addition of PEEK (BioHPP) granules followed by transferring the mould into the specialized PEEK pressing machine (For2Press).

Finally, the Removal of the investment material with the subsequent Finishing and conditioning of each sample were done according to the manufacture instructions.

As for Acetal samples after the fabrication of the required castable templates by CAD/CAM and 3D printing technologies. Spruing in A special dental flask used to accommodate into the pressing machine (Thermopress 400) was done following the manufacture instructions.

A class III stone featuring expansion that can be controlled individually was used for investing process followed by wax elimination then a special metallic cartridge filled with the thermoplastic Acetal grains heated to plasticize the resin at 220°C for 15 minutes, and injection pressure was adjusted to 7.5 bars. After pressing was done Removal of the investment material with the subsequent Finishing and conditioning of each sample were performed according to the manufacture instructions.

Half of the total number of each material samples were selected and immersed in distilled water for 24 hours before testing.[8]

Guided with the American Society for Testing and Materials (ASTM) International standards (2017), Designation: D 790 for Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials, specimen shall be 50.8 mm [2 in.] long by 12.7 mm [1⁄2 in.] wide, tested flatwise on a 25.4-mm [1-in.] support span then, from the stress deflection curve, the Flexural Strength was calculated. It should be noted that no fracture failure was recorded in any of all tested specimens for both materials.[9]

3. RESULTS

Sample size calculation was done using the comparison of strength between PEEK and ACETAL resins. As reported in previous publications[10,11] the mean±SD of strength in PEEK resin group was approximately 192.1±5.4, while in ACETAL group it was approximately 72.4±2.3. Accordingly, we calculated that the minimum proper sample size was 10 samples in each group to be able to detect a real difference of 5 units with 80% power at α = 0.05 level using Student's t test for independent samples.

Independent Samples Test for comparing the Flexural Strength values between both PEEK and Acetal materials at the Thickness of 1mm, where n=10

Sample Condition	Materials	Mean	SD	T value	P value
Dry	PEEK	125.27	7.75	39.604	0.000*
	Acetal	24.67	2.10		
Wet	PEEK	122.54	1.97	21.411	0.000*
	Acetal	84.83	5.20		

SD: Standard deviation ** Significant: P<0.05*

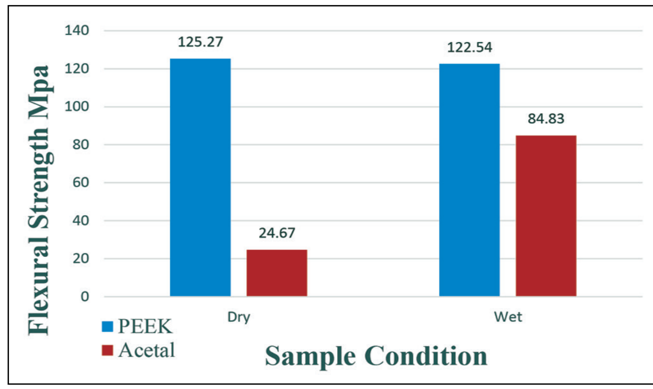

Figure (1) —Flexural Strength of both PEEK and Acetal materials at thickness 1 mm

Independent Samples Test for comparing the Flexural Strength values between both PEEK and Acetal materials at the Thickness 1.5mm, where n=10

Sample Condition	Materials	Mean	SD	T value	P value
Dry	PEEK	161.84	4.17	89.124	0.000*
	Acetal	29.65	2.13		
Wet	PEEK	151.73	6.76	23.710	0.000*
	Acetal	96.73	2.84		

SD: Standard deviation ** Significant: P<0.05*

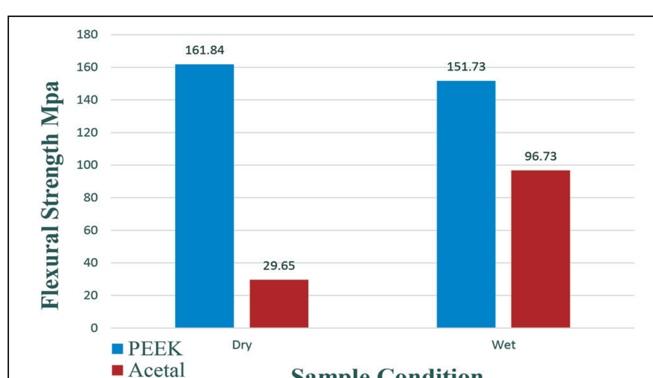

Figure (2) —Flexural Strength of both PEEK and Acetal materials at thickness 1.5mm

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Independent Samples Test for comparing the Flexural Strength values between both PEEK and Acetal materials at the Thickness of 2mm, where n=10

Sample Condition	Materials	Mean	SD	T value	P value
Dry	PEEK	180.03	6.87	63.202	0.000*
	Acetal	36.61	2.07		
Wet	PEEK	186.69	7.85	32.113	0.000*
	Acetal	106.48	0.78		

SD: Standard deviation ** Significant: P<0.05*

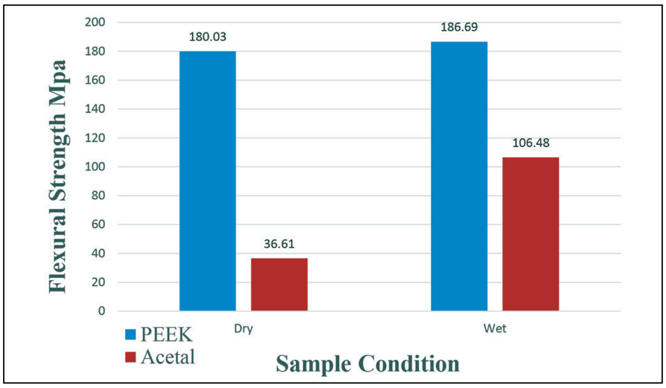

Figure (1) — Flexural Strength of both PEEK and Acetal materials at thickness 2 mm

Independent Samples Test for comparing the Flexural Strength values between both PEEK and Acetal materials at Specific Thickness, where n=10

Sample Condition	Materials & Thicknesses	Mean	SD	T value	P value
Dry	PEEK 1mm	125.27	7.75	34.946	0.000*
	Acetal 2mm	36.61	2.07		
Wet	PEEK 1mm	122.54	1.97	23.879	0.000*
	Acetal 2mm	106.48	0.78		

SD: Standard deviation ** Significant: P<0.05*

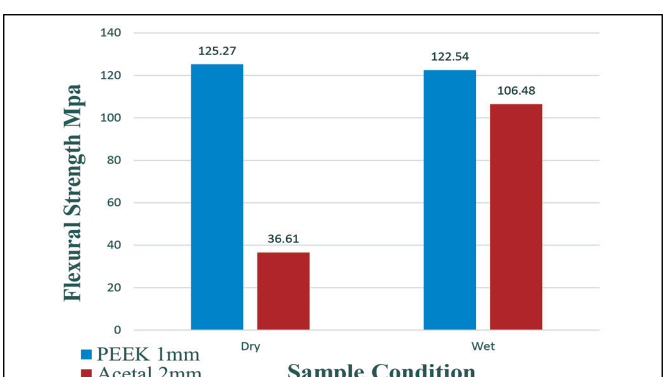

Figure (4) — Flexural Strength of both PEEK and Acetal materials at different specific thicknesses

4. DISCUSSION

Prosthesis fracture may result from insufficient prosthetic space, or occur when the loads applied exceed the strength of the prosthetic materials. A review study of the clinical complications of implant prosthesis, reported that 12 % of overdenture cases undergo prosthesis fracture.[12]

A Retrospective Analysis of Survival and Prosthodontic Complications revealed a correlation between the overdenture base thin thicknesses; especially around copings, and the possible susceptibility to deformation or fracture. As nearly 34% of overdentures showed signs of cracks or an obvious fracture of denture base, mainly around supporting abutment teeth and at midline. The aim of reinforcement is not solely to prevent denture base fracture, but also to enhance functional rigidity for occlusal stability, and to distribute the masticatory load to the underlying denture-supporting areas.[13]

It was concluded that 2-mm denture base thickness had sufficient fracture strength without reinforcement and a positive relationship between acrylic resin thickness and fracture resistance was found.[14]

An experimental and finite element analysis studied Influence of denture tooth thickness on fracture mode of thin acrylic resin bases, concluded that a minimum thickness of 2.5 mm composed of denture base and tooth was sufficient enough to resist fracture under normal masticatory forces.[15]

The incorporation of a metal framework is a common technique to strengthen an overlay prosthesis, especially in instances of limited vertical space when the reduced denture base acrylic thickness renders the prosthesis prone to fractures.[16,17]

It was found that with the increased requirements of esthetics, more patients are requesting that dentists to conceal RPD clasps by placing them closer to the gingiva or offering an esthetic alternative replacement to metal containing RPD.[18]

Studies on PEEK revealed its success as a framework material that offers good strength with reasonable esthetics.[19]

PEEK frameworks veneered with composite as a treatment modality when lack of sufficient restorative space encountered.[20]

The method of construction of denture bases material had significant effect on its mechanical properties whether, CAD/CAM constructed or by injection molding. Acetal resin showed higher fracture toughness mean values higher than acrylic resin.[21]

Authors found no significant difference in the stiffness or proportional limit for direct retainers fabricated in these thermoplastic – PEEK & Acetal – materials from their metal counterparts.[22]

A Study investigated the influence of two different partial denture framework materials on the supporting structures of implant-retained partial overdenture. Where Acetal resin framework material produced less bone changes around partial overdenture supporting structures than the metallic framework.[23]

The flexural strength and water sorption of injection-molded PMMA base material was tested and concluded that, thermoplastic resins can be a suitable alternative to conventional PMMA acrylic resins as denture base materials.[24]

Acetal resin frameworks may be as thin as 0.3- 0.5 mm as reported by some authors, while in other studies the minimum recommended cross section was 1.4mm.[25]

Multiple studies were conducted to evaluate the minimum critical thickness of PEEK, while some preferred a thickness of 1.3mm as framework, others found it adequate at 1mm but unnecessary, and proposed another alternatives, while other authors reported that, the thickness of PEEK at a critical value of approximately 0.2 mm must be avoided in order to preserve their friction and wear properties.[26]

In the present study, PEEK samples showed significant disproportioned increase in strength accompanied with the increase in thickness, as with 0.5mm increase in thickness, it led to 29.19 % increase in the flexural strength, while 1mm increase in thickness offered 43.71 % increase in the flexural strength. These result confirm the proposed flexural strength of the material as the bending strength recorded higher than 150MPa as mentioned in previous studies.[27]

Acetal samples showed significant increase in flexural strength values with the increase in thickness. These results came in accordance with other studies on similar injectable thermoplastics.[28]

It worth mentioning that, the increase in the flexural strength values was directly proportioned to the increase of the corresponding thicknesses, as it recorded with 0.5mm increase in thickness an increase of the flexural strength by 20.18 %, and with 1mm increase in thickness an increase of the flexural strength by 48.39 %.

All Acetal dry samples failed to record flexural strength values more than 65 MPa which is the minimum desired flexural strength of denture acrylics according to the international standards for polymer materials and ISO 20795-1 for denture base polymers. Hence, the group of dry Acetal samples in the present study with their respective thicknesses does not have acceptable flexural properties for clinical use.[29,30]

When comparing both PEEK and Acetal materials, PEEK samples recorded significantly higher flexural strength values than their Acetal counterpart in all tested samples, whether, wet or dry at each thickness.

Acetal samples with a thickness of 2mm even in wet condition (the strongest Acetal samples tested) failed to record sufficient flexural strength compared to PEEk's 1mm samples (the weakest PEEK samples tested), which recorded significantly higher flexural strength values.

5. CONCLUSIONS

1. The flexural strength of PEEK samples was 3 times higher than Acetal samples.
2. Acetal thickness should be more than 2mm.
3. Water has a significant effect on the strength of Acetal material.

6. RECOMMENDATIONS

1. Further clinical studies to compare the strength of different designs of PEEK frameworks.
2. Further clinical studies to investigate the effect of strengthening by PEEK and Acetal frameworks on the general strength of the denture base.
3. Investigating the effect of other processing techniques on the strength of each material.

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