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COMPARATIVE EVALUATION OF PHYSICAL PROPERTIES OF CONVENTIONALLY CONSTRUCTED VERSUS CAD/CAM MILLED FRAMEWORKS FOR KENNEDY CLASS I PARTIAL DENTURES

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ABSTRACT

Aim: The objective of this study was to compare the physical properties (retention, surface roughness, and wear) of conventionally constructed (pressed) bioHPP removable partial denture (RPD) frameworks versus computer aided designed - computer manufactured (CAD/CAM) RPD frameworks.

Materials and Methods: Over standardized epoxy resin cast models, twenty frameworks were fabricated and divided equally into two groups, group A received ten conventionally fabricated (pressed) bioHPP frameworks and group B received ten CAD/CAM milled frameworks. Each framework was subjected to insertion/ removal cycles by using universal testing machine, (360, 720, 1080, 1440, 2116 cycles) representing time intervals baseline, three, six, nine- and twelve-months respectively, where retention, wear and surface roughness were measured before and after each time interval.

Results: Group B(CAD/CAM) milled RPD frameworks results showed statistically significant difference with higher mean values than group A (pressed) RPD frameworks results in all measured parameters throughout all time intervals.

Conclusion: Within the limitations of this study, it could be concluded that either with milled or pressed way of construction BioHPP remains a reliable material that could be used to construct a highly accurate RPD framework with acceptable physical properties.

KEYWORDS: BioHPP, CAD/CAM, pressed RPD frameworks**,** Kennedy class I, retention, surface roughness, wear.

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INTRODUCTION

Replacement of missing teeth to restore esthetics and/or function is one of the most important needs for patients attending dental clinics. The choice between several treatment modalities for replacing missing teeth is influenced by clinical, dentist and patient related factors. Many treatment modalities are available such as dental implant, removable partial denture and fixed partial denture.[1]

Kennedy class I removable partial denture presents significant challenges as it is subjected to vertical, horizontal and torsional forces. Moreover, Kennedy class I removable partial denture lacks posterior retention, forces acting in occlusal direction will tend to move the denture away from the ridge contact. When the denture base is lifted the denture tends to rotate around an axis passing through the tips of the distal retaining clasps. During treatment of distal extension cases, protection of the teeth and the supporting tissues from eventual destruction should be considered through better stress distribution, partial denture material and design variations, and The rotational movement can be prevented by the indirect retainer which is rigid component of the partial denture placed anterior to the axis of rotation.[2]

Traditional RPDs with chrome cobalt frameworks and clasps have been the most common and inexpensive treatment option for the rehabilitation of partially edentulous patients. However, the esthetically unacceptable display of metal clasps, the increased weight of the prosthesis, the potential for metallic taste and the allergic reactions to metals considered as disadvantage that led to the introduction of a number of thermoplastic materials as as nylon and acetal resins.[3]

Nylons provide improved esthetics and reduction of rotational forces on the abutment teeth due to their low elastic modulus. The major drawbacks of a nylon RPDs are the inability for relining procedure, beside, the lack of occlusal rests as well as rigid frameworks that could lead to occlusal instability and sinking of the denture toward the tissues, especially in Kennedy class I and II cases. On the other hand, acetal resin shows adequate mechanical properties to form a framework more rigid than nylon with retentive clasps, connectors, and supportive elements; however, the acetal resin material lacks natural translucency and vitality.[4]

Poly-ether-ether-ketone (PEEK) as alternative restorative material has been successfully used over the last years in the medical and dental fields , this material presents high biocompatibility, good mechanical and physical properties, high temperature resistance, high polishing and low absorption properties, low plaque affinity, and good wear resistance, with a higher level of design freedom and a higher level of functional integration beside it is considered as a cheaper alternative to precious metal or other materials.[3]

High Performance Polymer (bioHPP)is a PEEK variant that has been specially optimized for the dental field by adding a special ceramic filler with grain size of 0.3 to 0.5 μm, which creates acceptable mechanical and physical properties concerning color stability, plaque deposition and extremely good polishing properties.[4]

It is well known that, bioHPP frameworks can be constructed either by injection(press) method or computer aided designing/ computer aided manufacturing (CAD/CAM) method.

The BioHPP material could be pressed into a mold of a framework pattern to construct RPD. However, the literature reported numerous inaccuracies concerning the fit of the various components of RPD framework constructed by lost wax technique due to the multiple steps included. Although injecting thermoplastic resins into molds is considered a conventional method of fabrication, it is not a common technology in dental laboratories because the need of expensive equipment and this could be a disadvantage. [5,6]

On the other hand, the construction of computer aided dental prostheses has become common practice in dentistry and considered fundamentally important for patients seeking more rapid, accurate, and functionally efficient prosthetic rehabilitation.

Physical properties including retention, surface roughness and wear could be affected by the method of construction [7], Therefore, a question may arise regarding the effect of different methods of construction of RPD framework on its physical properties?

This study will try to answer this question

MATERIALS AND METHODS

Twenty frameworks were fabricated and divided equally into two groups, group A received ten conventionally fabricated (pressed) bioHPP frameworks and group B received ten CAD/CAM milled frameworks.

For the two groups, primary surveying of the acrylic cast was done to ensure the presence of desirable undercut needed for the clasp assembly using broken arm survayor. Guiding planes were prepared on the distal surface of the second premolars bilaterally using fissure bur, Rest seats were made in the far zone of the second premolars bilaterally using size two round bur. Another two rest seat preparations were done on the distal side of occlusal surface of the first premolars to act as indirect retainers. A silicone mold was used to duplicate the acrylic cast into twenty epoxy resin casts, divided equally between the two groups.

The casts were scanned using shera ecoscan 7 scanner to design the sterolithrography STL file of the RPD frameworks, casts were digitally surveyed to get proper path of insertion and removal, proper path of insertion was chosen after adjustment of the tilt to ensure the presence of 0.5 mm undercut in the mid buccal undercut which is the desired position of the retentive tip of the retentive arm of the clasp assembly.

STL file designing: The denture base was designed with relief gap of 0.4 mm. Lingual bar major connector was chosen to connect the denture bases bilaterally after leaving about 0.4 mm space relief (figure 1). RPI Clasp assembly and indirect retainers were properly designed choosing the occlusal rest and adapting it to the rest seat preparation. Proximal plates were drawn at the proximal surfaces of the abutments from the rest to the denture base crossing the distolingual line angle. I-bar retentive arms were designed on the second premolars to engage the undercuts on the midbuccal surfaces determined by the digital surveyor mentioned previously. Two occlusal rests were designed to seat properly in their rest seat preparations on occlusal surface of lower first premolar bilaterally to be used as indirect retainers. Minor connectors were designed to connect both mesial and distal occlusal rests to the lingual bar bilaterally. The design was finalized using the sculpt tool to add or remove material from the design, smoothening of the needed areas was done to avoid any sharp undesirable areas. Finally, stereo lithography (STL) file of the removable partial denture design produced by the software and used to start milling process (figure 1).

Fig. (1) STL adapded on the cast

For Group A (pressed): Ten wax patterns were milled according to previously performed STL file using shera eco mill 5 axis milling machine, then the patterns were seated on the casts to check its accuracy. Spruing and investing of wax patterns were done. The ring of each pattern was preheated in the pre-heating oven (between 630°C and 850°C) for elimination of the wax. The melting procedure of the bioHPP is carried out in the preheating oven at 400°C for 20 minutes. The for 2 press machine (figure 2) completed the pressing process by lowering the piston (4.5 bar, 230 seconds) and keeping the pressure for 35 minutes. RPD framework was divested, the sprues were separated and the pressed RPD frameworks were seated on the cast after proper finishing and polishing according to manufacturer instructions to check its accuracy. (figure 3)

For Group B (CAD/CAM milled): The STL file of the same design was used to mill ten frameworks directly from BioHPP blanks. BioHPP blanks of 16 mm were used and inserted in the same 5 axis milling machine, five different sizes burs were used by the milling machine to produce the frameworks (figure 4). After completion of the milling, the blanks were removed from the machine and the RPD frameworks were retrieved. After finishing and polishing according to manufacturer instructions, the RPD frameworks were seated on its casts to check its accuracy.

Each RPD framework seated on its cast was fixed to the lower compartment of a materials testing machine (figure 5) with a loadcell of 5 kN. Each framework was attached through centrally positioned orthodontic wire loop (0.14'') between 2nd premolar and 1st molars to facilitate the aligning with the loading axis of machine and proper load distribution. A tensile load with pull out mode of force was applied via materials testing machine at a crosshead speed of 5 mm/min. The load required to totally dislodge sample was recorded in Newton. The tensile load pull was repeated representing insertion/removal cycles representing baseline, at C1, C2, C3, C4 respectively and the load required to dislodge the cast was recorded after each cycle. Data were recorded using computer software.

Wear results were obtained by measuring the weight loss before and after each cycle using electronic analytical balance with an accuracy of 0.0001 gr. to weigh the difference in weight before and after the five interval cycles.

Surface roughness was measured for both groups before and after the insertion and removal cycles by optical profilometery after each time interval. Data were collected, tabulated and statistically analyzed.

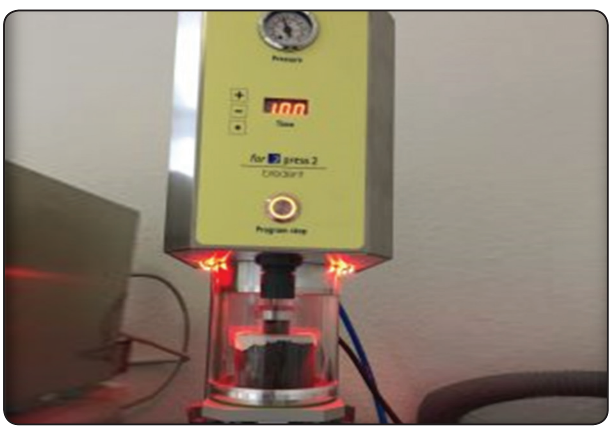

Fig. (2) Pressing machine

Fig. (3) Pressed frameworks seated on the cast

Fig. (4) BioHPP framework in the milled blank

Fig. (5) Framework in universal testing machine

TABLE (1): The Mean, standard deviation values of retention in different groups

Variables		Retention				
		BASELINE	C1	C2	C3	C4
Group A (Press)	Mean	0.31[b]	0.31 [b]	0.24[b]	0.23[b]	0.21[b]
	SD	0.16	0.15	0.08	0.01	0.03
Group B (CAD/CAM)	Mean	2.27[a]	2.24[a]	2.15[a]	2.11[a]	2.08[a]
	SD	0.69	0.62	0.48	0.47	0.46
P-value		<0.001 *	<0.001 *	<0.001 *	<0.001 *	<0.001 *

*Superscripts with different small letters indicate statistically significance difference within the same column. *; significant (p≤ 0.05) ns; non-significant (p>0.05)*

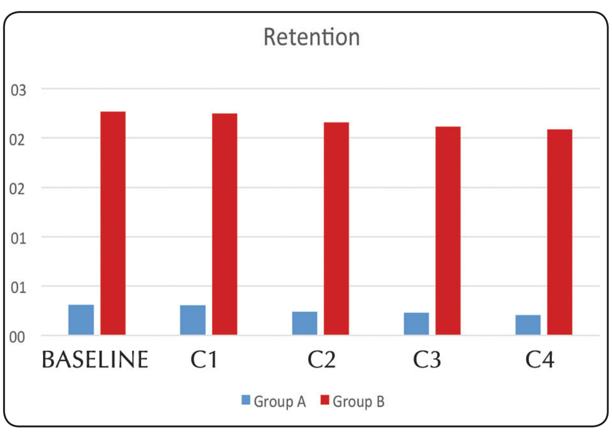

Fig. (6) Bar charts representing retention test in different groups

RESULTS

Retention Test

Relation between groups

A statistically significant difference was found between the two groups at baseline, after 3,6,9,12 months where $p < 0.001$ with the highest mean was recorded for group B in all stages and the lowest mean value recorded for group A at all time intervals, with slight decrease in retention through the time intervals.

2. Wear

For both groups there was a slight increase in weight loss due to wear through the time intervals baseline, 3,6,9 and 12 months with no statistically significance difference at baseline and after three month, and with statistically difference at 6,9 and 12 month time intervals

Surface Roughness:

Relation between groups

A statistically significant difference was found between the two groups after 12 months where p-value = 0.005 while there was no statistically significant difference between the two groups in the other time intervals as p-value is >0.05.

TABLE (2): The mean, standard deviation values of weight loss due to wear in different groups.

Variables		Wear				
		Baseline	C1	C2	C3	C4
Group A (Press)	Mean	1.687^a	1.685^b	1.684^d	1.686^c	1.687^a
	SD	0.32	0.32	0.32	0.32	0.32
Group B (CAD/CAM)	Mean	1.729^a	1.728^b	1.721^c	1.729^a	1.727^d
	SD	0.08	0.08	0.08	0.08	0.08
P-value		1.0 ns	1.0 ns	1.0 ns	1.0 ns	1.0 ns

TABLE (3): The Mean, standard deviation values of roughness in different groups.

Variables		Surface roughness				
		Baseline	C1	C2	C3	C4
Group A (Press)	Mean	0.254^b	0.255b	0.256^b	0.247^b	0.259^a
	SD	0.00	0.01	0.00	0.02	0.00
Group B (CAD/CAM)	Mean	0.246^b	0.248b	0.251^b	0.240^b	0.256^a
	SD	0.01	0.02	0.00	0.01	0.00
P-value		0.14ns	0.93ns	0.37ns	0.16ns	0.005*

Superscripts with different small letters indicate statistically significance difference within the same column. *; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

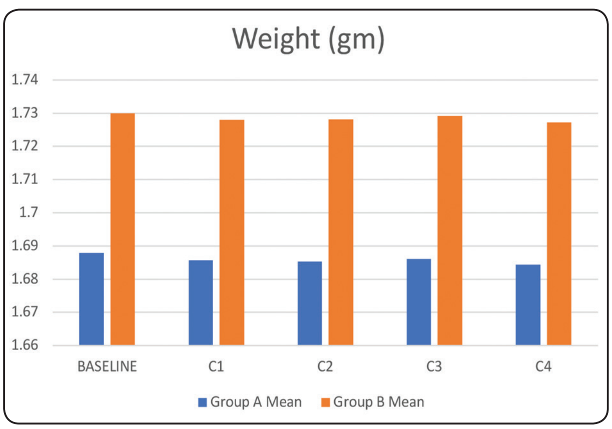

Fig. (7) Bar charts representing the weight in different groups

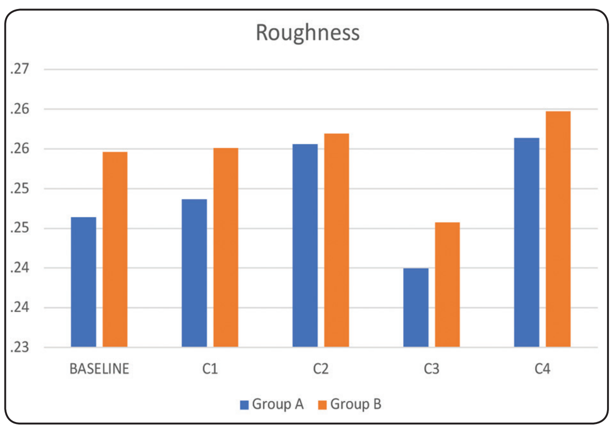

Fig. (8) Bar charts representing roughness test in different groups

DISCUSSION

It was clear that retention of group B (CAS/CAM) is better than group A frameworks, also group B frameworks showed less surface roughness and wear than the other group, as digital technology and the CAD designing provided accurate design need for the partial denture frameworks, also CAD designing for RPD framework is more simple and adjustable which goes with the results of this study.[8]

It is well known that **Stock et al** mentioned that the accuracy of the milled BioHPP was better than the conventional pressed ones that possess long processing chains. The pressing process included a more difficult sequence with high potential for errors, such as the manual construction of the wax model, the unpredictable expansion coefficient of the traditional investment material which caused countless dimensional changes and the contraction of the material during the cooling time that changes the fitting values.[9]

Bilgin et al., stated in his study that CAD/CAM milling systems can save time and facilitate dental laboratory procedures so that they can be used routinely as alternatives to casting. Beside that all laboratory procedures can be standardized by computerized technology which would minimize the human variations during fabrication of any prosthesis.[10]

On the other hand, many studies stated that, the conventional fabrication methods steps necessitate considerable human intervention and materials manipulation that may additionally offer inherent processing shrinkage and/or expansion. This may lead to increased processing errors and inaccuracies which may explain the decreased retention values of conventional dentures in comparison to those of digital dentures in addition to the increase of surface roughness.[11]

For surface roughness and wear of bioHPP, there is no previous study showed the effect of method of fabrication on bioHPP either milled or pressed on its surface properties. But it was mentioned in many studies that the surface roughness of any material directly or indirectly affects surface wear. Beside that some papers showed that bioHPP either milled or pressed has high polishing qualities, low plaque affinity, and good wear resistance.[7]

Moreover, another study stated that, CAD/CAM fabricated materials show a reduced risk of porosities and therefore higher and more solid mechanical and physical properties properties. Despite the limitation of Although Many studies stated that modified PEEK (BioHPP) exhibits perfect desirable properties needed for partial denture frameworks such as, its lightweight for improved patient comfort, no thermal or electrical conductivity, non-allergenic, and metal-free (no metal taste). In addition, shock absorbent during chewing and have high resistance to abrasion and decay. Also BioHPP provides better occlusal stability and better esthatics if properly fabricated .[7]

A study stated that BioHPP has a great potential as framework material. This is a good alternative to Cr-Co frames for the patients with high aesthetic requirements. But in clinical situations the results might be different.[12]

Digital technology is being used to efficiently create clin- ically successful and reliable dental restorations. In the near future, CAD/CAM may well become the preferred fabrication method for most dental prostheses.[13]

There is no definte study shows difference in mechanical and physical properties of either milled or pressed frameworks. In this study it was clear that CAD/CAM method of fabrication is better was than pressedthis study, it was concluded that PEEK based restorations shows better surface properties than those of PMMA based materials so it can be used for long term restorations. [14]

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