Computer-aided Design and Computer-aided Manufacturing Fabricated Polyoxymethylene used for Maxillary Removable Partial Denture Framework

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Abstract
The increasing need for a dental substitution of partially edentulous has resulted in the development of removable partial denture (RPD) material and fabrication technique. Polyoxymethylene (POM) or acetal resin is one of an interesting alternative material for RPDs due to superior esthetics, high strength, elasticity and lightweight. Furthermore, POM is available to design and fabricate using computer-aided design and computer-aided manufacturing (CAD-CAM) systems that are used for RPDs fabrication due to more simple procedure and more accurate fit compare to the conventional. The aim of this case report was to describe the treatment for upper partially dentate patient who had no desirable of metal-color and heavyweight denture.

POM was chosen as a RPD framework material and combined CAD-CAM system in design and fabrication. 3D model was scanned from master cast owing to higher precise technique for capturing the physiologic extension in tissue-borne RPDs. The framework component was similar to conventional RPDs. Nonetheless, differences are the thickness of all components must be 2.0 mm for adequate strength of denture and except for direct retainers that should be thicker (1.5 mm) and engage deeper undercut (0.5 mm) than metal clasp. Air abrasion on POM which is low surface energy material, must be done to increase surface area on account of being main adhesion between framework and polymethylacrylate of mechanical retention.

The combination of CAD-CAM technique and POM block in fabrication of maxillary RPD framework resulted in accurate fit of denture; more lightweight and more pleasurable wear as a non-metal denture. After 1 year of use, denture revealed well-condition and proper function. Using POM for RPD framework in this article showed patient satisfaction on the appearance with no metal display and also lighter weight of denture. The fabrication technique was a convenient method and created precisely fitting of denture framework led to reduction of insertion time.

Keywords: Acetal, CAD/CAM, Polyoxymethylene, Prosthodontics, Removable partial denture.
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Introduction
The growing number of elderly persons in the global population and increased life expectancy has resulted in a greater proportion of partially dentate adults.¹ ² ³ The objective of replacing teeth and associated structures is to improve appearance and masticatory efficiency, to prevent undesirable tooth migration and to improve phonetics.⁴ Removable partial denture (RPD), one of the favorable options, is chosen by dentists when the length of edentulous ridge contraindicates a fixed partial dentures, as ridge support is needed, or there is a guarded prognosis of their periodontal condition. In addition, the advantage of RPDs is to overcome financial constraints and provide more convenient hygiene access.¹ ⁵ Several studies have indicated that an unaesthetic appearance is a component of RPDs, leading to prosthetic failure.³ ⁶ To overcome esthetic issues, the denture fabricated technique and materials were developed.

The problems of RPDs include: patient dissatisfaction, compromised function, esthetics and oral health.⁷ Therefore, for success of RPDs,
it is important to minimizing future problems by accurately planning and custom fabrication for individual patient's need. The conventional RPDs fabrication process uses direct waxing method to design a stone cast. Nowadays, Computer-aided design and computer-aided manufacturing (CAD-CAM) systems are widely used in dentistry to fixed restoration, implant and to design and fabricate a removable prostheses. While the conventional fabrication of RPDs is complex, error-prone and time consuming; CAD-CAM technique using milling technique in denture fabrication was proven to be better in accuracy than conventional technique.

Metal-based dentures have been replaced with high-performance polymers because of the unesthetics metal-color, heavy weight and metal allergies of the patient. Contrastingly, polymers is metal-free material which have better esthetics, higher elasticity and are lightweight. Apart from properties, interest in polymers has grown due to their easy of fabrication by using CAD-CAM technique. There are various types of polymers that suitable for denture fabrication that was used for decade such as polyamide, polyoxymethylene (POM) and polyetheretherketone (PEEK). A case report of using PEEK as a framework of denture indicated good denture adaptation and patient’s satisfaction of lightweight of denture. Polyoxymethylene or acetal resin is formed by polymerizing formaldehyde. POM has been widely used in the automotive industry and become competitive with metal. Because of high percentages crystallinity, POM shows high stiffness, high fatigue resistance and good appearance. POM is higher wear resistance, fracture toughness and microhardness in comparison with polymethylmethacrylate (PMMA). Furthermore, POM has been used in medical field as an implant material because of good biocompatibility, chemical and thermal stability. In 1986, it was first used in dentistry as an alternative material for denture base and denture clasp owing to its superior esthetics and strength. In use as a clasp, POM clasps had no deformation while a metal clasps loose retention, although previous studies revealed that POM had lower retention than metal. However, the increasing of thickness and undercut of POM clasp provide sufficient retention in clinical use. Furthermore, POM had low water and color staining. Thus, the use of POM as a clasp has adequate scientific evidence without any controversy. At present, POM is available in CAD-CAM blanks that are appropriate for digital dentistry era. The property of materials used for removable partial denture framework is compared in table 1.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Ideal requirement</th>
<th>Type of materials</th>
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<tbody>
<tr>
<td>Biological</td>
<td>Biocompatible</td>
<td>Allergic to metal</td>
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<td>Allergic to manomer</td>
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<td></td>
<td></td>
<td>Biocompatible</td>
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<td>Mechanical</td>
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<td>Modulus of elasticity</td>
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<td>elasticity</td>
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<td></td>
<td>100-220 GPa</td>
<td>3-5 GPa</td>
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<td></td>
<td>High Flexural</td>
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<td></td>
<td>strength</td>
<td></td>
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<tr>
<td></td>
<td>~2500 MPa</td>
<td>~70 MPa</td>
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<td></td>
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<td>~120MPa</td>
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<tr>
<td>Physicaks</td>
<td>High Thermal</td>
<td>Thermal conductivity</td>
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<tr>
<td></td>
<td>conductivity</td>
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<tr>
<td></td>
<td>9.4 Wm.K</td>
<td>0.21 Wm.K</td>
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<td></td>
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<td>0.3-037 Wm.K</td>
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<td>Others</td>
<td>Good esthetic</td>
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<td></td>
<td>Metal color</td>
<td>Nearby natural tooth</td>
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<td>and tissue color</td>
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<td>More color and vary capcity</td>
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<td></td>
<td>Low cost</td>
<td>Higher cost than PMMA</td>
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<tr>
<td></td>
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<td>Low cost</td>
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<td></td>
<td>High cost</td>
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<td></td>
<td>Light weight</td>
<td>Density</td>
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<td>8 g/cm³</td>
<td>1.19 g/cm³</td>
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<tr>
<td></td>
<td></td>
<td>1.4-1.5 g/cm³</td>
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Table 1. Comparison of property of material used for removable partial denture framework.

Because of strength limitations of POM, which are superior to PMMA but inferior to metal, the use as a framework particularly in tissue-supported RPDs is controversial. Nevertheless, as POM’s material properties are considered to have passed ISO standards, it can be used as a denture base material.

This clinical case report describes the treatment of a patient who was partially dentate and had no desire to use metal as a denture material. The treatment used POM as a framework material to combine with CAD-CAM system in designing and fabricating removable partial denture.

Case Report

A 62-year-old Thai male came to see a dentist at Prosthodontics Clinic, Faculty of Dentistry, Chiang Mai University with a complaint of poor previous denture and pain during mastication. Past medical history showed the patient had high blood pressure and gout with sulfa allergies. The patient's expectation was to receive a functional, lightweight and no display of metal prosthesis. During the Intraoral examination (figure 1A-1C), the following

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problems were noted: poor acrylic fixed protheses, permanent maxillary left lateral incisor, permanent maxillary left canine, permanent maxillary left first molar and permanent mandibular left first molar were missing, generalized abrasion at buccal side of tooth, dental caries, defective restorations with dental caries exposed pulp, periodontal pockets were founded at some teeth around 4-7 mm, gingival recession at facial aspect of anterior teeth and good condition of full metal crown of permanent mandibular right first and second molar. The relation of anterior teeth was edge-to-edge. The patient showed group function occlusal relationship bilaterally with no parafunction habit. The patient’s smile fully exhibited average smile line. A panoramic radiograph revealed generalized acceptable alveolar bone level.

Diagnosis: A facebow (Hanau Springbow, Water Pik, Fort Collins, USA) was used to help mount a diagnostic cast onto semi-adjustable articulator (Hanau Modular Articulator, Whip Mix, Louisville, USA). An interocclusal record was made with the aid of a Lucia jig and polyvinylsiloxane occlusal registration material (EXABITE II, GC, Tokyo, Japan). This process was important to evaluate the available interarch space and to determine the appropriate surfaces of teeth to place rest seat.

Treatment procedure: After completed emergency and hygienic treatment, teeth preparation was performed for zirconia crown with space available for rest seat and proper contour for RPD as a plan in diagnostic waxing and final impressions were made with polyvinylsiloxane impression material (Extrude, Kerr, Romulus, Germany). Zirconia crown (Katana Zirconia ML, Kuraray Noritake Dental, Aichi, Japan) were made at the position in existing vertical dimension and appropriate contour and rest seat and cemented with resin cement (RelyX U200, 3M ESPE Dental, USA) as shown in figure 2A. Stock tray with irreversible hydrocolloid impression material (Kromopan, Lasco, Florence, Italy) was used for the final impression of upper RPD, an interocclusal record was made with polyvinylsiloxane occlusal registration material (EXABITE II, GC, Tokyo, Japan), subsequently a facebow record was transferred from patient’s face. After the master cast was poured and surveyed by using a surveyor, upper RPD was designed and determined rests and clasps position (figure 2B). Master cast and antagonist cast were mounted in semi-adjustable articulator.

3D scanner (3shape D900L, 3shape A/S, Copenhagen, Denmark) was used for scanning master cast to create a 3D model. Digital 3D design software (3shape Dental system, 3shape A/S, Copenhagen, Denmark) was used to re-determine block out, major connector, minor connectors, rests and clasps position followed the treatment plan (figure 2C-2E). The clasp position and thickness can be simply determined in all perspectives using software as shown in
The framework was designed to follow the conventional RPDs. To increase material strength, major connector outline was maximized without interference to oral structures and thickness, which was at least 2.0 mm. According to less retention of POM clasp, retentive clasp was made using 0.5 mm undercut and 1.5 mm thickness (figure 2D).18

POM CAD-CAM block (TSM Acetal Dental, Pressing Dental S.r.l, Repubblica di San Marino, Italy) was milled to form a framework by milling machine (figure 2F) (VHF S2, VHF camfacture AG, Ammerbuch, Germany).

Figure 3. Using silicone-disclosing medium to check denture adaptation.

Figure 4. Insertion of removable partial denture with POM framework. (A) Occlusal view. (B) Frontal view. (C) Right side. (D) Left side.

Inspection of framework adaptation to patient’s teeth in patient oral cavity using a silicone-disclosing medium (Fit-Checker, GC, Tokyo, Japan) revealed according to the ease of adjustment, framework indicated good adaptation (figure 3). Occlusion was checked and adjusted, fine adjustment using carbide bur with slow speed handpiece and polishing using non-aggressive polishing paste with cotton brush under slight pressure and slow speed to prevent material from overheating of POM. Afterwards, artificial teeth were placed on framework in master cast that mounted in semi-adjustable articulator. After completed, try-in teeth and patient accepted, the area that contacts PMMA and artificial teeth was air abrasion with aluminum oxide, pink wax was replaced by heat-cured PMMA. Finally, the last step was to polish using carbide bur and silicone polishing bur for acrylic resin. Upper RPD was inserted and inspected for denture adaptation and occlusion (figure 4A-4D). Polishing denture was done following by material’s protocol.

After denture delivery, patient was satisfied with the light-weight and his appearance while wearing denture (figure 5). 1-year follow up showed that the denture was well-cleaned and in a good condition. However, patient needs to continue periodically recall.

Figure 5. Extraoral photographs after treatment wearing maxillary removable partial denture with POM framework without metal display.

Discussion

Due to the disability of capturing the physiologic extension in tissue-borne RPD, scanning from a master cast was chosen for more proper intaglio surface in CAD-CAM fabrication system.24 Accordingly, the appropriate selection of material leads to treatment success; POM was selected to use as a framework because its color, weight and sufficient strength for tooth-borne RPD. Commercial POM is available in 18 VITA shades in tooth color and 3 pink shades, so POM is able to match more patient’s teeth and gingiva. Recent studies
indicate that comparison of CAD-CAM milled materials (PEEK, POM and PMMA), POM had highest color stability.\textsuperscript{25} 1-year recall showed good color stability. Due to the material’s density as shown in table 1, POM is 5.7 times lighter than metal, resulting in greater patient satisfaction. The previous showed the more tissue coverage of denture led to the more gingival inflammation.\textsuperscript{26} Therefore, the design of POM for denture base or framework is smaller with lesser tissue coverage compared to PMMA because of higher flexural strength, microhardness and fracture toughness, which provides better patient’s oral hygiene and health.\textsuperscript{14, 23}

The toxicity from formaldehyde is still a concern of using POM. Although, there is an in vitro study indicating the release of formaldehyde, human mesenchymal cells and mouse fibroblast cell toxicity\textsuperscript{27}, there is no POM allergic report of any kind in dentistry. Furthermore, there are some problems in the study design such as the report of formaldehyde being released at 200°C that exceeds the normal oral cavity temperature and POM in the experiment was not dental grade, thus it lacks stability.\textsuperscript{28}

Recent studies showed agreement the present case report that the most accurate, adaptation and reproducible in both denture base and RPDs fabrication\textsuperscript{5}, \textsuperscript{29} is the ease of framework adjustment in try-in framework visit. Moreover, CAD-CAM constructed POM denture indicated higher mechanical properties than conventional method.\textsuperscript{14} Accordingly, benefits of CAD-CAM technique for POM framework construction are more accurate and have higher mechanical properties than conventional technique.

There are various studies involving a POM clasp, where the POM clasp showed less retention compared to metal clasp but abundantly higher fatigue resistance in various insertion and removal cycles.\textsuperscript{17, 18, 30} Using POM clasp of 1.5 mm thickness and 0.5 mm undercut is sufficient retention for RPDs, which is 6.6 N. Therefore, POM clasp has to be thicker than a metal clasp. Contrastingly, on the good side, POM clasp showed no tooth abrasion compared to a metal clasp.\textsuperscript{31} Because of a few decades of POM utilization in dentistry, particularly as a RPDs framework, there are no long-term studies more than 6 months and previous studies are contentious. To evaluate the denture’s efficiency in a recall visit, it is essential to check denture adaption to ensure that there are no deflection of material after absorbing patient’s masticatory force and material surface texture and color to ensure that material has a sufficient resistance to oral environment. Currently, this case report has the longest follow-up period. After denture evaluation indicated good adaptation of denture base. POM denture was able to maintain clasps retention, shiny and smooth surface.

\textbf{Conclusions}

POM has a tendency to replace metal in dentistry. The construction of framework using CAD-CAM technique from POM showed good denture adaptation; more lightweight and more pleasurable wear as a non-metal denture. A denture showed well-condition and proper function of denture at 1-year recall.

\textbf{Acknowledgements}

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\textbf{Declaration of Interest}

The authors report no conflict of interest.

\textbf{References}


