Evaluation of surface roughness and fracture resistance of maxillary conventional & digital complete dentures: An Invitro study

Eman Gamal Abdelgalil Abdelghaffar1

Aim: to evaluate the surface roughness and fracture resistance of complete dentures made using heat-cured polymethyl methacrylate (PMMA) resin manufactured by conventional technique & digital complete dentures manufactured by additive manufacturing technique.

Materials and Methods: A total of 24 complete dentures were made (n=24), 12 dentures were made using heat-cured polymethyl methacrylate (PMMA) resin manufactured by the conventional methods. 12 dentures were designed by Exocad software program & constructed using additive manufacturing technique. Surface roughness was evaluated using optical profilometry. Fracture resistance was evaluated using universal testing machine. Data were analysed using unpaired t-test where α = 0.05.

Results: There was no statistically significant difference found between the two groups when comparing the surface roughness values (P=0.5137). Conventional PMMA dentures showed mean (2.52± 0.14 µm), while 3D-printed dentures showed mean (2.59± 0.38 µm). However, regarding the fracture resistance, there was statistically significant difference found between the two groups (P<0.5), the conventional PMMA dentures showed higher mean (572.49± 13.07 N), while the digital dentures showed lesser mean with (202.51 ± 10.35 N).

Conclusion: Conventional PMMA dentures and 3D-printed dentures had similar surface roughness. However conventional PMMA dentures had better fracture resistance when compared to 3D-printed dentures.

Keywords: Digital dentures, fracture resistance, surface roughness, complete dentures.

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Introduction

Digital technologies invaded our everyday practice even in Dentistry. Nowadays, digital dentures gained popularity in the dental field, also completely edentulous patients had the awareness of requesting the new technologies related to their treatment.  

Polymethyl methacrylate (PMMA) is the most common known material in fabricating denture bases because of its decreased cost, biocompatibility and accepted mechanical properties that can withstand the masticatory forces. The residual monomer of PMMA material can affect the mechanical properties and biological properties of the dentures such as porosity that can affect the dimensional stability of the denture base and also can lead to increased adherence of oral flora promoting denture stomatitis. PMMA material can be digitally constructed using CAD-CAM technology aiming to enhance the properties related to the material of the dentures and improving denture adaptation as well. CAD-CAM dentures proved that it can be efficiently used with greater patient acceptance. 

Surface roughness is an important property to evaluate different materials in Dentistry, since it has a direct effect on biocompatibility of the material itself. Surface roughness can affect bacterial and candidal colonization that may contribute to oral illness and infections. Many techniques are available for measuring the surface roughness which include contact and non-contact methods. The contact method has a stylus that touches the surface of the specimen, but it could cause scratches to the surface being measured. The non-contact method uses optical and ultrasonic methods. The investigation of fracture resistance of digital & conventional complete dentures is important to estimate the highest force that the prosthesis can withstand before fracture, since the most common form of failure are cracking and fracture of the dentures. Fracture resistance shows the ability of the prosthesis to withstand different masticatory forces. 

Cristache et al suggested adding nanocomposite material incorporated with titanium oxides in 3D-printed complete dentures, this increases the clinical performance of the 3D-printed dentures and might increase the fracture resistance of the dentures as well. Also, it is suggested to increase the denture base thicknesses to compensate for the lower fracture resistance. Another study suggested incorporating nano zirconium to the conventional heat-cures acrylic resin to increase the strength of the material. 

The aim of this in-vitro study was to evaluate the surface roughness and fracture resistance of 2 different types of dentures: Dentures fabricated using heat cured PMMA resin manufactured by the conventional methods & dentures designed by Exocad software program & constructed using additive manufacturing technique. The null hypothesis was suggested that no statistically significant differences could be found between the surface roughness and fracture resistance of the conventional and the digital dentures.

Materials and Methods

For both groups, a completely edentulous educational cast was used to fabricate the dentures. Occlusion blocks were made on the cast using chemically cured PMMA resin (Acrostone, Egypt) with thickness 3mm ensured by a graduated periodontal probe and wax rims (Cavex wax, The Netherlands, Holland).

Group A: Conventional PMMA dentures: One denture was constructed first, then a rubber index was made to maintain the same thickness of denture base material for the rest of the dentures. The educational cast
was duplicated to construct 12 dentures using the conventional methods. Mounting of the occlusion blocks were made on the articulator. Teeth setting & waxing up were done. Flasking of the dentures were done, wax was eliminated by putting the flask in hot water. Heat cured PMMA (Acrostone, Egypt) resin was used for packing of the acrylic resin, the flasks were inserted in the curing unit following the short curing cycle which is 70 degrees for 2 hours then maintained at 100 degrees for one hour. Minimal finishing was made just to remove any gross acrylic nodules and not to affect the denture base thickness, then polishing of the conventional dentures were done.

Group B: 3D-printed dentures: 12 dentures were digitally constructed. The educational cast & the occlusion blocks were scanned by 3Shape D850 scanner (D850,3Shape, Copenhagen, Denmark), then the STL files were uploaded to the Exocad software, and a new order was created. STL files of the casts and the occlusion blocks were virtually mounted. Upper cast analysis was made by the software program: the occlusal plane was pointed out by spotting three points. Incisive papilla was marked. Maxillary tuberosity was identified on both sides. Median palatine raphe was automatically detected by clicking “auto-detect.” Canine and first premolar areas were identified as well as the pterygomandibular fold. Lower cast analysis was also made, and the anatomical landmarks of the lower cast were identified using the same manner. Denture borders were drawn. Setting-up of the teeth was done automatically from the software program library. Selecting the desired path of insertion was made. Denture base was created 3mm for all denture designs. Then denture was finalized by previewing the upper and lower dentures. The STL files of the designed dentures were imported to FlashPrint software program (FlashPrint, Zhejiang Flashforge, China) for creation of supporting arms to be ready for 3D printing. The 3D printer (Duplicator7) was filled with pink resin (HARZ labs, Montenegro) for printing the denture bases and white resin (HARZ labs, Montenegro) for printing the denture teeth with 90 degrees printing angle. Finishing the dentures were performed by removing the supporting arms and minimal polishing was made. Denture teeth were attached to the denture base using the excess resin, then were placed in post curing unit (Mogassam, Egypt) for 15 minutes. All dentures were immersed in water at room temperature for 48 hours to simulate the oral environment.

Surface roughness evaluation: Each denture in the two groups was evaluated under 3 mega pixels digital microscope (U500x Digital Microscope, Guangdong, China), the most prominent part of the palatal area was examined, the distance between the microscope’s camera and the denture was 2.5 cm, the dentures were placed vertically. 8 LED lamps are responsible for illumination and can be altered using a wheel. The pictures of the surface roughness were taken under magnification of 90X with resolution of 1280 × 1024 pixels. For standardization of the surface roughness area, pictures were cropped to 350 x 400 pixels using Microsoft office picture manager. The cropped pictures were examined using WSxM software (Ver 5 develop 4.1, Nanotec, Electronica, SL), this leads to a 3D picture having different heights of the denture surface creating a 10 µm × 10 µm picture, this software program calculated the average & maximum heights expressed in µm in the central & in the side areas of this picture (Figure 1).

Fracture resistance evaluation: Each denture was fixed onto the lower member of a universal testing machine (Model 3345; Instron Instruments Ltd., USA) so that the fitting surface of the dentures were facing
A static compression load was applied on the dentures using stainless-steel rod with flat end (1.5cm x 2.5cm) that is attached to the upper movable part of the machine at a crosshead speed of 5 mm/min. The fracture load was recorded in Newton (Figure 2).

Statistical analysis
G*Power software for windows version 3.1.9.4 was used to calculate the sample size, based on the previous study, a sample size of 12 dentures in each group was calculated to have 80% power, α = 0.05, 1-β = 0.8. Statistical analysis was performed with IBM (IBM Corporation, NY, USA) SPSS (SPSS, Inc., an IBM Company) Statistics Version 20 for Windows. An unpaired t-test was used for comparison between both groups. The significant level was set at P ≤ 0.05.

Results
There was no statistically significant difference between the two groups (P=0.5137) regarding the surface roughness. Conventional dentures group showed mean 2.52 ± 0.14 µm, while 3D-printed dentures showed mean 2.59 ± 0.38 µm. Regarding the fracture resistance, there was statistically significant difference between the two groups (P<0.5), the conventional dentures showed higher mean 572.49 ± 13.07 N, while the digital dentures showed lesser mean with 202.51 ± 10.35 N. (Table 1) (Figure 3,4)

Table 1: Mean & standard deviation of surface roughness in µm & fracture resistance in N

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface roughness</td>
<td>2.52 ± 0.14 µm</td>
<td>2.59 ± 0.38 µm</td>
<td>0.5137**</td>
</tr>
<tr>
<td>Fracture resistance</td>
<td>572.49 ± 13.07 N</td>
<td>202.51 ± 10.35 N</td>
<td>0.05**</td>
</tr>
</tbody>
</table>

* Denotes statistically significant difference using unpaired t-test (p<0.05), **Denotes non-statistically significant difference using unpaired t-test (p>0.05)

**Discussion**

Concerning the surface roughness, there was no statistically significant difference between the two groups (P=0.5137), thus the null hypothesis that states that there was no statistically significant difference would be found in the surface roughness values of the two groups was accepted. However, the null hypothesis was rejected concerning the fracture resistance evaluation, since there was statistically significant difference between the two groups (P<0.5).

PMMA showed through history that it is the material of choice due to many reasons such as easy laboratory manipulation, ease of repair, relining and rebasing, in addition to low cost and availability in the market. However, it shows polymerization shrinkage, low fatigue strength and low fracture resistance. The introduction of CAD/CAM technology has been proposed to improve the mechanical properties in comparison to the conventional dentures. 20–24

Surface roughness is an important factor that is related to bacterial and candidal adhesion to hard surfaces, so if the roughness values are greater than the accepted range this would lead to oral infections.25,26 The accepted range for denture base surface roughness have been reported to be from 0.7 to 7.6 µm.27 The surface roughness method used in the present study is optical profilometry that measures the height of a surface in relation to a reference point, the change of the height measurements indicated the degree of surface roughness. 10–12

According to the present study, the values of surface roughness for both groups are within the accepted range. Surface roughness of conventional PMMA is reported to have many reasons such as the level of residual monomers and the polymerization method used for manufacturing of PMMA. 28 While, surface roughness of additive manufacturing technique is influenced by the method of manufacturing technique, such as the effect of the UV light to polymerize layer by layer, printing layer thickness and different build angles, all these factors influence the surface roughness of resin materials used in 3D-printing.29,30 Anderson et al19 reported that additive manufacturing technique produced more surface roughness than the conventional dentures, unlike the present study. Other studies31–34 reported higher surface roughness values for the conventional PMMA resins. Al-Qahtani et al 35 reported that 3D-printed resins have higher surface roughness when compared to the conventional heat cured acrylic resin, which supports the present study.

Evaluation of fracture resistance of complete denture is important, since the most common causes of failure are cracks and fractures of complete dentures, that is due to dynamic masticatory forces and impact...
forces that is directed to the denture. From the most common form of failures in maxillary dentures is midline fracture, since the prominent part of the midline acts a fulcrum around which the forces are focused and leads to fracture. 13,36,37

In the present study, the 3D-printed dentures had a lower fracture resistance when compared to the conventional PMMA dentures. This might be due to that the 3D-printed resins exhibit lower elasticity than conventional PMMA.38,39 Steinmassl et al 17 reported that conventional PMMA resins have higher fracture resistance than CAD/CAD resins which is consistent with the present study. Another study stated that the resins used with the 3D printing technology have inferior mechanical properties when compared to the other materials used in CAD/CAM technology.40

These results might be due to the compression manner of manufacturing technique of the conventional PMMA resin that add strength to the material itself, unlike the additive manufacturing technique that involve polymerization of layer by layer. The additive manufacturing technique requires final photopolymerization of the last layer created by the 3D printer. This can lead to polymerization shrinkage and compromise the mechanical properties of the material until the final polymerization happens. 41

Conclusion

Conventional PMMA dentures and 3D-printed dentures had similar surface roughness. However conventional PMMA dentures had better fracture resistance when compared to 3D-printed dentures.

References