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# Clinical Evaluation of Conventional Maxillary Heat-Cured Acrylic Single Denture Versus PEEK: A Crossover Study of Retention

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## *ABSTRACT*

**Purpose**: This clinical study aimed to evaluate the retention quality of conventional heat-cured poly methyl methacrylate (PMMA) compared to Poly Ether-Ether Ketone (PEEK) maxillary single dentures. **Materials and Methods:** Ten participants were eligible having completely edentulous maxillary arches opposed by class I Kennedy mandibular arches. Every patient received two maxillary single dentures fabricated by two different materials and techniques utilizing a crossover design. Each patient was provided with a single maxillary conventional PMMA denture fabricated by the conventional technique (group I) and a PEEK single maxillary denture fabricated by CAD /CAM technique (group II). The force-meter was implemented to measure the retention of the maxillary single dentures at time of denture delivery (T0) and then after 3 months of insertion (T3). Every denture was subjected to a slowly increasing vertical load until it was totally out of place (that was for 5 times at 10-minute intervals). The average retention of maxillary single dentures of both groups was analyzed using Paired t-test. **Results:** CAD/CAM PEEK maxillary single dentures showed statistically significant higher mean retention values than conventional heat-cured maxillary single dentures at time of insertion ($P = 0.031$),also, after three months post insertion ($P = 0.04$). **Conclusions:** CAD/CAM (PEEK) maxillary single dentures offered significantly higher retention than that of conventional heat polymerized single dentures. CAD/CAM (PEEK) maxillary single dentures could be a suitable choice when retention improvement is required. **Recommendation:** More long-term studies of variant evaluation methods are thus required to validate the results of this study.

***KEYWORDS***

*Heat cure, CAD/CAM, PEEK, Retention, single denture.*

## INTRODUCTION

Despite the variety of treatment methods for edentulous patients, the conventional complete denture (CD) treatment still prevails [(1)]. Nevertheless, some problems may arise after insertion of CDs. Of

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these problems; frequent complaints of insufficient retention, inadequate stability, tissue irritation, ulceration, and occasionally faulty esthetics [2].

However, many researches advocated implying CDs to rehabilitate the edentate maxillary arches. When care of the edentulous maxilla is considered, hence, the standards of patients for social, phonetic and esthetics as well as recovery are deemed requisite. Those standards could be fulfilled by employment of full maxillary dentures as a prosthetic intervention [3].

Combination syndrome or (anterior hyper function syndrome) denotes those patients having edentulous maxilla opposed by partially edentulous mandibles (anterior teeth only remain). This syndrome represents serious challenges to the prosthodontist ascribed to progressive damaging changes accompanied it. The prosthetic intervention is thus rendered more difficult by reason of signs and symptoms associated with combination syndrome. Obviously, implying dental implants for boosting both retention and support to the prostheses was currently reported in the literatures. Howbeit, some cases are yet in need for the conventional prosthetic treatment on the ground of either medical or economic reasons [4].

For those patients, the key factor in prosthetic rehabilitation success relies on targeting the appropriate stability, retention, and support of their prostheses that in turn enable them to resist the mechanism of combination syndrome and associated principal causing factors. These factors include; forces of high magnitude, unsuitable denture foundation and inappropriate occlusal contacts created by the remaining natural teeth. Moreover, using of the prostheses properly in the process of mastication is believed to be another crucial factor [4, 5].

The proper denture base material should have; good esthetics, biocompatibility, radiopacity, high bond strength with denture teeth and ease of repair. Additionally, it must be strong enough to tolerate functional and parafunctional masticatory forces. One of the most prevalent materials for CDs fabrication is polymethyl methacrylate (PMMA) [6]. It was reported to have a satisfactory combination of properties that factually accounts for its acceptance of use. Poly methyl methacrylate is a material that is synthetically obtained. It can be molded, packed, or injected into molds and it is turned into solid by chemical reaction (polymerization). They may be heat, chemically or light cured [5].

Poly methyl methacrylate is believed to be advantageous thanks to its excellent esthetics, ability to repair, simple processing techniques and lack of toxicity [6]. Besides the great benefits PMMA offers, there are some downsides that restrict its use. These drawbacks are; prone to high polymerization shrinkage, dimensional instability, and complicated processing procedures. Such downsides affect denture retention, mastication and speaking ability. Thereupon, needs were raised for novel techniques to overcome complete dentures downsides [7].

Incorporating Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) technology into CDs design and fabrication undoubtedly enhances dentures' quality and reduces lengthy laboratory work and procedures as well. CAD/CAM fabrication of CDs is attained by either subtractive Computerized Numerical Control (CNC) milling manufacturing, or by additive manufacturing via three-dimensional (3D) printing known as rapid prototyping (RP) [8].

The subtractive manufacturing utilizes end milling of solid block materials to produce physical model utilizing CNC machinery. Although the subtractive method is effective in CD fabrication, it exhibits some drawbacks. Such drawbacks involve; the large amount of wasted material while milling. Moreover, the milling tools are exposed to high abrasion and wear. On top of that, it cannot be used in deep undercut [9].

On the other hand, additive manufacturing is a process which represents layer by layer joining

to produce models relying on computerized 3D data. Additive manufacturing using 3D printers has drawn attention in the prosthetic dentistry field. Such technique comprises the ability to mold material based on CAD data. Eventually, this would influence the mechanical properties of the printed parts, the overall quality, and the time of manufacturing [10].

Poly ether-ether ketone has outstanding mechanical properties, high mechanical strength, low density, certain ductility, white color as well as dampening properties. Along with that, it is characterized by low solubility (0.5%), good biocompatibility, high heat resistance, water absorption values under different aging solution and maximum degree of crystallinity (48%) [11].

The retention of the denture is defined as the resistance to the denture movement away from its tissue foundation particularly in the vertical direction [12]. Total denture retention is a dynamic phenomenon, involving several variables. Concerning edentate patients, the dentures retention is of their prime concern. Masticatory efficiency was reported to be basically impacted by the retention of the denture and stability as well [13].

Poly ether-ether ketone is thought to be an innovative substitution material to PMMA. Nonetheless, little is known in the current available literatures assessing the PEEK polymer as a restorative dental material. Thence, the objective of the current study was to assess the retention of both single maxillary dentures made of PEEK and PMMA taking into the account that adequate retention is a crucial factor determining the CDs success by their wearers.

The null hypothesis was that no difference will be present in retention among the conventional heat cured PMMA acrylic single dentures compared to PEEK maxillary single dentures.

## MATERIALS AND METHODS

Ten participants were eligible and classified according to their characteristics (age, sex, arch form, and arch size) (Table 1). The patients were selected from the Outpatient Clinic, Prosthodontics Department, Faculty of Dentistry, Mansoura University, Egypt.

Each participant in the current study was provided with two single maxillary dentures in a random manner. All patients received two maxillary single dentures fabricated by two different materials and techniques utilizing a crossover design; maxillary conventional heat cured PMMA denture fabricated by conventional technique (group I) and PEEK denture fabricated by CAD /CAM technique (group II). The present study has been approved by Ethics Committee (No: 180501217), Faculty of Dentistry, Mansoura University. All the selected participants have been notified about the treatment plan and procedures in detail, in addition to the required follow-up recalls, then, they all signed written consents.

**Table (1)** *List of participants and their characteristics:*

| Characteristic | Number | Percentage % |
|---|---|---|
| **Age (y), mean ±SD** | 65.6± 7.87 | |
| **Sex** | | |
| Male | 7 | 70% |
| female | 3 | 30% |
| **Arch form** | | |
| Square | 5 | 50% |
| Round | 3 | 30% |
| Tapered | 2 | 20% |
| **Arch size** | | |
| A | 6 | 60% |
| B | 2 | 20% |
| C | 2 | 20% |

**Patient selection**

All patients had completely edentulous maxillary arches opposed by six anterior teeth and first premolars (Fig. 1). The patients had no local or systemic disorders (especially those that may affect the retention as diabetes mellitus with history of loose denture complaint). This was affirmed by taking the history coupled with laboratory examinations. They had well-formed maxillary ridges covered with firm mucosa with no bony undercuts to avert its effect on retention. Also, they had no or slightly unilateral, bilateral, distal, or anterior undercuts on the maxillary arch in addition to have satisfactory denture bearing tissue. All the participants were willing to participate and cooperate throughout the entire study.

Figure (1) Preoperative completely edentulous maxillary arches opposed by six anterior teeth and first premolars.

**Dentures Fabrication:**

For each patient, preliminary maxillary and mandibular impressions were registered by irreversible hydrocolloid impression material (Alginate Cavex, Holland, normal set impression material). The mandibular diagnostic cast was surveyed to draw the survey line and measure the depth of retentive undercut used for the design of R P D. occlusal plane orientation was performed for mandibular anterior teeth and first premolars to correct any occlusal plane discrepancies.

- Final impressions were recorded using silicone impression material (poly-C-silicone impression material, thixoflex M, medium, Zhermack, Italy) after applying an adhesive (Universal Tray Adhesive, impression silicones, Zetaplus, Zhermack, Italy) and molding the borders with Putty C-Silicone.
- Final maxillary and mandibular impressions were poured in dental stone (Zesus Dental Stone hard type, Italy) to get the master casts.
- Duplication of the maxillary mater cast was carried out (one cast for each denture).
- Upon the mandibular master cast, blocking out of all undesirable undercuts was accomplished. RPA clasp assembly (mesial occlusal rest, proximal plate, Aker retentive arm clasp) was chosen for the mandibular RPDs. Thus, the first premolars were blocked out at the distal half of the buccal surfaces for RPA clasp design. Duplication of the modified master cast (Zesus Dental Stone hard type, Italy) was completed. Thereafter, fabrication, investing, burning out and casting of the wax pattern with chromium cobalt alloy were all accomplished. Afterwards, the metallic frameworks of RPDs were tried in the patients' mouths.

**Construction of record blocks and establishment of Jaw relations:**

For both groups, mandibular acrylic trial denture base (Cold cure denture base material, Acrostone, England) with wax occlusion rims was constructed.

- **For (Group I):** upon the maxillary master cast, the acrylic trial denture base with wax occlusion rims was constructed.
- **For (Group II):** upon the duplicated maxillary master cast, the trial denture base made of PEEK and wax occlusion rims was fabricated. PEEK framework was performed by conventional lost wax technique. The wax model was made by using CAD/CAM machine.

**PEEK framework construction by injection molding technique:**

- After scanning of the master cast, construction of PEEK framework was performed by conventional lost wax technique. The wax model was made by using CAD/CAM machine Fig. (2) and Fig. (3).
- The wax model was fitted to the master cast and invested with a special phosphate- bond investment material (Brevest investment material for 2 press) in a special silicon ring.
- The mold was pre-heated up to 630°C-850°C. That was carried out to melt the wax away in addition to control the investment material expansion and then cooled at 400°C. At this temperature, PEEK granules have been brought to the cylindrical reservoir of investment mold, the melting procedure is conducted in the preheating oven. The melting temperature (400°C for maximum 20 min.) must be precisely noticed and controlled.
- After completely melting of PEEK granules, the cylindrical reservoir was being inserted by the press plunger, the investment mold was transferred to (for 2 press system). By raising the lift, the pressing step was full automatically accomplished and executed in a vacuum within 35 minutes. The automatic pressing procedure ended, and it was recognized by an acoustic signal and the blue LED light.
- The mold was cooled down to room temperature and it was devested as usual. Disconnection of the framework from the sprues was performed then finished as usual.

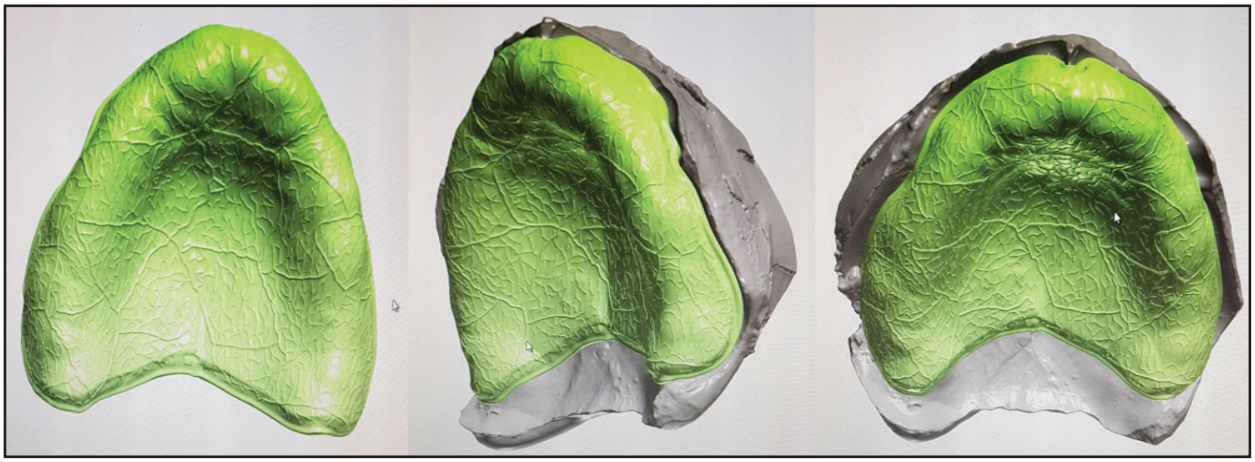

Figure (2) PEEK framework virtually designed in CAD software.

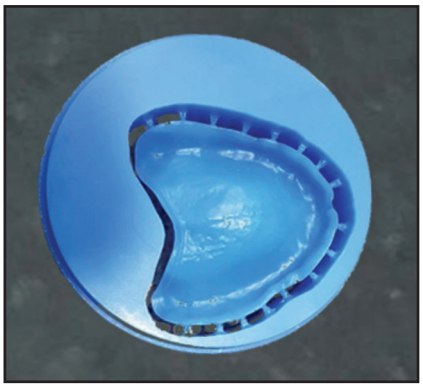

Figure (3) Maxillary denture base wax template

- The PEEK denture base was tried in the patient's mouth and the wax occlusion rim was constructed.
- For both groups, maxillary record blocks and mandibular acrylic trial denture base (Cold cure denture base material, Acrostone, England) with wax occlusion rims were used to record the maxillomandibular relations.
- Each maxillary cast was mounted on a semi-adjustable articulator (Hanau model H, Teledyne

Buffalo, New York, USA) using maxillary facebow (Hanau engineering company, Inc., Buffalo, New York). Centric jaw relation was taken employing wax wafer technique. At the pre-established vertical dimension of occlusion, the centric jaw relation record was taken from the patient to mount the mandibular cast on Hanau articulator.

- Conforming to the patient needs (age, sex, arch dimension, etc.), acrylic resin teeth (Acrostone plas cross linked acrylic teeth, Egypt) were chosen accordingly. The artificial acrylic teeth have been arranged. Waxing up of the denture was made then the waxed denture was checked in the patient mouth.
- For (Group I) and mandibular denture, conventional processing method was followed. The dentures were made from conventional heat cure acrylic resin (Acron Duo, Associated Dental Products Ltd., Kemdent, Purton, Swindon, Wiltshire, UK). Flasking procedures, wax elimination, processing, deflasking followed by finishing and polishing of the dentures were all executed according to the routine conventional method. Fig. 4( a and b).
- For (Group II): white resin teeth were utilized for teeth printing (Next Dent Teeth, Netherlands) to be attached to the PEEK denture base (that was previously fabricated by injection mold technique). The teeth were attached to recessed pockets in denture base via resin followed by finishing. Eventually, the denture was placed in the post curing unit (Mogassam, Egypt) Fig. 5(a and b).
- For both groups, clinical assessment of the retention, support, stability, occlusion, esthetics, and phonetics were carried out. Any necessary adjustments were made prior to delivery of the dentures.
- Evaluation of the occlusal relationship was performed using articulating paper, and any detected premature contacts were adjusted. Instructions of denture insertion and oral hygiene measures were given to the patients Fig (6).

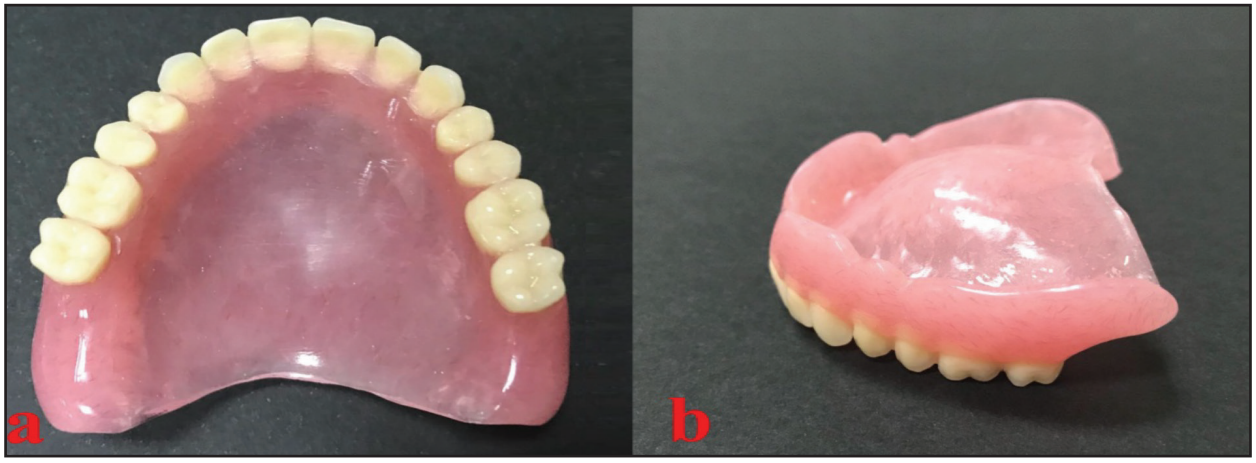


Figure (4) **a.** Polished surface of conventional maxillary heat-cured acrylic single denture. **b.** Intaglio surface of conventional maxillary single denture.

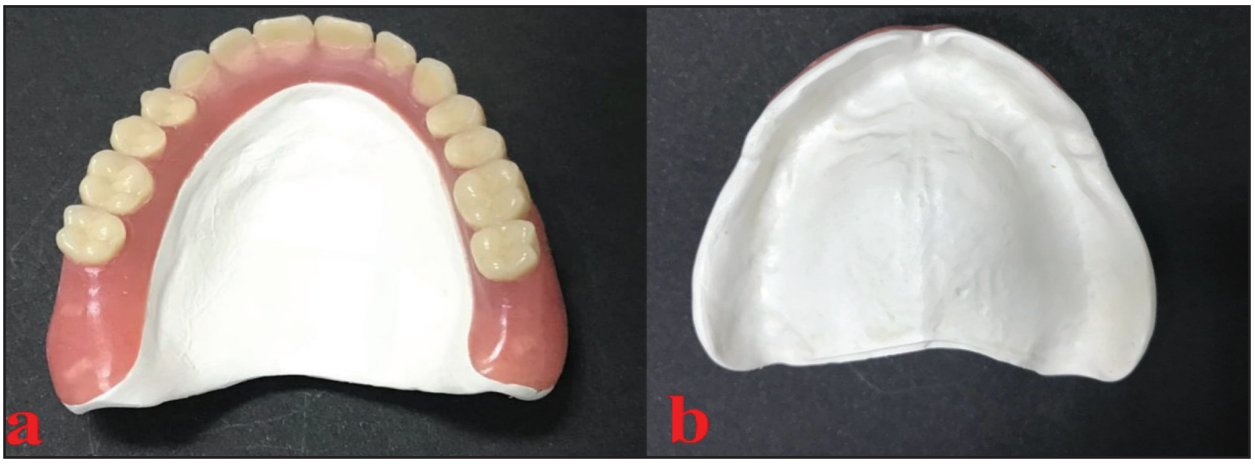


Figure (5): **a.** Polished surface of PEEK maxillary single denture. **b.** Intaglio surface of PEEK maxillary single denture.

Figure (6) PEEK maxillary single denture inserted in the patient mouth.

**Evaluation of Retention:**

Evaluation of retentive force of both maxillary heat cure acrylic resin and PEEK CAD/CAM dentures were measured at time of denture insertion (T0) and three months (T3) following each denture delivery (to enhance muscular adaptation) considering at least 1-2 weeks as a resting period in between. The evaluation was performed by a digital force-meter device [14] (Mecmesin Corp, Virginia, USA) as following:

The participant was asked to sit in an upright position with the head resting. A dislodging force was exerted by the digital force-meter device vertically on the maxillary complete denture. The pull end of the device was used to engage the attached four hooks attached to the maxillary denture (two on the buccal surfaces on each side of the maxillary denture) Fig. (7). Then it was pulled vertically downward until the denture was out of place [15,16]. Fig. (8). The force was recorded in Newton and measured as retention. For each participant, the test was repeated five times at 10-minute intervals to obtain five records; the mean of them was then calculated. The data was collected and analyzed.

Figure (7) Four right -angle metal hooks were attached to the denture.

Figure (8) Digital force-meter device for retention evaluation.

**Statistical analysis:**

Analysis of data was conducted using the Statistical Package of Social Science (SPSS) program for Windows (Standard version 21). Shapiro test was used to test for the normality of data.

Continuous variables were presented as mean ± SD (standard deviation) for normally distributed data. The two groups were compared with independent t- test. the threshold of significance is fixed at 5% level.The results were considered significant when $P \leq 0.05$.The smaller the p-value obtained, the more significant are the results.

## RESULTS

Table (2) and Fig. (9) revealed that CAD/CAM PEEK dentures group (II) showed statistically significant higher mean retention values ($P = 0.031$) than conventional PMMA dentures group (I) at time of insertion (T0). For (group I), the mean was (28.6±5.69 N) while for (group II), the mean was (41.8±7.50 N).

After three months of dentures delivery (T3), the retention mean values of the CAD/ CAM dentures group (II) were statistically significantly higher ($P = 0.04^{*}$) than the retention mean values as shown in Table (3) and Fig. (9). For group (I), the mean was (32.9±5.52N) while for (group II), the Mean was (44.7±7.22 N).

**Table (2)** *Comparison between group (I) and group (II) at time of denture insertion (T0).*

| | X | SD | Min | Max | T Test | P Value |
|---|---|---|---|---|---|---|
| **Group I** | 28.6 | 5.69 | 23.3 | 35.1 | 2.82 | 0.031* |
| **Group II** | 41.8 | 7.50 | 34.2 | 51.8 | | |

*X: Mean, SD: standard deviation, *Indicates significant difference at 5% level.*

**Table (3)** *Comparison between group (I) and group (II) after 3 months of denture (T3) insertion.*

| | X | SD | Min | Max | T Test | P Value |
|---|---|---|---|---|---|---|
| **Group I** | 32.9 | 5.52 | 27.1 | 39.4 | 2.61 | 0.04* |
| **Group II** | 44.7 | 7.22 | 38.2 | 54.2 | | |

*X: Mean, SD: standard deviation, *Indicates significant difference at 5% level.*

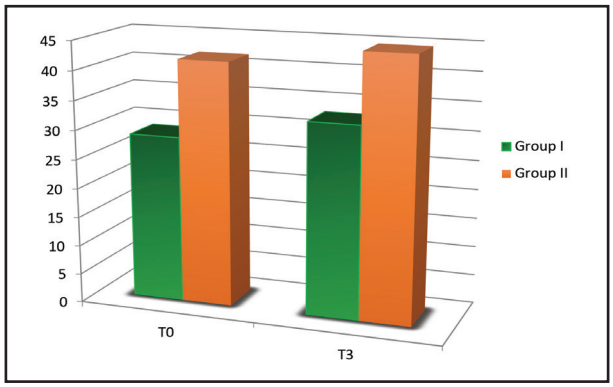


Figure (9) Bar chart shows comparison between group (I) and group (II) at different evaluation time (T0) and (T3).

## DISCUSSION

Contrary to other study designs, the crossover study enables the participants to experience all therapeutic approaches and to personally compare them. Furthermore, standardization of both subject and denture factors could be permitted by crossover studies. Likewise, regarding patient satisfaction with each prosthesis, the crossover study permits more precise comparing between the prostheses [17].

In the current study, the retention of maxillary single dentures constructed by conventional and 3D printed techniques were compared. Retention is an inherent factor that greatly influences patient satisfaction, which is considered as an important outcome that enables better evaluation of success of any prosthesis [18].

Several studies have proven that the dentures fabricated by conventional processing techniques suffer from dimensional changes due to

polymerization shrinkage and release of internal stresses. The resulting distortion compromises retention besides support and stability of the denture, which lead to adverse consequences on the patient's satisfaction. In turn, this assured the need for advanced techniques concerning fabrication of complete dentures [19].

The findings of this study exhibited superiority in the retention of the 3D printed dentures (PPEK) over the conventional dentures (PMMA). This could be attributed to the denture construction technique which has been utilized. This technique was used as it allows material conservation and displays the ability to print complex geometries with reasonable dimensional accuracy. This finding was concurred to an earlier study [20] which announced that 3D printed dentures elaborated better retention in comparison with CDs. This is mostly owing to that 3D printed denture demonstrated less shrinkage and distortion, along with consistent better adaptation compared to conventional dentures. The explanation is also in consonance with a previous study [21]. The authors concluded that 3D printed dentures presented better retention. They added that independent of denture type, retention improved over time.

In this context, the results are conforming to other previous studies [22-24]. The authors stated that prolonged success of prosthesis is pivoted on the optimum fit attained between the denture base and mucosal tissue, which in turn yields good retention. The authors declared that higher deformation was reported in the conventionally made dentures, whilst less deformation was associated with CAD/CAM fabricated denture bases. These studies used surface matching software focused on accuracy of the denture base.

In this study, upon comparing the retention values at denture insertion and after three months of insertion, CAD/CAM dentures showed statistically significant higher retention values over the conventional heat polymerized PMMA dentures .The results are going along with the reports of a former study [25]. The investigators affirmed that CD bases, that were milled, offered significantly greater retention than denture bases which were conventionally fabricated. This may be ascribed to the dimensional changes and the resulting distortion, especially at the post-dam area, due to water sorption of the conventional resin. The authors concluded that it was a probable advantage of digital dentures.

Poly ether-ether ketone was proclaimed to be involved as a framework material for CDs to reduce the incidence of denture deformation accountable for midline fractures. Nonetheless, slight reinforcement to CDs could be offered by frameworks of PEEK having 1 mm thickness. However, greater reinforcement could be provided by more rigid materials such as nano-zirconia (N–Zr), fiber reinforced composite (FRC), cobalt-chromium-molybdenum alloy with a thickness of 0.5 mm [26].

In that respect, PEEK was believed to be a suitable denture base material that resists notch concentration and fracture as well. That may be clarified by alike deformation of PMMA as well as PEEK due to their comparable elastic moduli which are 4 GPa and 2.7 GPa respectively [27]. Likewise, according to a preceding investigation [28], the authors inferred that denture bases made from PEEK displayed higher impact and tensile strengths compared with PMMA. Besides, the authors affirmed that after polishing of PEEK material, surface roughness was lowered, and stain resistance was better attained compared to PMMA. Hence, PEEK was rendered as a suitable material for fixed and removable dental prostheses fabricated by CAD/CAM. This was owing to its appropriate mechanical, physical and chemical properties [29].

From that prospective, the diminution of polymerization shrinkage of CAD/CAM CDs may result in a highly precise denture fit and eventual enhancement of retention. This is in keeping with a former study [30]. The investigators stated that great retention and proper suction effect of the CDs could be resulted from improvement of fit attributable to

lack of polymerization shrinkage. Also, the surfaces of master casts could be more accurately and precisely reproduced by CAD/CAM systems than traditional manufacturing procedures [25, 31,32].

Overall, the null hypothesis was rejected in the current study.

## CONCLUSIONS

Within the limitations of the current clinical study, the following conclusions were revealed:

1. CAD/CAM (PEEK) maxillary single dentures offered significantly higher retention than that of conventional heat polymerized dentures and PEEK is a suitable choice when enhancing retention is required.
2. CAD/CAM (PEEK) maxillary single dentures are much better than the traditional procedure in simplifying the laboratory procedures besides reducing chair times as well as with keeping the treatment quality. Furthermore, the CAD/CAM technology can use a material that is equipped with innovative properties.

## RECOMMENDATION

More long-term studies of variant evaluation methods are thus required to validate the results of this study.

### Conflict of Interest

No conflicts of interest in connection with this article have been explicitly stated by the authors**.**

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