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Surface roughness of dental resin composite: analysis and experimental results

Gianluca Gentile
Department of Industrial Engineering
University of Rome Tor Vergata &
Istituto Neurotraumatologico Italiano (INI)
Grottaferrata (Rome), Italy
Rome, Italy
dr.gianlucagentile@gmail.com

Maria Richetta
Department of Industrial Engineering
University of Rome Tor Vergata
Rome, Italy
richetta@uniroma2.it

Andrea Malizia
Department of Biomedicine and Prevention
&
Department of Industrial Engineering
University of Rome Tor Vergata
Rome, Italy
malizia@ing.uniroma2.it

Patrizio Vicini
Department of Urology
Istituto Neurotraumatologico Italiano (INI)
Grottaferrata (Rome), Italy
patriziovicini@inwind.it

Jean Francòis Ciparisse
Department of Industrial Engineering
University of Rome Tor Vergata
Rome, Italy
ciparisse@ing.uniroma2.it

Pasqualino Gaudio
Department of Industrial Engineering
University of Rome Tor Vergata
Rome, Italy
gaudio@ing.uniroma2.it

***Abstract*— Dental resin composites are tri-phase systems that composed by an organic phase, an inorganic phase and a silane phase. The quantitative ratio between matrix and filling part together with the matrix-filling legacy, the typology of the filling part and the chemical profile of the resin matrix are the main characteristics of the clinical profile of that materials. The surface texture and roughness has been recognized as another important parameter for the longevity of the restoration. In this paper the authors will show the main tests of roughness of particular composite used with two different technique and will critically discuss the experimental results.**

Keywords—resins, roghness, resistance, experiments

I. INTRODUCTION

The aim of Restorative dentistry is to restore the anatomy and the function of compromise dental elements in order to preserve and maintain the integrity of residual healthy tissues. Due to the increased demands by patients, functional needs are, nowadays, important as the aesthetic even for the posterior region restorations. In order to achieve these previous results, restorative dentistry must therefore avail the most suitable materials for resistance, biocompatibility and surface characteristics.

Gold, gold alloys, amalgams meet the physical, mechanical and clinical requirements of a restorative material, but their limits are being poorly aesthetics and require a less conservative approach than the adhesive materials.

In order to the scientific advances in formulation and the increased effectiveness of bonding procedures of resin composites , the non-adhesive materials have been combined and largely replaced by these materials. Thanks to the use of adhesive techniques, the invasive approach is drastically reduced geared only the elimination and replacement of pathological dental tissue [1].

The evolution of composite resins and adhesive techniques has led many clinicians to choose these materials even for the areas with a greatest occlusal stress [2].

Surface texture and roughness have long been recognized as parameters of high clinical impact for wear resistance, plaque accumulation, staining susceptibility and surface gloss [3, 4, 5]. After placement of the composite material, finishing and polishing are essential steps leading to the quality and success of composite restorations. A wide variety of polishing systems are available, including rubber polishers, felt wheels and abrasive brushes. The effects of those techniques on the surface texture of composite specimens have been subjected to several in vitro investigations [6]. In recent years authors have

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introduced new techniques to reduce or eliminate the finishing and polishing needs. Some of those techniques are mainly based on a preoperative occlusal registration (POR) using differente materials [7, 8] as transparent PVS (Poly-Vinyl-Siloxane) [9].

II. RESIN COMPOSITES

The term "resin composite" identifies those materials obtained by the combination of an organic polymer with inorganic particles of vitreous nature. The resin composite are tri-phasic systems characterized by the coexistence of the organic phase, the inorganic phase and silane phase. The latter has the purpose of binding the other two phases between them.

The resinous polymer constitutes composite matrix where the inorganic particles, which act as filler, are dispersed in [10].

The quantitative ratio between the matrix and filler, as well as the effectiveness and stability of the filler-matrix bond, the type of the filler and the chemistry of the resinous matrix define the clinical physical profile of the composite.

The resin matrix (or organic phase) is a mixture of methacrylic resins mainly composed of 2,2-bis [4 (2-hydroxy-3-methacryloxy-propyloxy) -phenyl] propane (Bis-GMA or monomer OF BOWEN) and / or by Urethane-Dimethacrylate (UDMA). The Bowen resin is composed by a succession of monomers derived from a synthesis reaction between bisphenol A (epoxy aromatic compound) and 2 molecules of glicidyl methacrylate. The BIS-GMA monomer realizes cross-linked polymers by addition reaction of methacrylate groups. The result is a resin with a different behavior from not modified acrylic resins with less polymerization shrinkage and better mechanical properties. The monomer, however, is considerably viscous, and for this reason is usually diluted with various monomers and oligomers of low molecular weight (viscosity controllers) in order to achieve adequate fluidity. Among the diluents are: TEGDMA, DUEDMA, MMA and EGDMA [1]

The filler indicates those inorganic substances added to the resin to solve the problem of the matrix shortcomings resistance and are represented in lot of cases from crystalline quartz, barium glass and pyrogenic silica. The filler increases the resin resistance and reduce the coefficient of thermal expansion. During the polymerization reaction, the resinous phase undergoes a substantial volumetric and linear shrinkage due to the approach between the monomeric molecules. The composite polymerization shrinkage can be reduced by increasing the percentage (in volume) of the fillers (dimensionally stable phase). However, the proportion of inorganic filler cannot exceed certain levels in order to avoid excessive viscosity and difficulties in material manipulation. These percentages differ according to the size and shape of the filler particles. Fine or irregular particles (with equal volume) possess a surface area much greater than the largest or regular particles. The fine or irregular particles have a high quantity of irregularities so the quantity of resin matrix needed to wet the entire filling surface (avoid the creation of sandy material) will be higher.

Nowdays, various new composites, based on nanoparticle fillers have been developed with the aim of satisfy the aesthetic proprieties required for anterior restoration, together with a number of mechanical properties necessary in posterior, stress-bearing areas [11].

III. MATERIAL AND METHODS

This experimental study was performed in accordance with the guidelines and the approval by the Ethics Committee of the University of Rome "Tor Vergata."

In the present study we chose to use a nano-hybrid composite with pre-polymerized filler (Premise-Kerr Hawe-Scafati (SA) -Italy).

A. Analysis in vitro

20 Plexiglas plates (fig 1) with a thickness of 4 mm with a central hole of diameter of 5 mm have been used to create the composite cylindrical specimens. Each plate was placed on another identical unperforated plate that worked as a shelf. The central hole has been wetted with vaseline oil, checking constantly the absence of excesses.

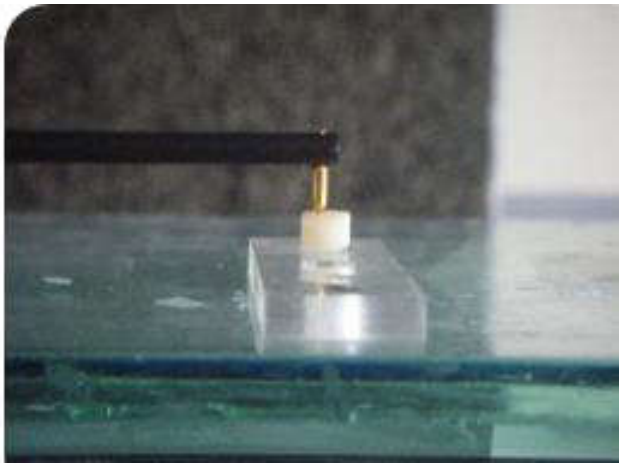

Fig. 1. Cylindrical specimens on Plexiglas plate

Group 1 (n=10) Rotary finishing and polishing.

The composite material has been inserted inside the mold's hole in 2 layers of 2 mm, each one followed by a 40 s light radiation. After curing, the specimens have been removed from the plexiglass and fixed on a plexiglass support with cianoacrylate glue (SuperAttack, Adhesive Henkel Loctite s.r.l Milan, Italy) to facilitate their handling. The surface of every specimens has been therefore submitted to finishing procedures with 30 µm and then 15µm grit flame shaped diamond burs (respectively FG 4236F and FG5236UF, KerrHawe) using high speed contrangle handpiece (5:1) to a speed of 20000 rpms under water spray.

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The polishing procedures has been performed with 2 steps siliconic points C13 and A13 (Identoflex - KerrHawe, Bioggio, Switzerland) using low speed contrangle handpiece 1:1 to a speed of 5000 rpms for 20s. Burs and silicon points were used tangentially to specimen's upper surface, always in the same direction and were let to touch the surface only while moving against the rotation direction for a total of 15 times.

For surface glossing silicate prophylaxis paste Cleanic (KerrHawe) on a natural bristle brushes, Pro-Brush (KerrHawe), were used on low speed contrangle handpiece 1:1 to a speed of 5000 rpms for 10 s without water spray and then for further 10 s under constant water spray irrigation.

Group2 (n=10) POR-PVS Technique.

A clear PVS Elite Glass (Zermack, Badia Polesine (RO), Italy) was mixed with automix tip under manufacturer instructions and delivered inside a custom made clear impression tray. An impression of an unperformed plexiglass bar (5 cm x 1.5 cm x 0.4 cm) was taken to obtain the impression of the surface which has to be reproduced. A first material layer of 2 mm was packed inside the plexiglass mold and subsequently cured for 40s from the upper surface. A second increment then was layered to fill completely the mold checking for a slight excess of material. Therefore the preliminary registration was fitted on the mold and firm constant pressure was applied for 10 seconds to permit the flow and the adaptation of the material before curing for 40s through the clear impression tray and Pvs. Once the impression has been displaced , the specimen was cured for further 40 seconds , extracted from the plexiglass mold and fixed with cianoacrylate glue on plexiglass support bar. No finishing nor polishing procedures was performed.

Preparation Groups 3 and 4 (GD3 and GD4)

In order to analyze the surface roughness of the natural polish, minimizing the samples handling, it was decided to use the palatal and lingual surfaces of 10 selected teethes. For each element were performed 4 surface analysis before any of the polish polishing maneuver (G3) and 4 surface analysis, following the procedures of polishing with diamond paste Cleanic conduct (KerrHawe, Bioggio, Switzerland), by the mean of a toothbrush to prophylaxis natural bristle Kumapam mounted to a 1:1 manipulator (speed of 5000 rpm for 10 s) without water jet and for an additional 10 s under constant irrigation. Particular attention has been paid to detect the values of roughness surface on the same areas of polish.

B. Analysis ex-vivo

For our case study, based on the analysis of the composite restorations profilometry performed in direct technique, was used 30 molars (fig. 2) free of caries disease, defects in the formation of the polish, cracks, iatrogenic or previous damage restoration extracted for orthodontic or periodontal reasons. All the elements just extracts were thoroughly cleansed and freed from any adherent soft tissue, plaque and tartar by means of manual curette and placed in 5.5% NaCl for a time of 5 minutes, for disinfection purposes.

These were then rinsed under the water jet stream for 30 minutes, and placed in physiological saline solution for storage.

All selected elements were observed by light microscopy (20x magnification) to avoid the presence of morphological alterations, infractions or polish fractures.

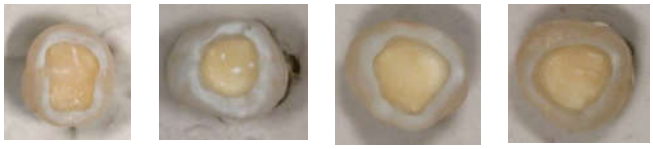

Fig. 2. Four of the 30 molars used

The chosen items were then randomly divided into 4 study groups:

- G1 (Group 1): Elements restored with Layering Technique procedures followed by Rotary finishing and polishing steps;
- G2 (Group 2): Elements restored with POR-PVS Technique ;
- G3 (Group 3): Natural elements unpolished;
- G4 (Group 4): Natural elements polished.

The samples has been analyzed with a TALYSURF CLI 1000 (TAYLOR HOBSON precision, Leicester, United kingdom) for profilometry acquisitions. (fig. 3)

Fig. 3. TALYSURF CLI 1000

The acquisition has been performed in inductive mode with a vertical resolution of 40 nm.

The mechanic acquisition mode (inductive gauge) is constituted by a probe composed by a stylus with diamond tip (fig. 4) that slid (in contact) with the surface of the sample following its profile.

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A position transducer converts the movement of the tip in the relative height values. A linear analysis together with a surface analysis (485 measures) have been performed over four areas, 0.5 x 0.5 mm, are acquired for each sample with a resolution of 201 points using a scanning speed of 100 µm /s and return of 500 µm /s. (fig 5)

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Talymap software also allowed digital surfaces reconstructions.

Statistical analysis of stylus profilometry roughness parameters (Sa and Ra) was conducted by one-way ANOVA followed by SCHEFFE' post hoc test.

Fig. 4. Inductive gauge

Fig. 5. Linear and surface analysis analysis on molar

I. RESULTS DISCUSSION

An high surface roughness of resin composite restorations have long been recognized as a significant clinical parameter for wear resistance, plaque accumulation [12], staining susceptibility and surface gloss. A previous study by Ikeda et al. [13] demonstrated that a smooth resin composite surface with lower roughness had less bacterial and biofilm adhesion compared to rougher specimens surface. In others studies no differences in plaque accumulation was found among composite surfaces polished with different methods achieving Ra values within 0.7 and 1.4 µm range [14, 15]. Willems & Lambrechts suggested to choose the mean surface roughness of human enamel in occlusal areas (i.e. 0.64 µm) as a reference value [16]). Nevertheless a universally accepted surface smoothness reference value does not exist yet.

The linear analysis of the composite disks shown the lower Ra values (the smoother surface) were shown in the group G2. After the execution of tests (Kruskal-Wallis and Mann - Whitney) it was possible to detect a significant statistical variability. Only the results G2 and G1 are similar, while in the cross comparison with G3 and G4 all cases shown significant differences. (fig. 6)

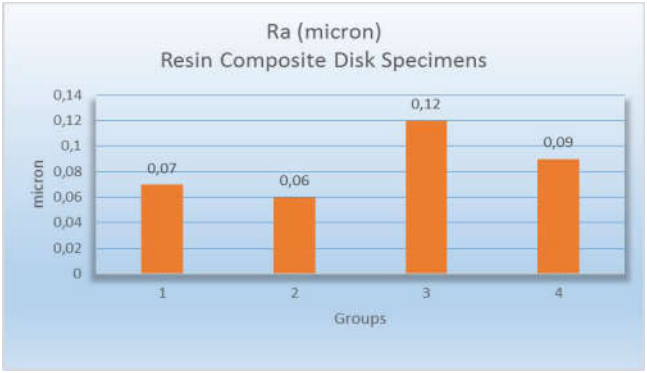

Fig. 6. Ra values of composite disk specimens

Linear analysis, directly performed on the molar restoration (fig. 7), shown that the surface roughness (Ra) are lower that the one obtained from the G4 group followed in order by G1, G2, G3. The Kruskal -Wallis test ($p < 0.001$) and Mann-Whitney showed the following statistically significant differences: The G4 group (more smooth) has proved to have Ra values statistically lower compared to G1 ($p < 0.05$), G2 ($p < 0.01$) and G3 (0.001). G1 and G2 are statistically similar results, showing both values lower than G3.

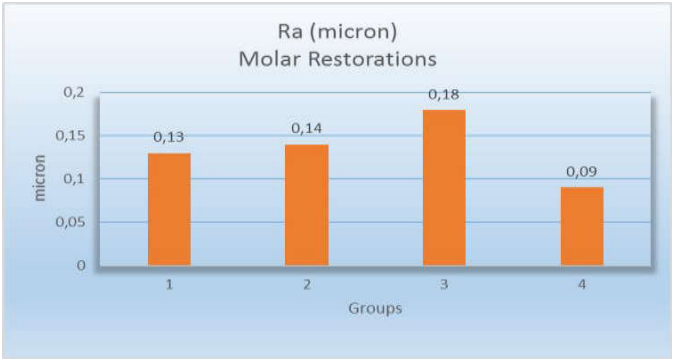

Fig. 7. Ra values of molar restoration

In the surface analysis, performed on disks, the greatest surface smoothness was obtained by the POR-PVS tecnique (G2), followed by the traditional technique (G1), from the

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polished enamel (G4) and the non-polished enamel (G3). G2, being the smoothest, was statistically similar to G1, while the differences with G3 and G4 ($p < 0.001$) were significant. (fig. 8)

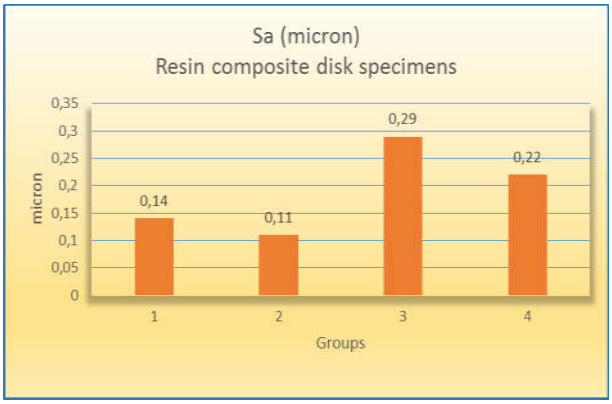

Fig. 8. Sa values of resin composite disks specimens

G1 was found statistically smoother than G3 ($p < 0.001$) and G4 ($p < 0.05$). G2 showed the same result as G1 with G3 ($p < 0.001$) but a more marked difference with G4 ($p < 0.005$). Finally G4 also has shown smoothest than G3 ($p < 0.005$). Statistical correlation has been found also between G1 and G3 ($p < 0.001$) and G1 and G4 ($p < 0.01$), as well as between the same polished enamel groups (G4) and unpolished (G3) ($p < 0.05$). The results of the One-way ANOVA is used to test the values of Sa (of composite restorations and natural cuspal enamel), it showed that the difference between the group G1 and G3 group is statistically significant ($p < 0.05$). G3 also statistically far more wrinkled G4 ($p < 0.001$) (which he received the lowest values). The G2 group shows no significant differences rather than the other groups, making it similar to the G1 group. It is noted that also in the last case, as in all the previous higher values of roughness were shown by the natural enamel not polished. (fig. 9)

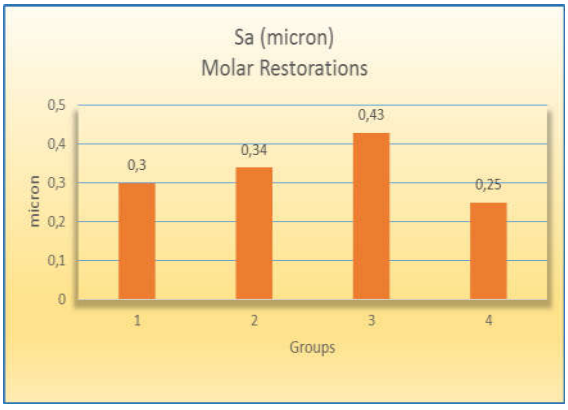

Fig. 9. Sa values of molar restoration

CONCLUSION

The surface studies (Sa) have always shown higher results than those obtained from single linear analysis (Ra) (even if the linear is still the most used analysis in literature). It means that a study of the area gives more information (peaks and valleys) compared to measurements on linear profiles also allowing the possibility to have axonometries and images for the qualitative evaluation of the surface.(fig 10, 11)

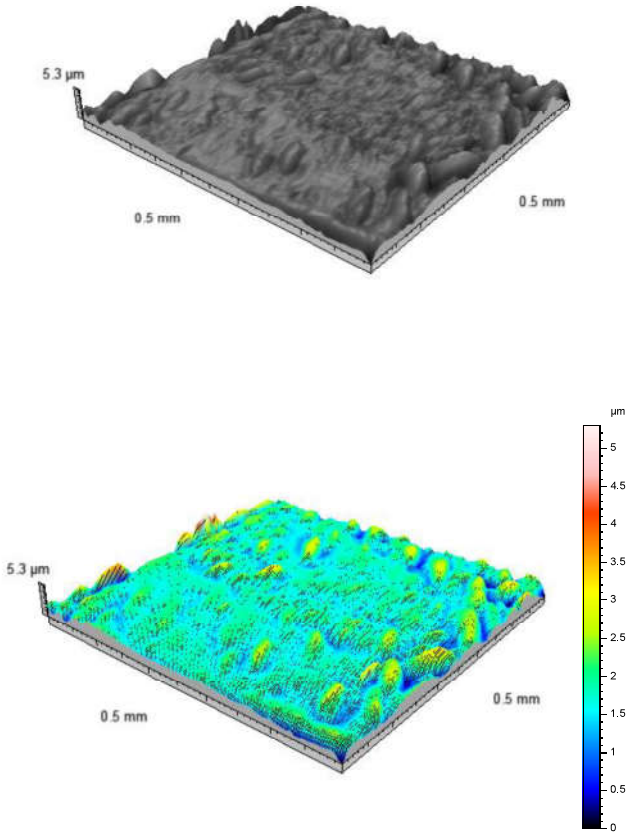

Fig. 10. Continuous and reticular axonometric

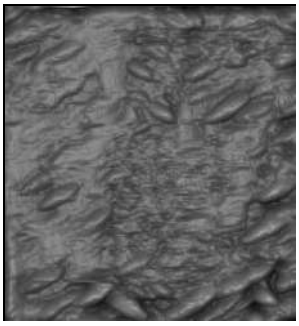

Fig. 11. Surface Photo Simulation

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The study carried out directly on the cusp slopes of extracted elements provided indication of how the results will present differences (POR-PVS Technique) between in vitro and ex vivo analysis. It suggests the need to numerically, by simulation, the clinical condition to demonstrate the real surface characteristics reachable with different systems.

The POR-PVS technique presents a quality of surface superimposable to that obtained through the use of traditional restoration techniques followed by sequential steps of finishing and polishing, however, bringing benefits of physiological anatomy faithful reproduction of the element, thus allowing a maximum precision of the restoration, as well as a saving in terms of instruments and Rates otherwise used for the classic finishing procedures.

Considering all the limitations of this ex vivo study we can conclude that:

1) In the analysis of the surface roughness it would be desirable that the authors refer to more comprehensive indices of Ra only such as Sa or use more highly precise methods of investigation such as the Atomic Force Microscope (AFM).

2) The surface roughness values obtained in vitro are not conducible to the clinical reality. Therefore in vitro studies are likely to have little practical relevance.

3) The POR-PVS Technique is able to provide a surface quality comparable to traditional techniques of finishing and polishing.

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