Original Article

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Dentistry Section

Evaluation of Surface Roughness in Clear Silicon Fabricated using Three Different Techniques: An In-vitro Study

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ABSTRACT

Introduction: Anterior composite restorations present many aesthetic challenges for clinicians. Direct veneers provide chairside advantages such as evaluating tooth anatomy, shade selection, and correcting tooth morphology according to the patient's desire. In today's world, the use of digitalisation and 3D-printed models has grown. However, limitations of these are unknown and a research gap exists, with surface roughness being a major issue.

Aim: To evaluate the surface roughness of clear silicon templates fabricated over 3D-printed models, blue inlay wax and dental stone.

Materials and Methods: This in-vitro study utilised both quantitative and qualitative approaches. The study was conducted at the Department of Conservative Dentistry and Endodontics, Manubhai Patel Dental College and Hospital, Vadodara, Gujarat, India. The study was completed over three months. A total of 36 surfaces of clear silicone template (Exaclear) were obtained from two blocks each of 3D-printed model, blue inlay wax and dental stone, measuring 30×10×10 mm. These blocks were divided into six units of 10×5 mm (N=36) and were divided into three groups: 1) 3D-printed model; 2) Blue inlay wax; 3) Dental stone. Surface roughness was evaluated using a surface roughness tester and Scanning Electron Microscope (SEM). Quantitative analysis of surface roughness was done using the surface roughness tester, and qualitative analysis was done using SEM. Statistical analysis was done using the posthoc Tukey Honest Significant Difference (HSD) test and statistical software SPSS Version 20.0.

Results: The quantitative analysis showed the highest Roughness average (Ra) value mean±Standard Deviation (SD) for Group 1 (11.97±4.43 µm), followed by Group 3 (2.42±1.07 µm) and Group 2 (0.63±0.86 µm). SEM showed the presence of voids only in Group 1.

Conclusion: Surface roughness of clear silicon template fabricated on wax surface is less as compared to templates fabricated on 3-D printed models.

Keywords: Aesthetics, Polyvinyl Siloxane, Three dimensional printing

INTRODUCTION

A beautiful smile and harmonious facial aesthetics are attributes that contribute to the well-being of any patient [1]. Aesthetics encompasses not only the enhancement of one's smile but also results in the improvement of the facial profile and jaw [2]. One of the main goals of dental treatment is to design smiles in the most natural and aesthetic manner, based on the specific needs of the patient. The possibilities to reach that goal have significantly improved over the last decade through specific treatment modalities that are based on aesthetic dental materials, technological advancements, and novel techniques [3].

Veneers using direct resins are one of the most conservative treatment options. Advancements in material sciences and technology have provided today's clinicians with strategies to transform the mechanistic approach of operative dentistry into a biologic philosophy [4].

Following recent advancements in adhesive and restorative dentistry, direct resin veneers have become one of the most prevalent treatments for clinical applications in aesthetic dentistry. These restorations are directly bonded onto the minimally prepared or even unprepared tooth surfaces in a single dental clinic visit. Direct veneers provide chairside advantages to the operator such as evaluating tooth anatomy, shade selection, and correcting tooth morphology according to the patient's desires. Furthermore, they have benefits like intraoral polishing, low cost, and easy repairability [5].

The injectable composite resin technique is an indirect/direct method that uses a transparent silicone index for the accurate and predictable translation of a diagnostic wax-up into a composite restoration. Flowable composites used in the injection moulding technique are preferred over conventional composites, as they can fill the mould under the silicone index without the need for external pressure. This technique can overcome problems such as index distortion and unappealing final outcomes [6].

Apart from the advantages, one of the major clinical problems associated with the injection moulding technique for composite veneers is the surface roughness of the template, which is eventually observed in the restoration before finishing and polishing. Clear silicone templates can be fabricated over different materials, but no literature exists on their surface roughness, which potentially affects the time required for finishing and polishing [7].

Thus, the aim of the present study was to evaluate the surface roughness of clear silicone templates fabricated over blue inlay wax and dental stone and 3D-printed models.

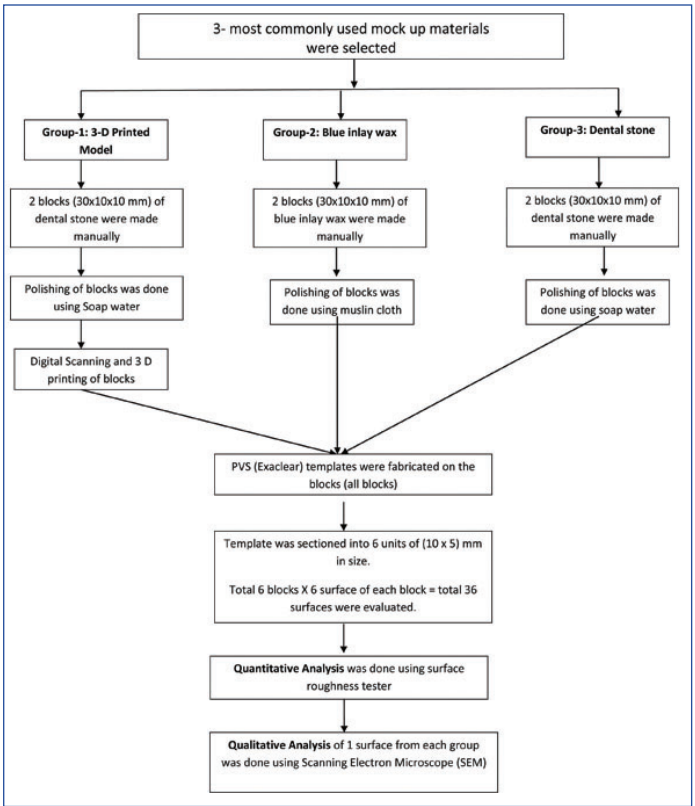
Null hypothesis: There will be no difference in surface roughness of clear silicone templates fabricated over dental stone, 3D-printed models, and inlay wax mock-ups.

MATERIALS AND METHODS

It is an in-vitro study that utilised both quantitative and qualitative approach. It was conducted at the Department of Conservative Dentistry and Endodontics, Manubhai Patel Dental College and Hospital, Vadodara, Gujarat, India. The present study was approved by the Research Committee of Manubhai Patel Dental College and Hospital under approval no. MPDC_263/CONS-48/23.

Sample size calculation: A sample size of 36 surfaces was calculated based on a 95% confidence interval with an anticipated

standard deviation of 0.18 units. Hence, a total of 36 surfaces were prepared and divided into three groups [Table/Fig-1].

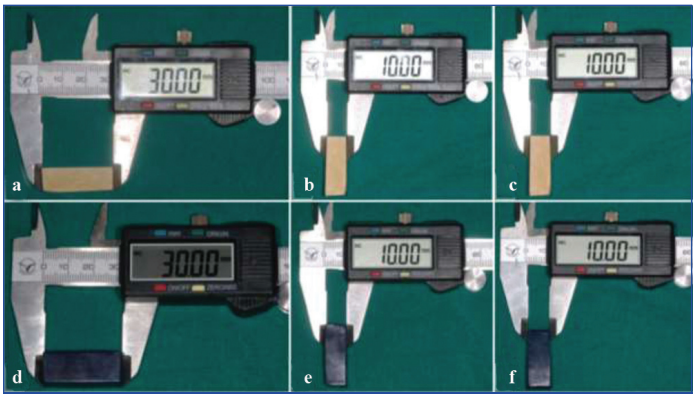


[Table/Fig-1]: Sample size distribution.

Study Procedure

Preparation of blocks:

- Three experimental groups were established. Two blocks of dental stone in the proper water/powder ratio were made by a technician without using any dye. The blocks were prepared manually, and the dimensions of the blocks (30×10×10 mm) were checked and corrected using Vernier callipers (Aerospace, India). Finishing was done using sandpaper (80 Grits). The blocks were polished with soapy water. The two blocks were digitally scanned (Medit Identica Blue scanner-LMT-mag.) and then 3D printed (Phrozen Mighty 4k printer; Material-model Resin).
- Group-2 (Blue Inlay Wax Type II): Two blocks were prepared by dental technicians using Blue Inlay Wax (Surana Dental Sky, Mangaluru, India) according to the specified dimensions. A wax knife and heated spatula (GDC, India) were used to achieve the exact dimensions, which were measured with Vernier callipers before the blocks were polished with a muslin cloth [Table/Fig-2d-f].



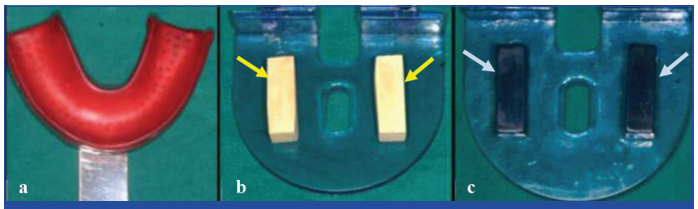
[Table/Fig-2]: Dimensions of the block: (a) Length of the block; (b) Breadth of the block; (c) Height of the block of dental stone; (d) Length of the block; (e) Breadth of the block; (f) Height of the block of Inlay wax.

- For Group-3 (Dental Stone): Two blocks of dental stone were made using the proper water/powder ratio with the help of a technician, without any dye; the dimensions of the blocks (30×10×10 mm) were checked and corrected using Vernier callipers and finishing was done with sandpaper (80 Grits). The blocks were polished using soapy water [Table/Fig-2a-c].

Preparation of the Exaclear template:

- For Group-1: Perforated Stainless Steel trays (No. 4) were used, and a single thickness of modelling wax sheet (Pyrax dental modelling wax sheets) was adapted onto its interior surface, covering the arch completely [Table/Fig-3a].

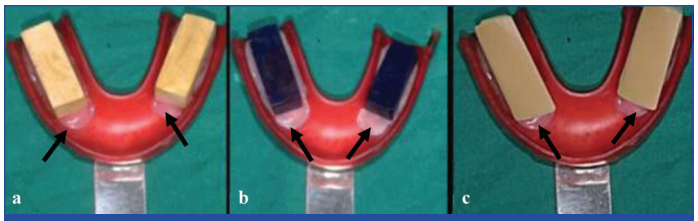
The 3D printed blocks were positioned on the base of the typhodont jaw corresponding to the selected tray size [Table/Fig-3b,c].



[Table/Fig-3]: (a) Tray covered with modelling wax; (b) Yellow arrows showing dental stone blocks stabilised on typhodont jaw; (c) Blue arrows showing Inlay wax blocks stabilised on typhodont jaw.

Polyvinyl Siloxane (Exaclear-GC, Australia) material was loaded into the dispensing gun and injected onto the wax sheet in the tray. The material was placed using a single stroke from one end of the tray to the other, maintaining a uniform flow. The trays were immediately inverted onto the base of the typhodont jaw, and impressions of the blocks were taken. The material was allowed to set for 10 minutes. The 3D printed blocks were then carefully removed from the impression tray using tweezers [Table/Fig-4c].

A similar procedure was carried out for Group-2 and Group-3 [Table/Fig-4a,b].



[Table/Fig-4]: (a) Impression of dental stone blocks using Exaclear material (black arrows); (b) Impression of Inlay wax blocks using Exaclear material (black arrows); (c) Impression of 3D printed blocks using Exaclear material.

Quantitative analysis: After making the Exaclear templates from all three groups, two Exaclear templates from each group were divided into six blocks each, making a total of 12 blocks (10×5 mm) for each group. Surface roughness evaluation was done using a surface roughness tester (Model: SJ-201P; Mitutoyo, Sr. No.: 310397; Probe No.: 323823; Block Sr. No.: 335307; Calibration).

Qualitative analysis: One block from each group was coated with a gold/palladium alloy and evaluated under an SEM (FE-SEM IT 800, JEOL) at an acceleration voltage of 1.00 kV and a magnification of 1000x.

STATISTICAL ANALYSIS

Statistical analysis was done using the posthoc Tukey HSD test for subgroup comparison and analysis. The test value was 42.602, and the level of significance was set at $p<0.001$.

RESULTS

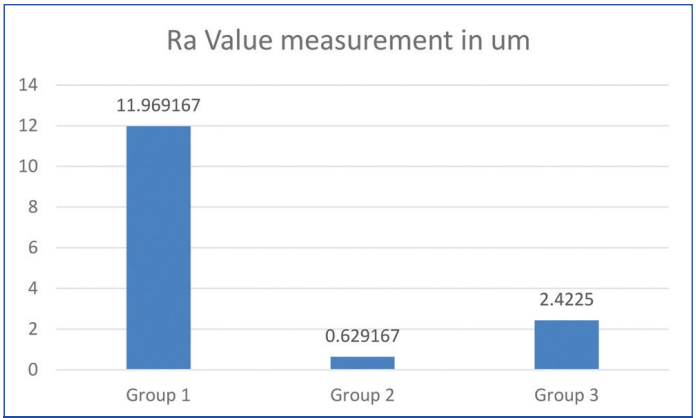
The mean and standard deviation of surface roughness for all experimental groups are presented in [Table/Fig-5].

The highest mean values were seen in Group-1 (11.97±4.43 µm), followed by Group-3 (2.42±1.07 µm) and Group-2 (0.63±0.86 µm). The largest difference between the groups was noted between

Surface Roughness/Groups	Group-1 (N=12) Mean±SD	Group-2 (N=12) Mean±SD	Group-3 (N=12) Mean±SD	F/Welch statistics (*represents welch test)	p-value	Group-1 vs Group-2 difference (p-value)	Group-1 vs Group-3 difference (p-value)	Group-2 vs Group-3 difference (p-value)
Ra Value measurement in µm	11.97±4.43	0.63±0.86	2.42±1.07	42.602*	<0.001	11.34 (<0.001)	9.55 (<0.001)	-1.79 (0.243)

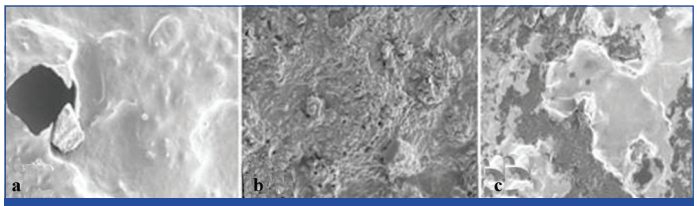
[Table/Fig-5]: The mean and standard deviation of surface roughness for all experimental groups.

Group-1 and Group-2 (11.34), which was significant, followed by Group-1 vs. Group-3 (9.547, significant) and Group-2 vs. Group-3 (1.793, not significant) [Table/Fig-6].



[Table/Fig-6]: Comparison of mean±SD Ra values between the three groups.

Concerning the qualitative analysis, SEM imaging showed the presence of voids only in Group-1. Group-2 and Group-3 exhibited relatively smoother surfaces [Table/Fig-7a-c].



[Table/Fig-7]: (a) Presence of voids in Group-1; (b,c); Absence of voids and smoother surface.

DISCUSSION

Dental composites are the most widely used material in clinical restorative dentistry [8]. The aesthetic outcomes of the injectable composite resin technique may be inferior to those of ceramic veneers, but the main goal is to improve aesthetics with stable function and occlusion, which can be achieved with this technique. With advancements in technology and dental material science, certain properties of flowable composites, like strength, wear resistance, translucency, and polishability, have improved over time.

Veneers from resin composite can be prepared using either direct or indirect technique [9]. With the veteran concept of the diagnostic preview or "mock-up," techniques to create the mock-up vary considerably, from the use of photographs, pre-mock-up study models, and laboratory-fabricated wax-ups etc., [10].

In the present study, three commonly used materials were selected for mock-ups as the experimental groups to evaluate the surface roughness of Polyvinyl Siloxane (PVS) material on these substrates. Exaclear (GC) is a transparent PVS material. This technique involves replicating the exact smile design template from a mock-up using Exaclear PVS material, preparing the teeth, and restoring the surface with injectable composite. From the above results, it can be said that the surface roughness of the Exaclear template prepared from the wax block is the least, followed by the dental stone and the 3D printed model.

There are various reasons that can lead to irregularities or surface roughness in the 3D printed model. Modifications of printing parameters and conditions affect the surfaces of printed objects [11]. One technical error is the thickness of the layer. Thicker layer heights result in larger void fractions, whereas using multiple thinner layers can also result in void formation in the model [12]. Another factor is printing speed. Higher printing speeds translate into smaller windows for heat transfer, which may result in the extrusion of partially melted extrudate. Hence, increases in printing speed have been found to be associated with the presence of a greater number of voids [13].

Also, the presence of voids in 3D printed models can be associated with decreased nozzle temperature. When there is a decrease in temperature up to 260°C, air entrapment can result in more number of voids [14]. On the other hand, the advantage of using wax is that one can achieve a smooth and well-polished surface, which will eventually result in less surface roughness of the restoration. The absence of surface roughness is fundamentally important for any restoration, as it can lead to various problems such as plaque accumulation, gingival irritation, poor aesthetics, and colour change. Therefore, the smoothness of a restoration plays a pivotal role in the success of the restoration [15].

Discolouration of composites in anterior restorative work is an aesthetic disaster for the patient. One of the main reasons for the discolouration of the composite over time is due to the surface roughness and inadequate polishing of the composite [16]. One of the problems associated with composite materials is their unpredictable colour stability [17]. Hence, a multistep, accurate polishing system is mandatory to keep the composite colour as stable as possible [18].

Limitation(s)

The surface roughness of the polished 3D printed model block, wax block, and dental stone block was not checked in the present study. The 3D printed model block was obtained after scanning the dental stone block; thus, the surface roughness of the dental stone block may be reflected on the 3D printed model block.

CONCLUSION(S)

According to the study results, it can be concluded that a polyvinyl siloxane template fabricated over wax exhibits less surface roughness compared to templates prepared over a 3D printed model and dental stone. It can be contemplated that a template fabricated over wax would lead to lesser roughness in composite restorations and, consequently, the restoration would require less finishing and polishing time. It can be concluded that the surface roughness of the block, template, and restoration can be correlated in an in-vitro set-up.

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