Assessment of Retention in Cases of Kennedy Class I Partial Dentures Fabricated by CAD-CAM milled Resin Technology

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Abstract

Purpose: This study aimed to compare the retention force between CAD-CAM milled PEEK versus CAD-CAM milled Acetal resin RPDs and the conventionally constructed Co-Cr removable partial dentures (RPD) used as a control group **. Material and methods:** Thirty patients with mandibular class I Kennedy were selected, all the patient had bilateral lower first premolars as last remaining abutments. Each patient received three types of removable partial dentures; Conventional (Co-Cr) RPDs, CAD-CAM milled poly-oxy-methylene (Acetal Resin) and CAD-CAM milled poly-ether-ether-ketone, (PEEK) RPDs, the patients were instructed to underwent a rest period for two weeks before they were delivered the other type of RPD. The retention was measured at the time of insertion as a baseline and after three months from delivery. **Results:** The retention forces in the conventional (Co-Cr) group were higher than that of CAD-CAM milled PEEK and milled Acetal RPDs engaging the same undercuts. There was a high significant difference in the retention force between CAD-CAM milled (Acetal and PEEK), and Co-Cr RPDs in favor of Co-Cr RPDs, and a significant difference between CAD-CAM milled Acetal and milled PEEK RPDs in favor of milled Acetal. **Conclusions:** Within the limitations of this study, it can be concluded that, the use of CAD-CAM technology can be a promising alternative to conventional technique. Although metallic prosthesis showed higher retention values, recent CAD-CAM technology by milling polymeric materials (Acetal and BEEK) exhibited sufficient retention to recommend usage under some clinical conditions; as when aesthetic demand or periodontal health is a primary concern.

Keywords: CAD-CAM, Acetal resin, BEEK, Retention

Introduction

The rehabilitation of partially edentulous subjects using removable partial dentures, is an essential prosthetic consideration, particularly for patients with free end saddle. The conventional cobalt-chromium (Co-Cr) RPDs is relatively inexpensive frameworks, and it is considered to be a reliable treatment option for some patients with partially edentulous ridges. However, aesthetic is compromised and the metal increases the prosthesis weight, and there is a recorded metallic allergy in some patients, and metallic taste was reported [1,2].

In addition, conventional construction of RPD is time-consuming, and the fit to the underlying denture foundation tissues has been reported as a major complaint to some wearers of RPDs. Recently various techniques are available for the fabrication of RPDs, and they have been proven to be less extensive and the accuracy and fit to the denture foundation areas are more accurate [(3)].
The technology of computed aided design and computer aided manufacture (CAD-CAM) has been used in many dental fields successfully and showed promising results for the construction of the frameworks of partial dentures**,** CAD-CAM technique in the construction of RPDs to provide better accuracy and fit. In addition, digital planning provides a digital cast and design that can be saved to be used in the future [(4,5)].

CAD-CAM researchs including in-vitro and in-vivo studies at the designing, planning, and construction of removable prostheses is still sparse. But the available data for RPDs constructed by CAD-CAM technology provided better esthetic and similar fitting comparing to the conventionally constructed RPDs. The CAD-CAM milling technique was successful in many situations; however, it is still under development, and the new studies may provide guidelines for clinicians. Also, there is a shortage of unified protocol consensus for their indication and clinical applications [(6)].
The interest in polymers recently has grown, as they can be easily fabricated using CAD-CAM technology. Polymers are materials, which are metal-free with superior esthetics, lightweight and higher modulus of elasticity compared to conventional (Co-Cr) RPDs. There are several polymers available for the fabrication of removable prosthesis and has been used for decades including Poly-ether-ether ketone (PEEK), poly-oxy-methylene (POM), and polyamide [(7)].

One of the interesting polymeric substitutes for conventional RPDs is (POM) or acetal resin, it possesses superior esthetics, lightweight, has higher strength, and high modulus of elasticity. In addition, (POM) has a higher resistance to wear, higher hardness, and fracture toughness compared to polymethyl methacrylate. Recently, Acetal resin is also available for CAD-CAM milling technique, As, digital design and fabrication is simple technique and the resultant prosthesis is more accurate. in addition to, recent studies for color stability of CAD-CAM milled materials included PMMA, PEEK, and POM who showed the highest color stability [(8-10)].

(PEEK) is a thermoplastic polymer, and have many advantages including being biocompatible, rigid, nonallergic, with an acceptable low specific weight, high chemical and thermal stability. Also, PEEK has good mechanical properties, that did not alter with the sterilization process, either by steam, ethylene oxide, or gamma rays. In addition, decreased plaque affinity due to highly polished surface, so it did not conduct any clinical inflammation, [(11,12)].

PEEK's modulus of elasticity is low and close to the elasticity of the bone this will decrease the applied stresses on the abutment teeth and provides a cushioning effect. Therefore, the retentive forces can be improved by using wide and short clasp arms, and the clasp apex slightly overlapping the abutment tooth center [(13-15)].

So, this study was designed to address the following question; would mill CAD-CAM RPDs by using (Acetal and BEEK) provide improvement compared to conventionally Co-Cr RPDs in terms of retention for RPDs wearers?

Material and methods

This study aimed to compare between the mandibular CAD-CAM milled Acetal RPDs versus PEEK RPDs, and using conventionally constructed (Co-Cr) RPDs as a control group regarding their retention, the study approved from the Ethical Committee of The Faculty of Dental Medicine for Girls, Al-Azhar University and given approval code of (REC-PD-23-13)

Clinical steps;

Study design:

-Ten patients were selected to be partially edentulous with mandibular class I Kennedy classification while the opposing arch was completely dentulous. The patients were chosen from the Outpatient Clinic of the Removable Prosthodontic Department, Faculty of Dental Medicine for Girls, Al-Azhar University, all the subjects had lower first premolars as last standing abutment teeth bilaterally.

- All patients in this study were classified into three groups according to type of partial denture studied.

Study grouping:

A total of thirty RPDs were fabricated for ten patients. Three sets of RPDs were made for each patient and were divided into three groups;

Co-Cr group: Ten Conventional Co-Cr RPDs were constructed using the conventional technique. (Control Group).

Acetal group: Ten Acetal RPDs were constructed by CAD-CAM milling technique.

PEEK group: Ten PEEK RPDs were constructed by CAD-CAM milling technique.

Construction of Co-Cr RPD by conventional technique;

- The primary impression for the upper and lower arches was recorded by alginate impression material (Alginate impression, Cavex CA37, Cavex, Holland BV) to produce study cast, then it was surveyed using dental surveyor (Ney Dental Surveyor, Net-tech, USA).

-The undercut was blocked out, the custom lower tray was constructed from self-cured acrylic resin (Cold-Cure Acrylic, Acrostone Manufacturing, and Import Co, Egypt).

-The maxillary cast was mounted to the semi-adjustable articulator using face bow record (Hanau 96 H2 articulator, Whip Mix, Louisville, USA). While the lower cast was mounted using an interocclusal record.

-The design was drawn at the study cast as follows, the denture base was planned to be a combined denture base, RPI clasp as a direct retainer, auxiliary cingulum anterior rest as an indirect retainer, and lingual bar as a major connector after making sure there was an available space between the gingival margin of the teeth and the floor of the mouth while the tongue is activated.

- In the second session, the guiding plane was prepared at the abutment teeth's distal surfaces. Mesial rest was prepared at the abutment teeth's occlusal surface, in the form of a saucer shape and about 2mm. in depth. The cingulum anterior rests were prepared distally at the canines, bilaterally in the form of inverted V. Fluoride paste was applied to the prepared teeth surfaces.

Using the custom try, final impression was made using a medium rubber base (Silaxil Regular base, Lascod S.P.A. Sesto Fiorentino, Florence, Italy) and border tracing was made using a green stick compound (HIFLEX, Tracing Sticks, Prevest DentPro, USA),

-The silicon duplicating material was used for twice duplication of the produced master (Dupliflex, Protechno, Spain), and the duplicated casts were saved for completing the processing for (Acetal and PEEK) RPDs, the master cast was surveyed and the design was drawn, then the distal base extension area, the lingual bar major connector area, the gingival margin gingival to the guiding plane, and the gingival margin beneath the minor connector were relived.

-The modified master cast was duplicated to obtain the refractory cast fabricated from investment material; the wax pattern was applied to the refractory cast according to the previously obtained design. The wax pattern was sprued, and invested into the casting ring, wax was eliminated, and the conventional RPD was cast using Co-Cr alloy. The metal framework was finished and polished and tried intraorally Fig (1).

-The functional impression was made using the metal framework where the acrylic custom tray was added to the metal meshwork distal extension bilaterally.

- Low-fusing compound (HIFLEX, Tracing Sticks, Prevest DentPro, USA) was used for border tracing before taking the final impression for the distal extension with zinc oxide impression material (Cavex Outline, Cavex, Holland BV), and the material was allowed to set under finger pressure.

- The modified master cast was sewed at the distal extension area to accommodate the new functional impression, and the cast was poured to create the new altered cast.

-The altered cast was duplicated for future use for scanning and fabrication of (Acetal and PEEK) RPDs by CAM-CAM technology. The centric occluding relation was recorded to the record block and mounted to the articulator for artificial teeth setting up of artificial teeth (New Acryl, Cross Linked Acrylic Teeth, Egypt).

-The final dentures were processed into heat-cure acrylic resin (Heat cured, denture base, Acrostone, Egypt) then were checked intraoral for retention, stability, and occlusal harmony, and denture extension. (Co-Cr) RPDs were delivered first to all patients and the retention was evaluated at base line then after three months, fig (1,2). Then all patients were instructed to take washing out period about two weeks before they were delivered the digitally constructed RPD.

Fig (1): Co-Cr framework on the mater cast

Fig (2): Delivery of Co-Cr RPD

Digital Construction of RPDs:

-The virtual models were previously obtained by scanning of the lower duplicated altered casts for milling Acetal and PEEK frameworks using an extraoral scanner by fixing the casts on the scanner table and scanned using a 3D optical scanner (Ceramill Map400 scanner, Amann Girrbach GmbH, Austria).

-Digital surveying was made for the virtual model to decide the path of insertion and removal, and the survey line was drawn on the abutment teeth to identify areas of undercut in a different color for virtually blocking out all undesirable undercut, the data was provided by STL file.

-The same design used previously with Co-Cr framework was used for the construction of milled (Acetal and PEEK) frameworks. The components of the RPD frameworks were chosen and placed digitally on the virtual casts in the correct position using STL file format from the software, fig (2,3) .

-The milling machine (Ceramill Motion Machine, Amann, Girrbach, Austria) was used for milling Acetal discs (TSM Acetal Dental, Pressing Dental Srl, San Marino, Italy) as the milling machine received the virtual 3D design of the framework in form of (STL) fil, to start the procedure of milling to produce acetal

RPD framework. Also, PEEK blocks (Bredent Medical GmbH & Co.KG, Germany) were milled by the same technology.

Fig (3): 3-D Virtual design framewok

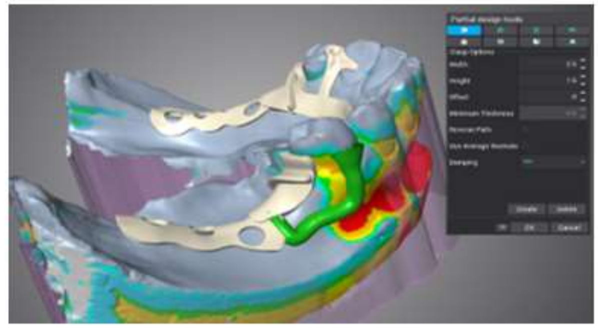

Fig (4): 3-D Virtual design on the virtual cast

-Acetal and PEEK frameworks were finished and polished following the manufacturer's instructions using non-aggressive pastes, to avoid excessive heat generation using silicone polisher's ,fig (5).
-Centric occlusion was recorded, mounted on the articulators, setting up of artificial teeth was made using the same type, shape, and size of artificial teeth that used for (Co-Cr) RPD, and finally the milled dentures were processed into heat cured acrylic resin by conventional technique as described before. Acetal RPD were delivered to each patient and was instructed to wear it for three months, fig (6).
The patients were instructed to underwent a rest period for two weeks before they were delivering the PEEK RPDs. Retention of digitally constructed RPDs were evaluated at the base line and three months from denture insertion.

Fig (5): Try in of milled PEEK RPD denture base

Fig (6): Delivery of finished milled Acetal RPD

Evaluation of the retention:

- Universal testing machine was used to measure the force of retention (INSTRON, USA) through recording the denture resistance to vertical dislodging force of Co-Cr, Acetal and PEEK RPDs at time of delivery and after three months from insertion using the following technique; the lower RPD was inserted intraorally after hooks were attached bilaterally to the buccal flange of the denture at the bicuspid area using cold-cure acrylic resin.

- To ensure complete fixation, the patient was instructed to sit in front of the force gauge stand device, resting his chin at the chin support area of the device to keep his lower occlusal plane parallel to the floor, the fork was attached to the hook intraorally at the pull end.

-The force gauge was moved vertically perpendicular to the lower occlusal plane of the patient and to the base of the device using the wheel in the stand of the gauge. the pull force required to dislodge the RPD framework from its place was measured using the force gauge, while the wheel was turned to move it in a tissue-away direction until vertical dislodging occurs, Fig (7).

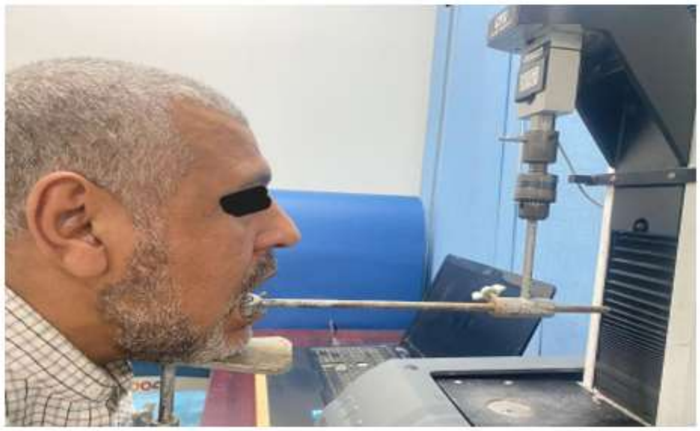

Fig (7): Retention measurement using Universal testing machine.

-All data were recorded for each patient and the mean was reported at the time of delivery, and after 3 months of insertion. Data were collected and statistically analyzed to compare the retention of the three dentures

STATISTICAL ANALYSIS

All data was collected, tabulated, and statistically analyzed using commercially available software program (SPSS Chicago, IL, USA), version 23.

RESULTS

The results for retention test statistical analysis for Cr-Co, Acetal, and PEEK frameworks as determined using One Way ANOVA test followed by post hoc analysis using LSD test, where the confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant at level of P-value < 0.05, and were summarized in **Table (1)** and graphically represented in **(Figure 4).**

The statistical analysis of retention of the tested groups at base line revealed that; the difference between the tested groups was statistically highly significant ($p \leq 0.000$). Where; the heights (mean ± SD) values of retention were recorded for Co/Cr group (44.41 ± 2.26) followed by Acetal group (39.70 ± 1.70), while the lowest (mean ± SD) values of retention were recorded for PEEK group (36.70 ± 3.17) frameworks respectively.

The statistical analysis of retention of the tested groups after three months revealed that; the difference between the tested groups was statistically highly significant ($p \leq 0.000$). Where; the heights (mean ± SD) values of retention were recorded for Co/Cr group (41.77 ± 2.92) followed by Acetal group (37.68 ± 2.52), then while the lowest (mean ± SD) values of retention were recorded for PEEK group (34.15 ± 3.17) frameworks respectively

The statistical analysis of retention values between the baseline and after three months in each tested group revealed that; A significant differences ($p \leq 0.001$. $p \leq 0.01$ and $p \leq 0.001$) in (Cr-Co, Acetal and PEEK) frameworks respectively. While the retention value was high at baseline and decrease with time, but the amount of change in the retention value was nearly similar in all tested groups P value=0.592.
The statistical analysis of retention values by using Post Hoc analysis revealed that; there was a significant difference ($p \leq 0.001$ and $p \leq 0.004$) in Co-Cr Vs Acetal groups at baseline and after three months.
The statistical analysis of retention values by using Post Hoc analysis revealed that; there was a significant difference ($p \leq 0.001$ and $p \leq 0.001$) in Co-Cr Vs PEEK groups at baseline and after three months.
The statistical analysis of retention values by using Post Hoc analysis revealed that; there was a significant difference ($p \leq 0.01$ and $p \leq 0.01$) in Acetal versus PEEK groups at baseline and after three months.

Table (1); Comparison between the retention values of Cr-Co RPDs group and those constructed by CAD-CAM technology (Acetal and PEEK groups)

		Co-Cr group	Acetal group	PEEK group	Test value	P-value	Sig.
		No. = 10	**No. = 10**	**No. = 10**			
Baseline After one week	Mean ± SD	44.41 ± 2.26	39.70 ± 1.70	36.70 ± 3.17	25.037•	0.000	HS
	Range	40.92 – 47.41	36.12 – 41.74	31.34 – 41.63			
After 3 months	Mean ± SD	41.77 ± 2.92	37.68 ± 2.52	34.15 ± 3.17	17.500•	0.000	HS
	Range	37.12 – 45.43	33.24 – 40.34	30.23 – 39.91			
Paired t-test	**T**	9.806	3.259	6.697			
	P-value	<0.001	0.010	<0.001			
Amount of change	Mean ± SD	-2.63 ± 0.85	-2.03 ± 1.96	-2.54 ± 1.20	0.535•	0.592	NS
	Range	-3.8 – -1.58	-3.98 – 2.2	-4.29 – -0.49			

Post Hoc analysis			
	Co-Cr Vs Acetal	**Co-Cr Vs PEEK**	**Acetal Vs PEEK**
Baseline	<0.001	<0.001	0.011
After 3 months	0.004	<0.001	0.011

P-value > 0.05: Non-significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant
•: One Way ANOVA test

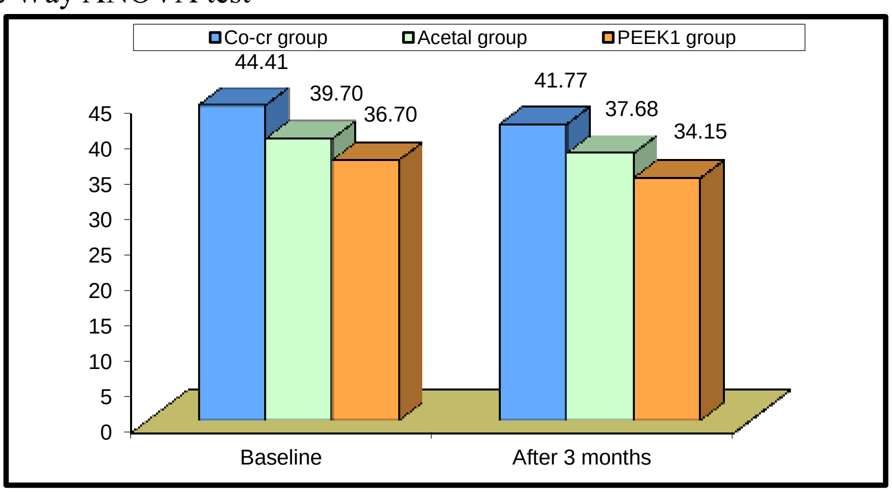

Fig. (4) Comparison between retention values of Cr-Co, Acetal and PEEK RPDs groups in follow up periods.

DISCUSSION

The question of searching for a material with ideal properties for fabricating the removable partial denture frameworks remains a matter of concern to researchers. Although many materials (metallic and polymeric) are available for denture construction, none of these materials meet all of the ideal requirements for partial denture components. [16]

To date, Cr-Co alloys are considered one of the most popular metal alloys used in the Construction of RPD frameworks. This is due to their high hardness, excellent resistance to corrosion and oxidation, lower price, and their thermal conductivity [17]. However, it has some defects, such as inflammatory reactions to the oral tissues, the existence of a metallic taste, and the failure to meet the patient's aesthetic requirements in cases where the retainers of the clasps appear [18].

The demand for RPDs that reveal little or no metallic retentive elements or supporting structures has increased as the demand for aesthetics dentistry has increased. (Acetal and BEEK) resins were improved to meet the patient's aesthetic needs, so they are being still under research for use in RPD frameworks, as (PEEK) has excellent chemical and mechanical properties, as well as perfect aesthetic characteristics. [19].

In this research, the retention values of (Co -Cr) RPD are higher than Acetal resin, which is consistent with Sato Y et al [20] because of lower retentive forces of acetal clasps are associated with higher flexibility of this resin in comparison to Co-Cr alloy. In Turner J et al's point of view, [21] to achieve stiffness comparable to that of a casted clasp of Co-Cr, acetal clasps must increase in cross-sectional area while decreasing in length, as both factors contribute to increased material rigidity.

In this study, the retention values of Co-Cr RPDs are higher than PEEK at insertion and after three months, and this is in agreement with Tribst et al who found in two in-vitro studies that Co-Cr alloy clasps showed higher retentive forces than PEEK clasps; in addition to, this study claimed that PEEK material should not be used for clasp fabrication due to how the stress values recorded during insertion and removal of clasps with deeper undercuts were higher than the material strength. [22]

This study hence concludes that the Co-Cr RPDs used in fabrication of removable prosthesis has superior retentive forces than the milled (acetal resin and PEEK) as the denture removal requires incredibly low retentive forces. This come in agreement with recent study stated that, the reported values of retention force of PEEK clasps were smaller than the observed values of Co-Cr clasps [23]. On the other hand, Evaluation of retention of digitally processed and conventional processed RPDs took place. The digitally processed RPDs were shown to be more retentive as they weren't associated with human intervention [24].

In this study, the use of milled (Acetal resin and PEEK) was proposed as executable RPD framework preserving both the abutments and residual ridge through comparing its clinical effects with that of casted Co-Cr frameworks in addition to improving esthetics, Given the limitations of the current study; the number of the patients involved, limited follow-up period that should be longer to make accurate estimation of bone resorption by radiographic evaluation and complete standardization of design of the frameworks, more recent studies should be taken into consideration.

However, a clinical usage of both (Acetal and PEEK) clasps is recommended, as the retentive clasp arm fabricated by milled (Acetyl resin or PEEK) aids in engaging deeper undercuts on the abutments than the cobalt chromium due to how flexible it is, and the long-term resiliency of polymeric RPDs. [25]

CONCLUSION

Within the limitations of this study, it can be concluded that, using CAD-CAM technology can be a promising alternative to conventional technique. Although metallic prosthesis showed higher retention values, recent CAD-CAM technology by milling polymeric materials (Acetal and BEEK) recorded retention sufficient enough to recommend using it under some clinical conditions; as when aesthetic demand or periodontal health is a primary concern.

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