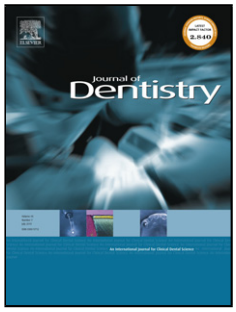
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A randomised controlled study on the use of finishing and polishing systems on different resin composites using 3D contact optical profilometry and scanning electron microscopy

Short title: Composite finishing and polishing systems.

Authors

1. Alaa Daud, Senior Clinical Teaching Fellow, Restorative Dentistry, University of Bristol Dental School, UK

2. Gordon Gray, Senior Lecturer in Restorative Dentistry, University of Bristol Dental School, UK

3. Christopher D. Lynch, Professor of Restorative Dentistry, University College Cork, Ireland

4. Nairn H.F. Wilson, Emeritus Professor of Dentistry, King's College London Dental Institute, UK

5. Igor R. Blum, Director, Maurice Wohl Dental Centre, Dental Institutes of King's College Hospital and King's College London, UK

***Corresponding author:**

Dr Igor R. Blum

Maurice Wohl Dental Centre, West Norwood Health & Leisure Centre, West Norwood, London SE27 0DF.

Phone: +44 (0) 20 30490741

Email: igor.blum@nhs.net

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ABSTRACT

Objectives: The aim of this study was to evaluate the effects of different finishing and polishing techniques on the surface roughness of microhybrid and nanofilled resin composites.

Methods: The resin composites included were Filtek Z250 (a universal microhybrid resin composite) and Filtek Supreme XTE (a universal nanofill resin composite). Ninety cylindrical-shaped specimens were prepared for each composite resin material. The polishing methods used included tungsten carbide bur (TC); diamond bur (Db); Sof-Lex discs (S); Enhance PoGo discs (PG); TC+S; Db+ S; TC+ PG; Db+ PG. Polymerisation against a Mylar strip without finishing and polishing acted as the control group. Surface roughness was measured using a 3D contact optical profilometer and surface morphology was examined by scanning electron microscope examination.

Results: The results showed that the Mylar-formed surfaces were smoothest for both composites. Finishing with the 20μm diamond finishing bur caused significantly greater surface irregularity ($P<0.0001$) and damage than finishing with the tungsten carbide finishing bur. The Enhance PoGo polishing system produced smoother surfaces than the Sof-Lex disc polishing system; this difference was statistically highly significant ($P<0.0001$).

Conclusion: For both composites, the Mylar-formed surfaces were smoothest. Where indicated clinically, finishing is better conducted using a tungsten carbide bur- rather than a diamond finishing bur. The Enhance PoGo system was found to produce a smoother surface finish than the Sof-Lex system.

Clinical Significance: If finishing and polishing is required the use a tungsten carbide finishing bur followed by Enhance PoGo polishing may be found to result in the smoothest surface finish.

Keywords: resin composite; polishing systems; surface roughness

INTRODUCTION

Advances in nanotechnology have led to the introduction of several new resin composite restorative materials (composites) with various claims of superior aesthetics. These materials are placed, however, using established techniques, with the inevitability that at

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least sections of the margins, if not the surfaces of restorations of these materials, need to be finished and polished, even when a careful matrix technique is applied.

Finishing refers to the contouring of the restoration to obtain the desired anatomy and complete any necessary occlusal adjustments, whereas polishing refers to the reduction of surface irregularities created by the finishing instruments.

One of the keys to achieving an aesthetic restoration is good surface finish [1]. Surface polish is important to the appearance and longevity of a tooth-coloured restoration [1]. The surface roughness of a composite restoration affects susceptibility to plaque accumulation [2-4], recurrent caries [1], suboptimal aesthetics of the restored tooth and potential for abrasion and wears kinetics. Surface roughness also influences resistance to staining [5] and the optical properties, including the reflectance of composite restorations.

Various instruments and methods have been advocated for the finishing and polishing of composite restorations. It has been shown that one-step polishing systems can be superior, or at least comparable to multi-step techniques, subject to the finishing regimen used prior to polishing [5,6].

Analysis of the surface roughness of resin composite restorations can be undertaken using a variety of methods, including profilometry for quantitative analysis and scanning electron microscopy (SEM) for qualitative assessments. Existing literature includes limited information on surface roughness analysis of microhybrid and nano-resin composites using optical three-dimensional (3D) profilometer [7,8].

The aim of the present study was to compare and contrast the surface roughness of specimens of a microhybrid and a nanofilled composite to determine the most effective

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regime for the finishing and polishing of these resin systems. Surface roughness was investigated using optical 3D profilometry and SEM.

The null hypotheses were that there are no differences in surface roughness values between the two composites and no differences in surface roughness values following the use of the different finishing techniques and polishing systems on the two composites.

MATERIALS AND METHOD

Preparation of composite resin specimens

Two light-polymerised composites were selected for use in this study: Filtek Supreme XTE universal restorative nanocomposite (batch number 20081112, 3M ESPE, St. Paul MN, USA) and Filtek Z250 universal microhybrid composite (batch number 20081110, 3M ESPE). The compositions of the two composites are shown in Table 1.

Ninety cylindrical specimens of each of the two composites were prepared using a ready-made plastic Teflon mould (Curing Depth Tester, Dentsply, UK) with a cylindrical cavity of 4mm in diameter and 4mm in depth. The mould was lubricated using Vaseline (Pure Petroleum Jelly, London, UK). A microscope glass slide (Fisherbrand, Fisher Scientific, FB58620, UK) 1.0mm thick was placed under the mould. A straight, transparent Mylar strip (Hawe Transparent Strip, KerrHawe, Switzerland) was interposed between the microscope glass slide and the mould. The composite material was placed in the mould using a smooth-surface, round ended condenser, care being taken to avoid any air inclusions or folds in the composite adapted to the Mylar strip. The composite was polymerised in layers <2mm thick using a cordless LED curing light (Dentsply,

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SmartliteTM PS). The output intensity was measured after every 10 specimens, using a Coltolux light meter (Coltene/Whaledent) to ensure that the output >900 mW/cm2.

Once polymerised, each specimen was extruded from the mould and stored separately in a labelled micro-centrifuge tube in distilled water at 37˚C for 24 hours. The specimens were handled using dressing tweezers applied to the sides of the cylinder to protect the flat, Mylar-formed surface of the composite from any damage or contamination.

Finishing and polishing

The 90 specimens of each composite were divided at random into nine groups, each comprising 10 specimens. Each group of Filtek Supreme XT specimens was paired with a group of Filtek Z250 specimens. A summary of the surface treatments applied to the flat, Mylar-formed surfaces included in the 20 specimens in each of the nine paired groups are detailed in Table 2. The allocation of surface treatment to paired specimen groups was random, using random number tables. Specimen were grasped and held in mosquito forceps (3M, ESPE, St. Paul MN, USA) during allocated surface treatment, having been marked on the side to ensure that all finishing and polishing took place in the same direction. Before being returned to its water-filled tube, each specimen was rinsed thoroughly under cold, running water. The Sof-Lex discs (3M, St. Paul, MN, USA) and Enhance PoGo systems (Dentsply Sirona, York, PA, USA) were single use. The diamond and tungsten carbide finishing burs were replaced after three specimens.

Surface roughness

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A non-contact (3-D) optical profilometer (ProScan-2000; Scantron Industrial Products, Ltd., Taunton, UK) was used to measure the surface roughness (Ra - arithmetic mean of the absolute departures of the roughness profile from the mean line) of the 10 specimens in each of the 18 specimen groups. The scans were then auto-levelled and filtered to obtain the Ra values in units of μm.

Surface morphology

The surfaces of two randomly selected specimens from each group were examined under SEM to investigate the surface morphology of the finished surfaces. The specimens were sputter coated with a 15nm layer of Pt/Pd to aid conductivity and examined using a Jeol JSM 5600 LV SEM (Jeol Ltd., Japan) at an operating voltage of 15 kV in the secondary electron mode. Scanning was conducted over a 3.0 x 3.0 mm area with an x and y step-size of 0.01 and 0.10 mm and number of steps of 400 and 30, respectively.

Analysis

A statistical analysis programme Stata/IC version 10.1 (StataCorp, College Station, TX, 2009) was used to calculate the mean and standard deviation. An R version 2.8.0 (R Foundation for Statistical Computing, Vienna, Austria, 2008) was also used to calculate the

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p-values from the Tukey-Kramer tests. The data appeared to be not normally distributed and accordingly, the data were transferred to a natural logarithm.

Taking the natural logarithm of all measurements reduced this problem and allowed a three-way ANOVA (with composite, bur type and polishing method as factors) to be carried out. Tukey-Kramer testing (which adjusts for multiple tests) was then used to carry out pairwise comparisons between the different finishing methods and composites. The significance level was set at 0.05.

RESULTS

The profilometric findings are presented in Table 3. These results revealed that there was no significant difference in roughness values between the two composites with any of the finishing and polishing regimens ($p=0.15$), nor was there any evidence that the composites were affected differently by the methods of finishing or polishing ($p=0.81$ and $p=0.35$ respectively).

In contrast, there was evidence that the degree of roughness is influenced by both the method of finishing and polishing, with the most significant difference ($p<0.0001$) in roughness being associated with the use of the diamond finishing bur (Figs.1a and 1b).

For both composites, the smoothest finish was achieved by the Mylar strip. When finishing was necessary, there was a strong evidence (Tukey-Kramer pairwise comparisons) that the tungsten carbide bur provided a smoother finish than the diamond finishing bur, regardless of the polishing technique used ($p < 0.0001$). SEM examinations have confirmed these findings as shown in Figs. 2a and 2b.

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When the tungsten carbide bur was used for contouring, the Enhance PoGo system produced better results than the Sof-Lex system ($p < 0.0001$), but when the diamond bur was used, there was no evidence of a difference in roughness between the two polishing systems ($p=0.94$). Overall, when finishing was required, the smoothest finish was produced by the use of the tungsten carbide bur followed by Enhance PoGo polishing system (Figs.3 and 4).

DISCUSSION

It is widely accepted, that the smoothest surface obtainable on a composite restoration is that formed by a well-applied matrix strip [9-12], assuming the matrix was not allowed to move during the polymerisation of the surface layer of the composite. The smooth surface formed by the matrix, which may include some imperfections - air inclusions and folds [13], tends to be rich in resin, but free of any air-inhibited composite. Removal of the limiting resin layer, together with flash excess which is common, even with a well-placed matrix, by finishing-polishing procedures tends to leave a harder, more wear resistant and aesthetically stable surface [12]. Factors influencing the polishability of a composite include the nature and size of the filler particles, the filler loading, access to the surface(s) to be polished, and the nature and extent of surface irregularities left following finishing or free-hand placement [8].

The present study was considered important, given that many surfaces, or at least margins of composite restorations require finishing and polishing, irrespective of the matrix system, if any, used, and relatively little information having been published on how best to finish

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and polish restorations of state-of-the-art composite restorative materials. With composite now being the most widely used restorative material globally, and the quality of the surface finish at the time of placement being an important factor in the in-service performance and longevity of restorations, it is considered that the findings of the present study should be of immediate practical relevance in clinical practice.

The finding that the Mylar matrix-formed surfaces of composites of different composition exhibited similar surface roughness (smoothness) is in agreement with previous studies [9-12]. The Filtek Supreme XTE baseline specimens were marginally smoother than the corresponding Filtek Z250 specimens. This could be related to the filler composition of the two materials [12,13]; Filtek Supreme XTE containing nano-particles with an average size of 11nm and Filtek Z250 being a microhybrid composite containing particles with an average particle size of 0.6μm. This finding is in agreement with the findings of Kormaz et al. [11], who showed that for 'Mylar strip groups', the surface roughness values for Filtek Supreme XTE and Filtek Z250 were not significantly different ($p>0.05$).

The use of the carbide and, in particular the diamond finishing bur resulted in a substantial increase in surface roughness values for both composites. This finding, confirmed by a Tukey-Kramer pairwise comparisons is consistent with the findings of other authors [3,14,15] and is in agreement with the results of previous studies [6,16,17]. These findings emphasise the importance of polishing all surfaces and margins of composite restorations which have been finished. Leaving finished surfaces, in particular diamond finished surfaces unpolished will greatly increase susceptibility to plaque and stain accumulation and retention, adversely affecting restoration performance and, in turn, longevity. It is not considered appropriate to adopt the attitude that finished composite surfaces will, relatively

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quickly become smoother in clinical service when subjected to oral hygiene procedures, obviating the need for polishing clinically. If anything, evidence indicates that composites left with relatively rough surfaces at the time of placement will remain relative rough in clinical service.

The use of the 20µm diamond finishing bur was considered to cause destructive surface alterations in surfaces of both composites (Table 3). This finding is of particular importance given that light operating pressures were used and the diamond bur, which copiously water cooled, was applied for 20s only. It is suggested that the extensive use of diamond finishing burs, especially if used with other than light operating pressures and in the absence of effective water cooling, may be found to cause substantial damage to the surfaces and margins of composite restorations. While further work would be required to investigate the use of diamond burs to contour newly placed composite restorations, the findings of the present study would favour the use of tungsten carbide burs to finish composite restorations prior to polishing.

The Sof-Lex polishing system, although effective in reducing surface irregularities after finishing, in particular finishing with the diamond finishing bur, failed to leave surfaces as smooth as those formed by a Mylar matrix (Table 3). This was in agreement with other studies [11,17]. The ability of aluminium oxide containing discs to produce a smooth surface is thought to be related to their ability to cut the filler particles and matrix equally [16]. Great care was taken in the present study to use the different grades of Sof-Lex discs at recommended operating speed. Further work would be required to ascertain the speeds at which different grades of Sof-Lex discs are typically applied in clinical practice and what

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effects deviations in recommended speeds of application may have on the quality of surface finish.

The finding that finishing the specimens of the two different composites, selected for inclusion in the present study, resulted in no significant differences in surface roughness (P=0.15) is in agreement with the findings of previous studies [10,17]. The findings of the present study lend support to the conclusion of these workers that the Enhance PoGo polishing system produced the smoothest surfaces following finishing. This, together with the added relative simplicity of using the Enhance PoGo system, favours its use, at least for the finishing of state-of-the-art composites such as those investigated in the present study. The finding that the Enhance PoGo system failed to leave Filtek Supreme XTE surfaces as smooth as Mylar formed surfaces is in contrast with the findings of Ergücü and Türkün [18], who concluded that Mylar strip- and PoGo finished Filtek Supreme XTE surfaces were equally smooth. This might be explained by methodological differences in the two studies, notably the type of profilometer pick-up instrument (mechanical vs optical profilometry) used. Similar explanations may exist for contrasting findings from other studies. For example, Üçtaşli et al. [15] evaluated the effect of Sof-Lex and PoGo polishing systems on the surface roughness of a microfill, hybrid and packable composite resin and concluded that Sof-Lex discs produced a smoother surface than PoGo for all tested materials. Similarly, Koh et al. [6] reported that Sof-Lex polishing discs resulted in significantly smoother surfaces when compared to PoGo polishing discs for Filtek Supreme. Standardisation of methodologies to investigate the efficacy of finishing and polishing systems for composite restorative materials could help eliminate such conflicting findings.

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CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

For both composites, the Mylar-formed surfaces were smoothest. Where indicated clinically, finishing is better conducted using a tungsten carbide bur - rather than a diamond finishing bur. The Enhance PoGo system was found to produce a smoother surface finish than the Sof-Lex system. If finishing and polishing is required the use of a tungsten carbide finishing bur followed by Enhance PoGo polishing may be found to be most effective.

ACKNOWLEDGEMENTS

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Figures:

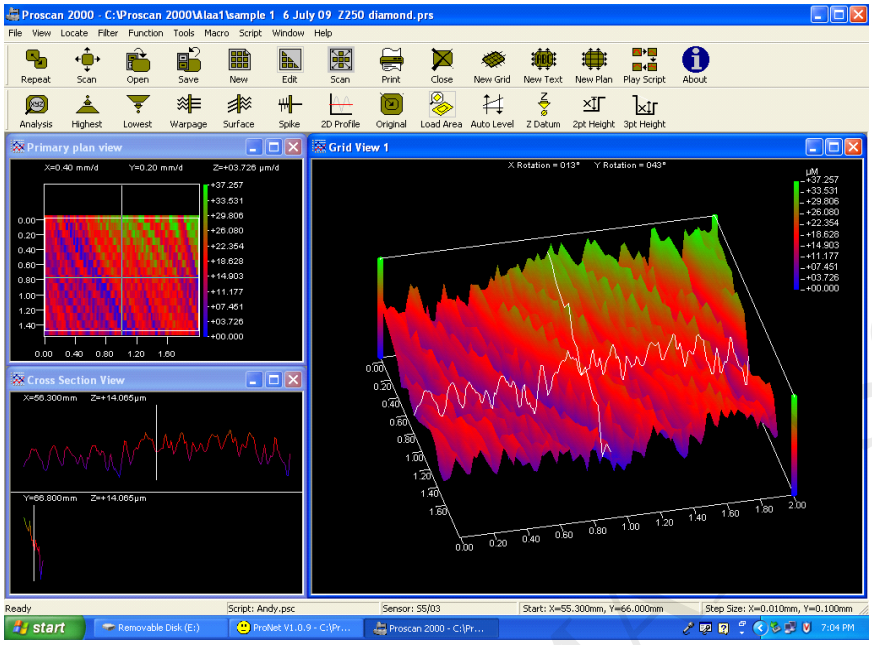


Fig.1a. Profilometric image of Filtek Z250 finished with a diamond finishing bur

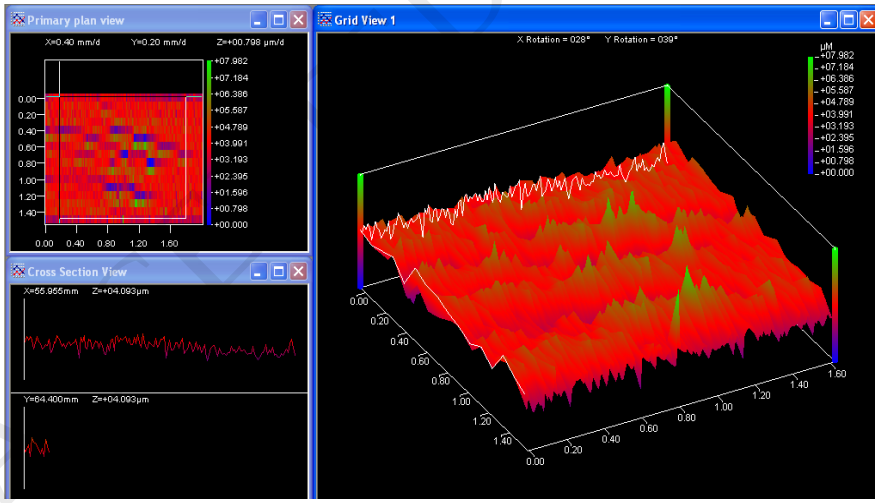


Fig.1b. Profilometric image of Filtek Z250 finished with a tungsten carbide bur

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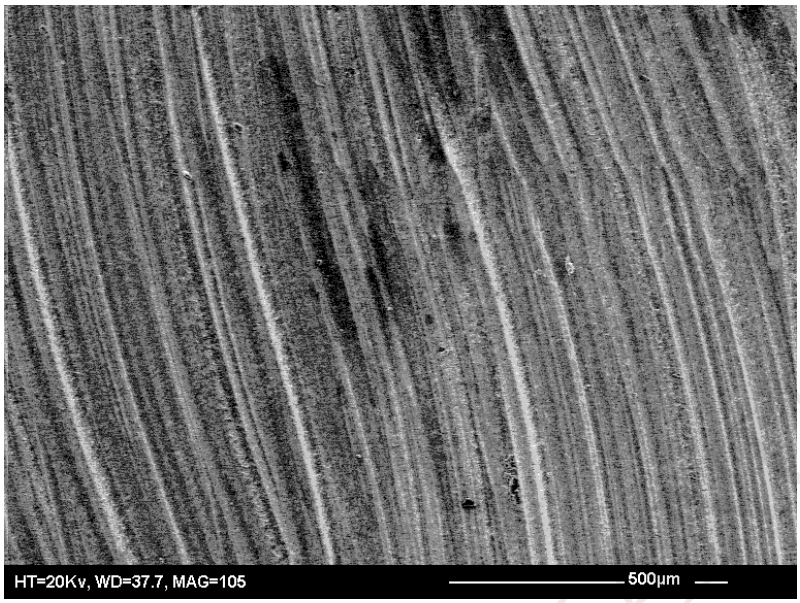


Fig. 2a. SEM image of a of Filtek Z250 composite resin specimen following finishing with the 20um grit diamond finishing bur (x 100 magnifications).



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Fig. 2.b. SEM image of a of Filtek Z250 composite resin specimen following finishing with a tungsten carbide bur (x 100 magnifications).

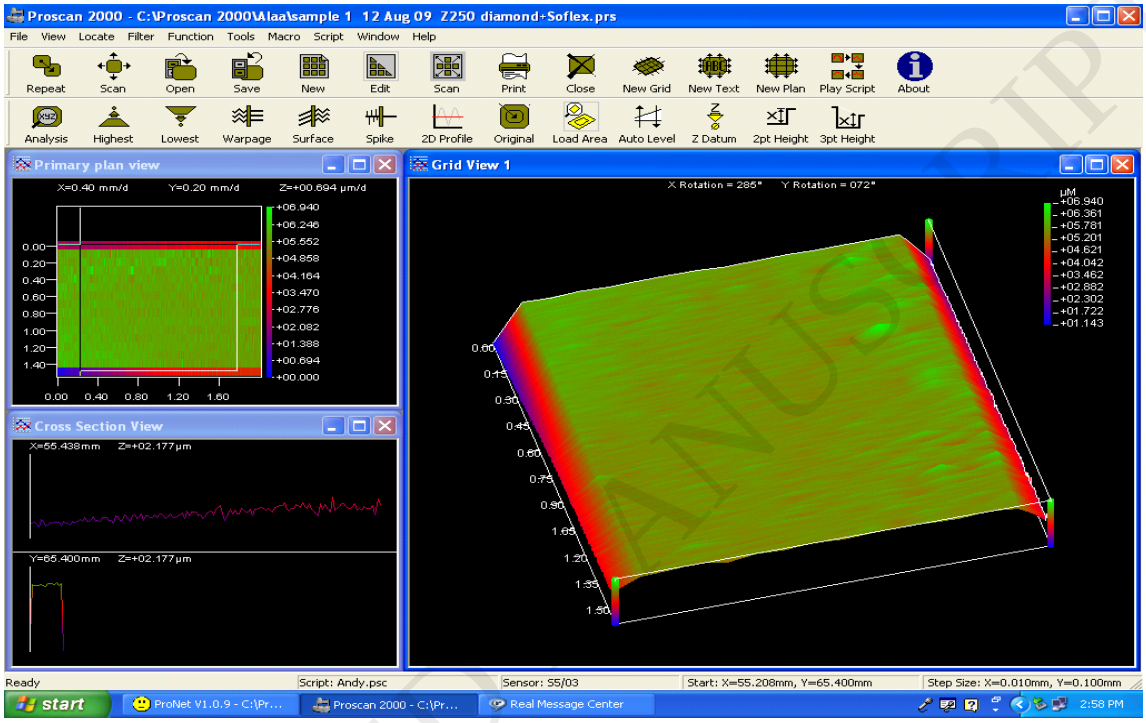


Fig.3: Profilometric image of Filtek Z250 finished with the tungsten carbide bur and polished with Enhance PoGo.

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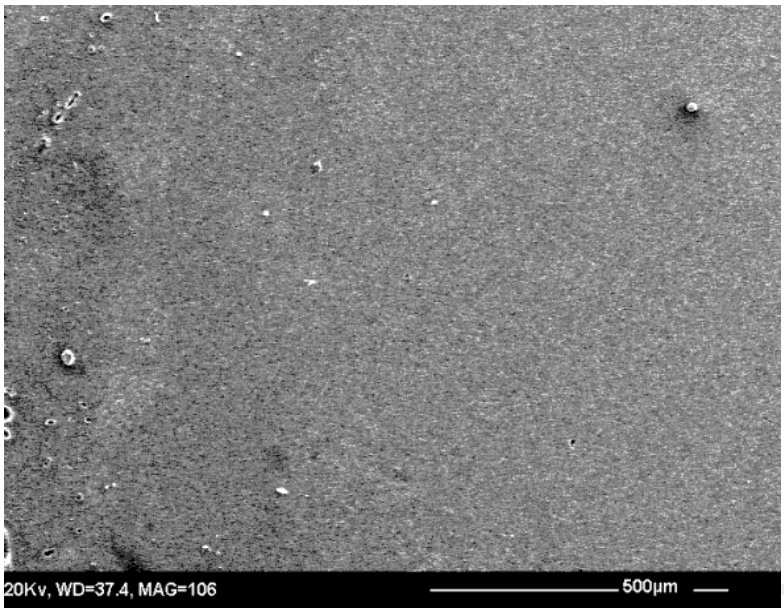


Fig. 4. SEM image of Filtek Z250 finished with the tungsten carbide bur and polished with Enhance PoGo (x 100 magnification).

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Tables:

Table 1. Details of materials and instruments investigated

Material	Manufacturer	Filler composition	Filler loading	Filler particle size	Resin type
Filtek Supreme XTE	3M ESPE, St Paul, MN, USA	Silica/Zirconia cluster fillers	63.3% by volume	4-20nm (average 11nm)	Bis-GMA, UDMA, TEGDMA Bis-EMA
Filtek Z250	3M ESPE, St Paul, MN, USA	Silica/Zirconia cluster fillers	59.5% by volume	0.01-3.5µm (average 0.6µm)	TEDGMA UDMA Bis-EMA
Enhance PoGo discs	Dentsply Caulk, Milford, DE, USA	Cured composite of urethane dimethacrylate, fine diamond powder, silicon dioxide 7 µm, Al2O3			
Sof-Lex discs	3M ESPE, Dental products St Paul, MN, USA	Al2O3 flexible discs 100 μm (C) 29 μm (M) 14 μm (F) 5 μm (SF)			

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Table 2. Surface treatments allocated to the nine paired groups of composite specimens

Paired groups	Surface treatment
1	Polymerised against Mylar strip-no finishing or polishing
2	Water-cooled, multifluted, fine-needle, tungsten carbide bur only (9904, 30 Blade Needle, Jet Burs, Sybron Ltd, Canada) applied with light operating pressure for 20s
3	Water-cooled, tapered, fine (20µm grit), finishing diamond bur only (UnoDent, Israel) applied with light pressure for 20s
4	Sof-Lex (3M ESPE St. Paul MN, USA) polishing only, using single-use reducing grit size discs: 1982 C (3000rpm), 1982 M (3000rpm), 1982 F (10,000rpm) and 1982, SF (30,000rpm) only, with each grit size disc being applied dry under constant pressure for 30s, and the specimens being washed and air-dried between successive discs, according to manufacturer directions
5	One-step PoGo (Dentsply Sirona, USA, Batch Nº 081023) polishing only -initial 20s 10,000rpm, followed by 20s at 2000rpm under constant pressure and without water cooling, according to manufacturer directions
6	Tungsten carbide bur finishing followed by Sof-Lex polishing
7	Tungsten carbide bur finishing followed by PoGo polishing
8	Diamond finishing bur followed by Sof-Lex polishing
9	Diamond bur finishing followed by PoGo polishing

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Table 3. Mean Ra values obtained for finishing and polishing regimens investigated when applied to the two selected composites.

	Mylar Strip Ra(µm)	**Db** Ra(µm)	**Db + S** Ra(µm)	**Db+PG** Ra(µm)	**TC** Ra(µm)	**TC+PG** Ra(µm)	**TC+S** Ra(µm)
XTE	0.06	2.48	0.23	0.25	0.26	0.09	0.16
Z250	0.07	2.82	0.25	0.25	0.27	0.10	0.16

XT= Filtek Supreme XTE; Z250= Filtek Z250; Db=Diamond finishing bur; S=Sof-Lex discs; PG= Enhance PoGo discs; TC= Tungsten carbide finishing bur.

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