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Evaluation of Retentive Forces of Two Types of Digital Partial Denture Framework Materials: An in-Vitro Study

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Abstract— Introduction: The use of CAD/CAM in the manufacture of PEEK and acetal frameworks helps to increase the accuracy and retention of the partial denture frameworks. **Aim:** is to compare the retentive force of peek and acetal digitally milled partial denture frameworks. **Materials and Methods**: Twenty digital partial denture framework were milled by CAD/CAM, divided into two equal groups **(n=10)**, ten digitally milled PEEK frameworks and ten digitally milled acetal frameworks. Preparation the clasp of two partial denture was designed on CAD CAM software with thickness 2 mm. and designed hook at the central and bilateral at 5,6 area occlusally to pullout the cast clasps later. Instron universal testing machine model 3345 England used with tensile load at crosshead speed of 5 mm/min until automatically stopped. **Results:** Retentive force of PEEK was higher than retentive force of acetal in bilateral and unilateral measurement. **Conclusion:** PEEK should be considered as a substitute framework material for a well-designed Cr-Co RDP.

Key words: Kennedy class I, epoxy resin, CAD/CAM, modified polyetheretherketone, acetal, retentive force.

Introduction

Partial edentulism is one of the widely studied topics in dentistry, it resulted from caries, periodontal problems, traumatic injuries, impactions, supernumerary teeth, neoplastic and cystic lesions. (1)

Replacement of missing teeth is one of the most important needs for patients attending clinics to restore esthetics and/or function. Many treatment modalities are available for replacing missing teeth; removable partial denture, fixed partial denture or dental implants. (2)

Polyoxymethylene which is formed by polymerizing formaldehyde, may be used as an alternative denture clasp material. Acetal as a homopolymer has good short-term mechanical properties, but as a co-polymer has better long-term stability. (3)

PEEK became an attractive material for producing CAD/CAM removable prostheses especially by milling production. The resulting non-allergic prostheses are lighter than those made of other conventionally used materials. (4)

Evaluating RPD retention by applying dislodging forces to the center of the frameworks in a vertical direction to the center of the denture by means of an Instron universal testing machine. (5)

This in-vitro study was made to evaluate the retentive forces of acetal and PEEK digital partial denture framework materials.

Materials and Methods

The sample size for this study was calculated according to Arkin, Jaykaran and Tamghna used the following equation:

$$N = \frac{(Z_\alpha)^2 * (S)^2}{(d)^2}$$

N = Total sample size

Z_α= Is Standard normal variate and its equal 1.96 at P< 0.05

SD = Standard deviation of variable

d =Absolute error or precision

Zα	SD	d
1.96	4.55	2

Total sample size $N = \frac{(1.96)^2 x (4.55)^2}{(2)^2} = 19.883 \approx 20$

Total sample size for fraction resistance is 20 Samples for two groups

Fabrication of epoxy cast

- Ready made lower dental stone cast with class I kennedy classification was used. The missing teeth were 2nd premolar, 1st, 2nd and 3rd molar on both sides (Figure 1).
- Impression silicone was used for making negative replica of the ready made mandibular cast (Zetaplus, Zhermack, Italy).
- The silicone impression was poured by highly lustrous epoxy resin left for complete setting (Kemapoxy 150,chemicals for modern building international,Egypt) (Figure 2).

Figure 1 : Ready made stone model **Figure 2:** pouring of epoxy resin

Prosthetic procedures

- Cast prepration for Kennedy class I design was done on the epoxy cast.
- In right and left 1st premolar occlusal saucer mesial rest was be prepared, 2.5mm long, 2.5mm wide, 2mm deep at the center and 1.5mm deep at the mesial marginal ridge.
- After surveying the cast, the survey line was drawn to receive RPA clasp.

Scanning procedure

- The epoxy cast was optically scanned (Figure 3).
- All undesirable undercuts were then blocked out and 0.5mm retentive undercuts were chosen gingival to the survey line on the buccal surfaces of the abutment teeth.
- After blocking out of all undesirable undercuts, the final digital cast was ready (Figure 4).

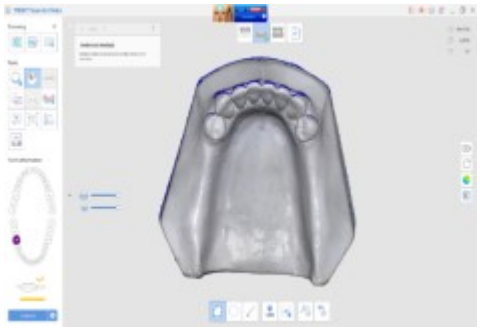

Figure 3: Optically scanning of the epoxy cast **Figure 4:** Final digital cast

- All components of the framework were selected from the menu and placed digitally on the modified virtual master cast in the correct position.
- The clasp was designed on CAD with thickness 2.5mm at the origin and 2mm at the retentive tip

and it was designed hook at the middle of the lingual bar and bilaterally at 5,6 area occlusally to pullout the cast later (Figure 5).

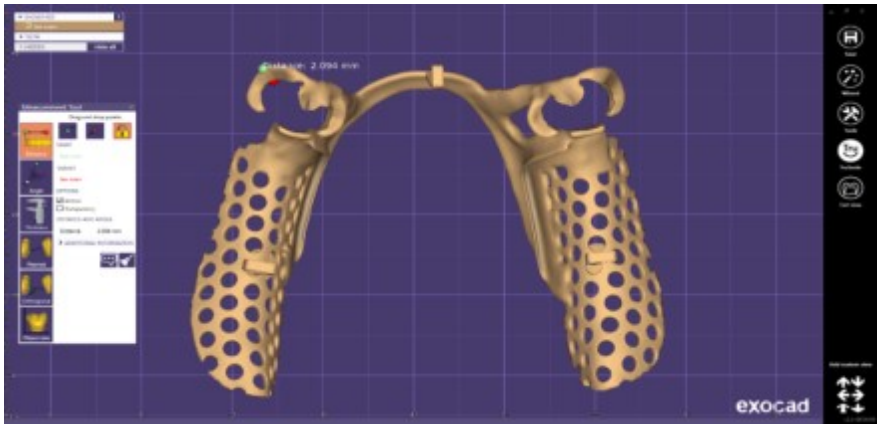

Figure 5: Checking of the virtual framework

Framework construction

- The definitive STL design file was used for denture base fabrication.
- The discs of acetal and peek used in fabrication frameworks that was designed using CAD CAM software.
- The virtual 3D framework (STL) file was sent to the milling machine to begin the milling process of peek and acetal discs (Figure 6).
- After the framework was milled, they removed from milling machine.
- The peek and acetal framework was then finished, polished and seated on the master cast to check the fitting (Figure 7).

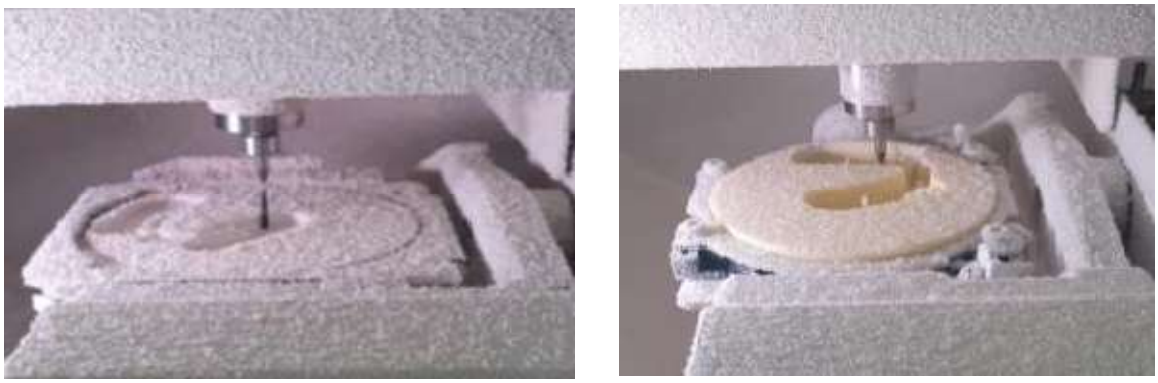

Figure 6: Digital milling of peek and acetal frameworks

Figure 7: Final peek and acetal framework fitted on the epoxy cast

Retention evaluation

- The retention of removable partial dentures in both groups were measured at time of insertion by using universal testing machine (Figure 8).

Figure 8: Instron model 3345 universal testing machine

- The universal testing machine was pullout the framework of acetal and peek centrally from the three hooks and repeated ten times for each framework and average measurement (Figure 9).
- This method was repeated 10 times for both acetal and peek framework.

Figure 9: Instron pull out the framework centrally

- Second universal testing machine unilaterally pulled out the framework of peek and acetal once from the right side and once from the left side (Figure 10).
- This method was repeated 10 times for both acetal and peek.
- Data calculated and recorded using computer software blue hill universal instron England.
- Data were collected, tabulated and statistically analyzed to compare between the two groups.

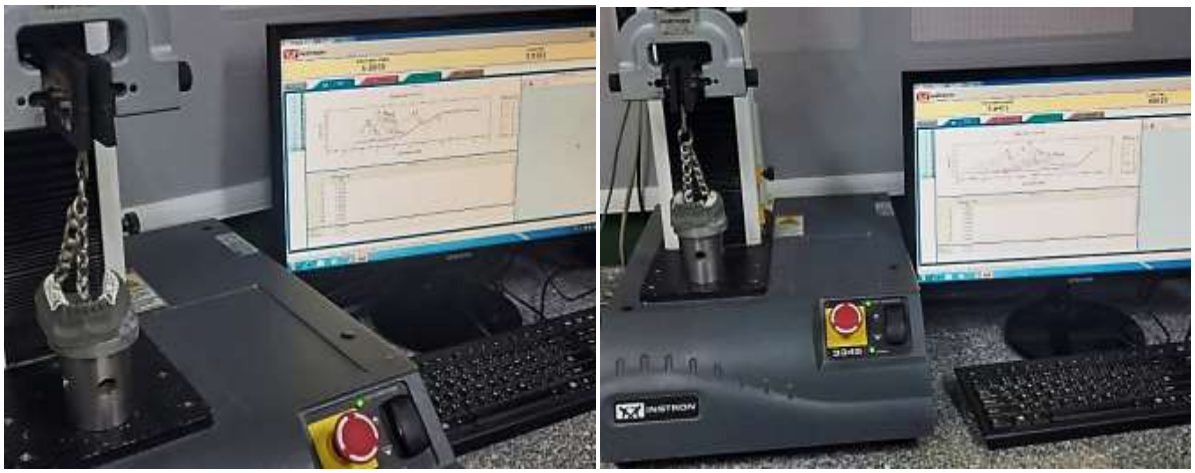

Figure 10: Instron pulled out the peek and acetal framework unilaterally

Statistical Analysis

- All data were collected, calculated, tabulated and statistically analyzed.
- Descriptive statistics were calculated in the form of Mean ± Standard deviation (SD), range (Max- Min), and median.
- Independent sample t-test and Paired sample T-test were used to assess the difference between groups and different sides.
- A $P < 0.05$ was considered statistically significant.

- Statistical analysis was carried out using the SPSS software version 26 (Statistical Package for Social Science, Armonk, NY: IBM Corp).
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Results

The results in **table 1** showed the comparison between group A (peek) and group B (acetal) for the maximum load. Statistical analysis showed a significant difference between group A and group B for maximum load (P<0.001), the group A recorded high values (7.609±1.007) than group B (1.373±0.115) using independent T-test at P value <0.05.

Table 1, The comparison between two group for the maximum load

Groups	Max.Load Newton(N)		Mean Difference	95% Confidence Interval of the Difference		Indep. T. test	Sig. (2-tailed)
	Mean	SD		Lower	Upper		
Group A	7.609	1.007	6.236	5.563	6.909	19.46	<0.001**
Group B	1.373	0.115		5.514	6.958		

Test used: independent T test at P<0.05
**;means significant Difference between groups

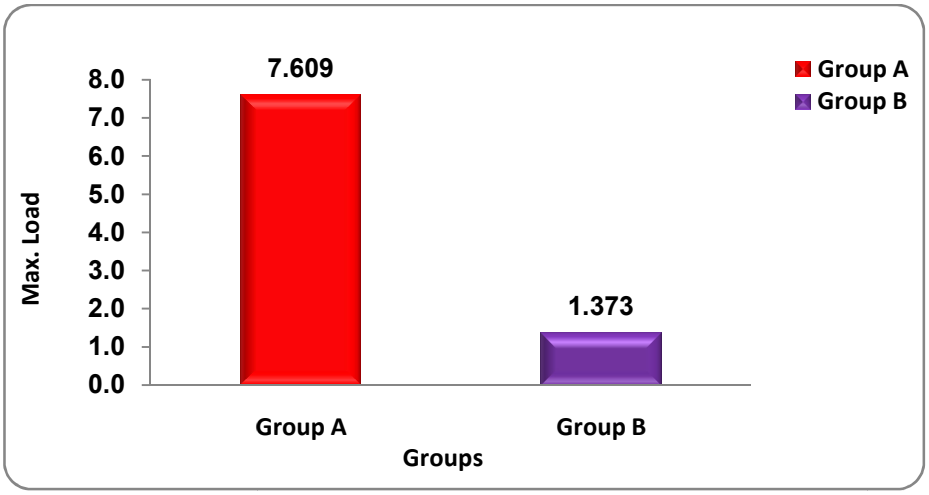

Figure 11: Comparison between retentive force of PEEK and acetal bilaterally

The results in **table 2**, showed descriptive statistics of retentive force in each studied groups (PEEK & Acetal) in the right and left sides. For peek group at right side, the retentive forceranged from 3.706 to 5.121 with average 4.553±0.423 and median 4.611. On the other side (left side) the retentive forceranged from 3.552 to 4.011with average 3.702±0.148 and median 3.624. regards to Acetal group, the retentive force at the right side ranged from 0.424 to 0.577 with average 0.486±0.047and median 0.480. while the left side the retentive force ranged from 0.609 to 1.132 with average 0.758±164 and median 0.680.

Table 2, Descriptive statistics of retentive force in each studied groups

Groups	Sides	retentive force						
		Min	Max	**Mean**	**SD**	Median	**95% CI Confidence Interval**	
							Lower	**Upper**
peek (n = 20)	Right (n=10)	3.706	5.121	4.553	0.423	4.611	**0.553**	**1.148**
	Left (n=10)	3.552	4.011	3.702	0.148	3.624	0.539	1.162
Acetal (n = 10)	Right (n=10)	0.424	0.577	0.486	0.047	0.480	0.157	0.384
	Left (n=10)	0.609	1.132	0.758	0.164	0.680	0.151	0.391

Discussion

Bilateral long span class I kennedy classification was chosen as a convenient and economic treatment options.(6)

In this study, CAD/CAM technology was used in fabrication of removable partial dentures.
This technique seems to have multiple advantages including; improved fitting accuracy, quick fabrication, fewer laboratory steps required, and fewer sources of error. Another advantage of this fabrication method is the possibility of saving the patient digital data and images for future replacement in case the patient missed his denture.(7)

Based on the scan data of primary cast, digital surveying was performed virtually in space to determine the same vertical path of insertion and removal and to measure the amount of undercuts that would be used, it,s a more accurate way than the manual surveying as reported by Mehl A.(8)

The distance between the gingival margin of the remaining teeth and the functional depth of the floor of the mouth was at least 8 mm because lingual bar major connector was used as a component part of mandibular RPD to ensure sufficient area for cleansing as well as maintaining the bar rigidity. (9)

The clasp was designed to engage 0.5 mm retentive undercut and at least 1 mm from the gingival margin to produce a more esthetic result.(10)
Saucer shape occlusal rests were prepared on abutment teeth to provide vertical support for the partial denture and transmit vertical forces with the long axes of the teeth. (11)

Nonmetal frameworks have advantages over metal frameworks. Due to its white color and high strength, exhibits a perfect balance of the properties desirable to frameworks: lightweight for improved patient comfort, no thermal or electrical conductivity, non-allergenic, and metal free dentures is a taste neutral (no metal taste).(12)

A studypresented a novel method to fabricate CAD/CAM one-piece PEEK RPDs and evaluated their fit in vitro. The in vitro fits of one-piece PEEK RPDs were better than that of traditional cast framework RPDs. (13)

Acetal resin is very strong, resists wear, fracture, is quite flexible, also resist occlusal wear and are well suited for maintaining occlusal vertical dimension. Acetal does not have the natural translucency and vitality of thermoplastic acrylic and polycarbonate, and this material might offer better results for short-term temporary restorations.(14)

Few studies evaluated the retentive force of clasps fabricated from PEEK and acetal material. Most of the studies in this field have been focused on testing the feasibility of the technique and they have shown that digital direct or indirect metal fabrication can produce accurately fitting RPDs.(15)

Universal testing machine (instron model 3345) was used to measure the retention force Newtons needed to dislodge the RPD away from its basal Seat. (16)

The loss of retention of each clasp was chosen for comparison because it gave the results in numbers, which are considered more accurate and easier for comparison between subgroups rather than the percentage of loss. (17)

Whatever the type of used clasp, RPD must be retained successfully as long as the force required to flex the clasps over the maximum bulbosities of the teeth is greater than the force which is attempting to dislodge the denture.(3)

Thermoplastic clasps might achieve clinically acceptable retention at dimensions differing from those of metal clasps, possibly requiring thicker clasp to engage a deeper undercut. (18)
Tooth shape and clasp design may affect the retentive force, and the clasp retention could be determined by the depth of the undercut available on the tooth.(19)
previous studies have suggested using a deeper retentive undercut for clasps made of thermoplastic resins material to provide clinically accepted retention. Reviewing literature indicated that increasing the thickness of the clasp arm would increase its retentive value. (20)

According to the results of the present study, the PEEK (Group I) showed a statistically significant higher retentive force (7.609±1.007 N) when compared to the acetal (Group II) (1.373±0.115 N) engaging the same undercuts.

A previous study stated that 3 to 7.5 N is the retentive force required for adequate retention and functioning of PRDPs, while another study found that 5 N could give an acceptable degree of retention. (21)

Salma fathyagreed with our findings as she evaluated retention of PEEK and acetal clasps and reported acetal clasps retention and deformations were remarkably reduced, while PEEK clasps properties were high. (22)

Other studies are in agreement with our results, the clasp made from PEEK material of 2 mm thick showed significantly higher retention force compared to Acetal claps. Loss of retention of the clasps due to fatigue resistance test was considered as a good indicator of permanent deformation of the clasps.(23)

El-Segai AA and Abbasconcluded that the novel clasp made from PEEK material showed significantly higher retention force compared to Acetal claps. Loss of retention of the clasps due to fatigue resistance test was considered as a good indicator of permanent deformation of the clasps. (24)

Fayyad agreed with our findings as she evaluated retention of different thermoplastic materials and reported the peek higher retention than other thermoplastic clasp. (25)

The results of this study showed that PEEK has statistically significant higher retention values when compared to acetal. The results showed that Acetal group had the lowest retention mean value when compared to the PEEK with significant difference between them. This is due to PEEK has high impact strength. (26)

A study concluded that retentive forces of PEEK clasps are higher than acetal resin. This may be due to composition of PEEK could provide its priority of higher strength properties among tested resins. (27)

Conclusion

Within the limitations and conditions of this in vitro study, it was concluded that:

1. PEEK digital frameworks showed higher retention than acetal digital frameworks in unilateral and bilateral measurement.
2. PEEK should be considered as a substitute framework material for a well-designed Cr-Co RDP for patients with taste sensitivity or allergies to conventional Cr-Co frameworks.

Conflict of interest statement

The authors declare that they have no conflict of interest.

Authors contribution

All authors are equally contributed.

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