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Evaluation of Surface Roughness of Two 3D Printed Resin Material

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Abstract
Purpose: *this in vitro study evaluates the surface roughness of two commercially available 3D-printed resin subjected to different surface treatments.* ***Methods:*** *a total of 36 specimens (saremco and senertek , n=18) was distribute into two groups, each group then subdivided into three group (control, polished and polished with glaze, n=6 per group). Surface roughness (Ra) was measured using Atomic Force Microscopy (AFM).* ***Results:*** *AFM shows a significant difference within the group and between two groups of 3D printed resin.* ***Conclusion:*** *overall surface roughness was less in saremco compare with senertek, on the other hand surface roughness was less in polished and glazed then in polished only and both of them is within acceptable value of roughness for saremco but in senertek only polished and glazed was within acceptable value.*
Keywords*: 3D printing, CAD/CAM, Surface roughness, AFM*

Introduction

Over the past forty years, three-dimensional (3D) printing has become a rapidly developing industrial technology. It is an additive manufacturing method (AM) that uses three-dimensional model data to create a wide range of complex assemblies and intricate shapes [1]. The method consists of printing consecutive material deposits on top of one another. These printers can handle a wide range of materials, including metal alloys, polymers, composites, and ceramics, making them suitable for use in a variety of dental specialties [2].

Nowadays, polymeric materials are generally employed to fabricate both temporary and permanent dental crowns; in the additive manufacturing industry, polymer-based printing accounts for the majority of materials used [3]. Several variables about the printing process and component makeup may affect these materials' mechanical properties. Because of the way the materials are produced, printed objects are categorized as isotropic. Important factors to consider are the light-polymerization of these materials, the length of exposure, and the post-curing protocols [4].

The field of prosthodontics has seen a revolution in patient care with the introduction of digital technology, namely computer-aided design and computer-aided manufacturing (CAD/CAM). Pre-polymerized resin blocks are milled to create the required shape in the CAD/CAM milling process, also known as subtractive manufacturing. Reductive manufacturing approaches reduced the inherent issues of traditional PMMA-based provisional materials, such as excessive polymerization shrinkage and high residual monomer. Dental prosthesis construction may be made more affordably with 3D printing technology as it produces less waste material and reduces manufacturing time when compared to CAD/CAM milling [5].

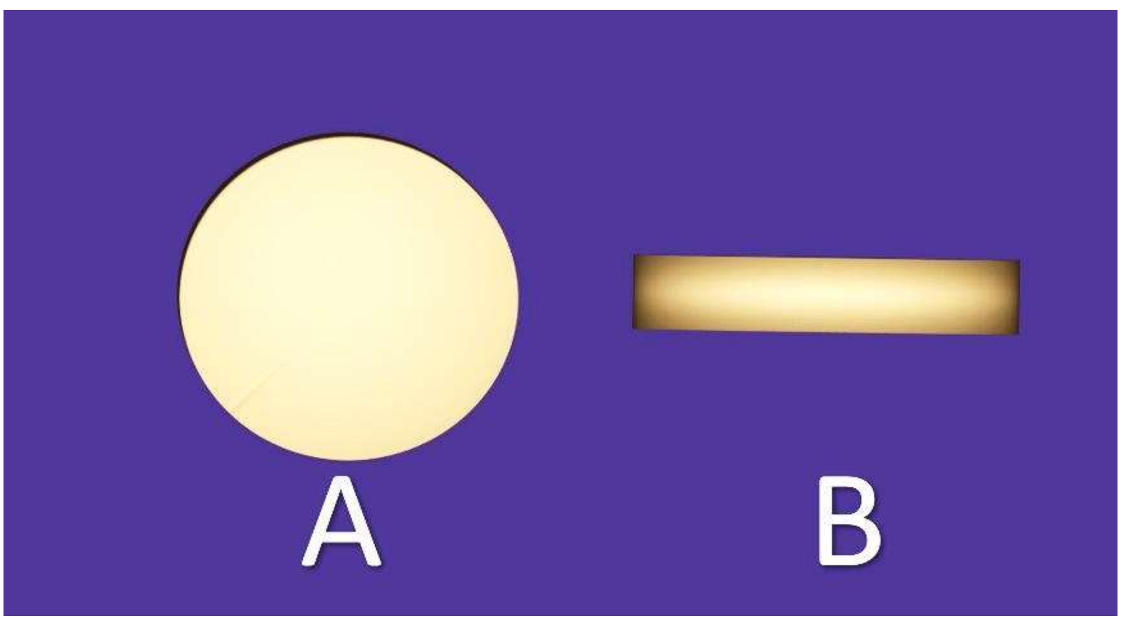
Senertek and saremco resins are the two commercially available types of 3D printed resin. Both of them are flowable, light-curing polymers but there are some differences in their compositions. Full crown and bridge restorations have been used effectively to gain the appearance and functioning of damaged natural teeth, while dental ceramics are components used to form a dental prosthesis that replaces lost or damaged teeth [6]. The surface roughness of any restoration has been a great attention for investigators and clinicians because of its crucial clinical property with a clear effect on dental esthetics and oral hygiene. The surface roughness (Ra) amount measured in micromillimeter (μm) and the agreeable value of (Ra) is believed to be 0.2μm; rising in superficial roughness of restoration over the acceptable value (0.2μm) is deemed clinically critical because this will increase the possibility of extrinsic discoloration, plaque accumulation, gum recession, and periodontal disease [7].

Ceramic restorations with roughened occlusal surfaces can cause increased wear on the opposing teeth, whereas smooth surfaces reduce plaque formation and bacterial retention [8]. Surface roughness often varies according to the AM method. AM alone cannot create components that satisfy both mechanical and surface roughness criteria [9]. As a result, post-processing procedures are usually required after the components are printed to enhance mechanical properties and surface quality, allowing them to be utilized as intended [10].

The post-processing operations may be separated into four steps: device removal, cleaning, post-polymerization, and the removal of supporting structures [11]. Atomic force microscopy (AFM) is integrated into the non-contact profilometer. Given that AFM provides both qualitative and quantitative information on a variety of physical characteristics, including size, shape, surface texture, and roughness, it is a useful tool for characterizing nanoparticles and nanomaterials. It is also a technique that can image almost any kind of surface, including biological materials, glass, ceramics, polymers, and composites [12]. The aim of this study is to evaluate the surface roughness of two resin using AFM

Materials and Methods

A 10*5mm disc was design through EXO-CAD as shown in figure (1) then it was printed with ASIGA 3D printer (Figure 1).



Figurer 1. Disk sample; A diameter of the disk 10mm, B thickness of the disk 5mm.

A total of 36 disks was collected 18 disks for each type of resin as A group for Senertek and B group for Sarmco which is further divided into three groups (n = 6 per group) according to the surface treatment applied.

Post-processing: post-processing procedures are usually required after the components are printed to enhance mechanical properties and surface quality, allowing them to be utilized as intended [10]. The post-processing operations may be separated into four steps: device removal, cleaning, post-polymerization, and the removal of supporting structures [11].

Sample removal from 3d device: After the operation, the sample is physically removed off the construction platform [11].

Cleaning: When the printed item is removed from the build platform, it retains some uncured and unexposed resin. The cleaning procedure increases quality by eliminating contaminants and unexposed resin that has adhered to the printed object. This is accomplished by immersing or soaking the printed component in alcohol for a few minutes, then washing with the same alcohol. Isopropyl alcohol is favored for cleaning, however other alcohols can be used [13].

Post-polymerization: Post-polymerization is advised to complete the polymerization of the material using a UV-polymerization equipment [11]. The postpolymerization settings examined had a substantial effect on the material's fracture resistance and flexural strength. Dry post-polymerization conditions acquired the strongest fracture resistance and flexural strength mean values compared to the water- and glycerin-submerged conditions. This is because this substance may absorb water when submerged in it or with glycerin [14].

Removal of supporting structures: This is mostly a manual operation in which the support tree-like structure is removed from the part, leaving an uneven surface. This uneven surface, once the support structures are removed, leaves certain places on the surface known as nibs. These nibs are found anywhere a support structure makes contact with the component surface. Sanding such a surface may be a rapid way to obtain a smooth surface, but this is only practical for big flat surfaces [15]. To achieve a high degree of smoothness, it is advised that you follow the manufacturer's polishing procedure instructions.

Acrylic Disc Holder: A specially made acrylic disk holder from cold cure acrylic powder and self-cure liquid facilitated the samples' polishing process. It has two square pieces joined by two screws and a central hole that fit with the diameter of the disk but its less depth than the desk (4mm) to allow 1mm of the disk up to facilitate its polishing (Figure 2) [16].

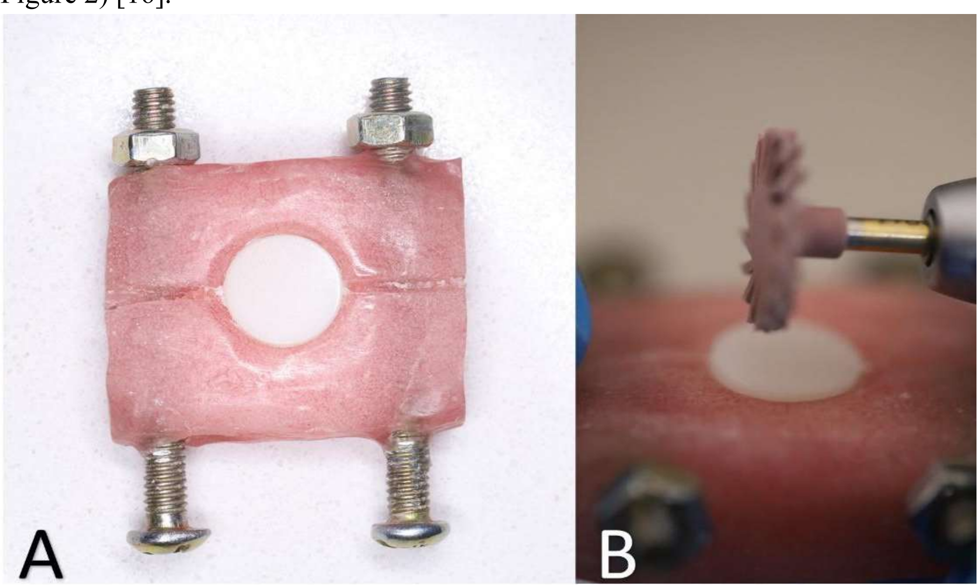


Figure 2. A acrylic disk holder tightened on disk. B 1mm thickness of disk above acrylic disk holder.

Groups of surface roughness

1. The untreated group, which served as a control group this group will act as a standardization group for each type of resin
2. The two-step polishing system group, whose surface was treated using eve polishing diacomp plus polishing burs as shown in figure .an acrylic disk holder was used. all the specimens was polished with the same hand piece , polishing burs and operatoras shown in figure (3) The speed of hand piece was adjust on the implamt engine at 12,000 RPM with anti-clockwise rotation as manufactural instruction.

Figure 3. A eve diacomp plus twist two steps polishing system (Germany), B implant engine set at 12000 RPM, C WAMED handpice with polishing bur.

3. The polished and glazed group, whose surface was treated via eve polishing diacomp along with polishing burs followed by coated with glaze layer through resin-exclusive photocuring glazing solution (Optiglaze, GC corporation, Japan).

After we complete the polishing steps we add a small drop of Optiglaze on the surface of specimens then we used bond brush to spread the material evenly on the surface, no air blowing is needed then we applied light cure LED (400nm–430nm wavelength) for 40 sec as manufactural instruction (Figure 4).

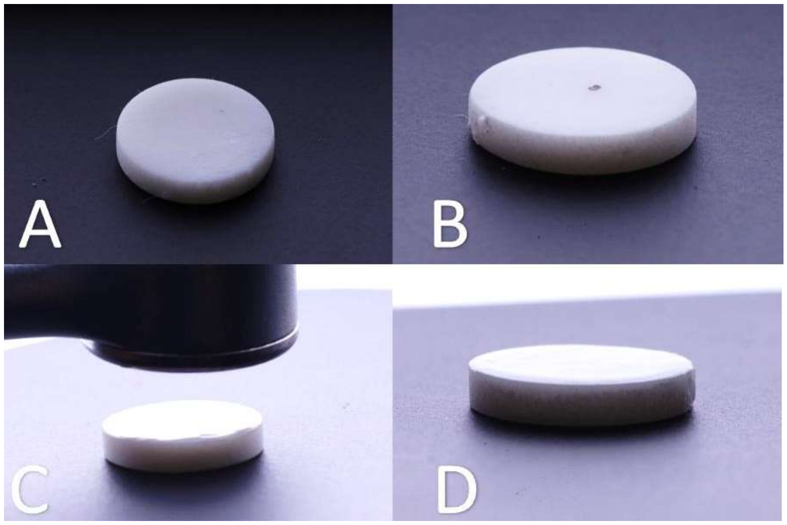


Figure 4. A: initial rough surface of disk, B: after surface polishing with eve, C: curing of Optiglaze with LED uint D: final surface of the disk.

Result

The surface roughness measurements for the senertik and saremco systems across the Control, Polished, and Glazed groups are presented in Table 1. In the Senertik system, the highest mean surface roughness was observed in the Control group (0.42 ± 0.06 µm), while the Polished group demonstrated a lower mean roughness (0.31 ± 0.07 µm). The Glazed group had the lowest surface roughness (0.05 ± 0.08 µm). Similarly, in the saremco system.

Table 1. Surface roughness of senertik and saremco systems in tested groups.

Company	Group (n=6, each	Mean±SD
Senertik	Control	0.42±0.06*^
	Polished	0.31±0.07*
	Glazed	0.05±0.08
Saremco	Control	0.23±0.05*
	Polished	0.07±0.09
	Glazed	0.02±0.06
Data expressed as mean±SD, *^indicate significant difference at p value using One-Way ANOVA, * as compared to Glazed, ^ as compared to Polished group		

The ANOVA test revealed a statistically significant difference in surface roughness among the three groups for both the **senertik** and **saremco** systems (P = <0.001) (Table 2).

Table 2. Surface differences between **senertik** and **saremco** systems

Company	Sum of Squares	df	Mean Square	F	P-value
Senertik	0.42	2	0.21	63.83	<0.001
Saremco	0.14	2	0.07	74.99	<0.001

Post hoc comparisons using the **Tukey HSD test** showed a significant difference between all groups for both the **senertik** and **saremco** systems (**Table 3).**

Table 3. Mean differences in surface roughness of Senertik and Saremco systems in tested groups.

Company	Group		Mean Difference	SE	95% Confidence Interval		P-value
					Lower Bound	Upper Bound	
Senertik	Control	Polished	0.11	0.03	0.02	0.2	0.01
	Control	Glazed	0.36	0.03	0.27	0.45	0.001
	Polished	Glazed	0.25	0.03	0.16	0.34	0.001
Saremco	Control	Polished	0.15	0.01	0.10	0.20	0.001
	Control	Glazed	0.21	0.01	0.16	0.25	0.001
	Polished	Glazed	0.05	0.01	0.06	0.10	0.001

A **t-test** was conducted to compare the surface roughness between the **polished** and **glazed** groups for both the **senertik** and **saremco** systems, demonstrating significant differences (**Table 4).**

Table 4. Surface roughness between the **Polished** and **Glazed** groups for tested company.

Company	Group (n=6, each)	Mean±SD	p value
Senertik	Polished	0.31±0.07*	0.001
Saremco		0.07±0.09	
Senertik	Glazed	0.05±0.09*	0.001
Saremco		0.02±0.06	

Data expressed as mean±SD, *indicate significant difference at p value using One-Way ANOVA.

Discussion

The surface roughness of a restoration alters under the influence of multiple factors, which include the fabrication technique, oral conditions, opposite dentition load, diet, material composition, and polishing techniques[17]. This in vitro study which evaluate the surface roughness of two different 3D printed resin in three state (control, polishing and polishing followed by glazing). As the orientation of the printing effects on surface properties of material, all specimens was printed at 180º degrees [18]. According to this study's outcome, the hypothesis that there is no significant difference in surface roughness within a group and between the two groups was rejected.

The AFM was the measurement tool used for measuring the surface roughness of these materials, the parameter used for measuring surface roughness was arithmetic average height which is also called R_a due to its easy define and calculate[19]. For groups of roughness, the control groups of both resins show a higher surface roughness ($R_a \approx 0.25\mu m$ and R_a= o.4µm) for sarmeco and senertek respectively which is more than the acceptable roughness value[7]. and this is axiomatic because the material is printed in layer by layer which lead to stairs effect[20].

While for polished groups it was less R_a value than control group ($R_a = 0.08\mu m$ and $R_a = 0.3\mu m$) for sarmco and senertek respectively. although it was less than in control but senertek group still showed a roughness value higher than the acceptable value,this value conflict with the result of Kraemer et al., Quirynen et al. and Bollen et al. as they showed that surface roughness of AM material was below the threshold of clinical relevance after polishing[21]. according to our study, the difference in roughness between two materials backs to the difference in their viscosity as demonstrated in lee et al. article about viscosity and build angle, he claims that increasing in the viscosity of resin will lead to an increase in their roughness[22].

On the other hand, both materials show promising surface roughness results after polishing and glazing (R_a=0.02 µm and R_a= 0.05 µm) for both saremco and senertek, respectively. Optiglaze solution is a mixture of multiple component like Silicon dioxide (Sio_2), photo-initiators and methyl methacrylate (MMA), MMA is the monomer of the mixture while Sio_2 responsible for increasing the strength due to the crosslinking interaction with polymers as it contained nanofillers, the overall material is hydrophobic gives the surface that coated with it this property which makes is less water sorption and finally more roughness resistance[23]. This study conflicts with Kraemer et al. who founds there is no significant superiority of coating over polishing compared with polishing only[20]. While it is similar to Dos Santos, et al. and Nam et al. as they found there is enhancing in the reduction of surface roughness after application of glaze material on the surface of 3D printed resin[23,24].

Methacrylate material was shown to produce a smoother surface due to its composition compared to bisacrylates. These materials are composed of smaller filler, which influences the polishability of the material to produce a smooth surface[25]. Hence, using methacrylates for restoration is a safer option because these materials do not contain large filler particles that interfere with surface smoothness. In addition, these materials respond better to the polishing techniques, resulting in homogenous and void-free surfaces[26]. It is important to say with the limitations of this study the result of a polished group of senertek is still below the clinically unacceptable range (10µm)[27].

Limitation of this study are the surfaces didn't expose to thermocycling, saliva and different coloring material (acid or alkaline) as these factors can affect surface properties and eventually final outcome of the prosthesis as shown in Aldahian et al. study, they pointed out that changes in the pH (acidic to alkaline) contribute mainly to surface changes of the restoration[28]. Surface deterioration of resin contribute to the acidity in different types of beverages which act by hydrolytic degradation of the surface of resin immersed in the selected media[29]. This study was compatible with Lussi et al. about the erosive activity of citric and other acids as ingredients of beverages[30]. Also, saliva component like proteins and enzymes can affect negatively on the characterization of the surface of resin and finally long term prognosis[27]. Thermal cycling (TC) is a standard procedure in dental research to replicate the in-vivo aging of dental materials by exposing them to repeated cyclic stresses to cold and hot temperatures in water baths to mimic thermal changes in the oral cavity[31].

Conclusion

With the limitation of this study 3D printing material shows promising result either for saremco or senertik material in glazed groups, however, saremco still shows beter result in polished groups this gives an advantage for saremco over senertik to be used for permanent restoration in term of surface roughness.

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