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Evaluation of the effects of polishing systems on surface roughness and morphology of dental composite resin

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Abstract

Objectives: The aim of this in vitro study was to evaluate the effects of 5 different 2-step diamond impregnated polishing systems (Sof-Lex Spirals, Venus Supra, Komet Spirals, CompoMaster and Shapeguard) on the surface roughness and morphology of a submicron hybrid composite resin material (Brilliant Everglow).

Materials and Methods: 200 composite resin discs were prepared with 180 SiC paper to produce a uniform baseline surface. The samples were randomly assigned to one of five groups and polishing was completed by one operator. The arithmetic mean surface roughness (Ra) was measured using contact profilometry and the surfaces were examined under SEM.

Results: Statistical differences ($p < 0.05$) were identified between the surface roughness remaining after use of the polishers. Diatech Shapeguard ($0.22\mu\text{m}$, SD 0.08) and Komet Spiral ($0.26\mu\text{m}$, SD 0.09) polishers yielded the lowest surface roughness (Ra) values whilst the CompoMaster polishing system led to the highest surface roughness values ($0.55\mu\text{m}$, SD 0.19).

Conclusions: Within the limits of this in vitro study of the efficacy of diamond impregnated 2-step polishing systems, Diatech Shapeguard and Komet Spiral polishing systems produced the lowest surface roughness values. These polishing systems yielded acceptable surface roughness values with regards to oral health and patient comfort.

Clinical relevance: Similarly designed polishing systems do not produce comparable surface roughness levels and clinicians should be aware of this when considering polishing protocols for composite restorations.

Introduction

The use of composite resin materials in tooth restoration has increased dramatically in recent decades¹ with patient's aesthetic demands, Government directives and advancements in the material properties being some of the reasons behind this increase. A significant part of the successful use of these materials is the ability to recreate anatomically correct restorations that mimic the dental hard tissues.

Surface finish as measured by surface roughness of dental composite restorations plays a significant role in their clinical success. A smooth, natural appearance is gained from proper contouring, finishing and polishing, which is necessary for the oral health of the soft tissues and restoration's marginal integrity.² A rough surface negatively impacts on the restoration's aesthetics which makes them susceptible to exterior staining and also diminish the amount of gloss, reducing the ability to reflect light. This in turn affects the perceived colour of the composite resin and loss in aesthetics occurs due to staining.

The accumulation of plaque is affected by the surface properties of composite resin restorations, in particular the surface roughness. Composite resins are vulnerable to development of cariogenic biofilms.^{3,4} and an increase in surface roughness results in an increase in retention of microorganisms resulting in faster colonisation and maturation of dental plaque. The attachment of proteins, predominantly gp340, and microbes contribute to an increase in virulence and in turn degradation of the restoration.⁵ Literature findings suggest that surface roughness of greater than 2 microns results in steep increases in biofilm formation whilst a value lower than 0.2 micron Ra is suggested to provide ideal surfaces for intraoral restorations.^{6,7} The effect of surface roughness is less dramatic in subgingival environments compared to supragingivally as there are more opportunities for the microorganisms to survive⁸ and there is less of an effect of the maturation of the biofilm. The salivary pellicle can also mask the effect that surface roughness has on biofilm formation, but it not thought to wholly counterbalance it.⁹

Additionally, a rough surface can cause patient discomfort due to the sensitivity of the patient's tongue to a perceived roughness and 0.3µm is thought to be the threshold at which patients will detect a difference.¹⁰

Surface roughness contributes to exterior discoloration. There is a direct relationship between the surface roughness and surface discolouration, however filler particle size, resin matrix composition in particular a low water absorption rate and the gloss produced after finishing are concurrent influential factors.^{11,12,13,14}

Surface gloss is an important factor in producing aesthetic restorations. Differences between a high gloss restoration and enamel are less obvious because the colour of the reflected light is more predominant instead of the colour of the composite resin material and conversely, low surface gloss can be detected between a well shade matched restoration and adjacent enamel.¹⁵ There are many studies that correlate surface roughness and surface gloss.¹⁶⁻¹⁸ It is well accepted that an increase in surface roughness will generally decrease the amount of gloss. However, improvements in surface gloss may not be not linear to improvements in surface roughness^{16,18} and varying filler particles play a significant role.¹⁹ There is limited evidence regarding the acceptable level of surface roughness to provide acceptable surface gloss results. Values below 1µm have been shown to produce a smooth and glossy surface in vitro²⁰ but there is a lack of a general consensus of required threshold levels.²¹

Clinicians are often bombarded with many choices when it comes to commercial resin composite restorative materials. Selection is dependent on many factors from the physical properties and clinical efficacy however the surface finish is an important consideration, which can influence aesthetics and oral function. There are many variables that can influence the immediate surface roughness of a dental material such as the type of material, polishing system, force and timing of polishing, polishing in wet or dry conditions and therefore comparing the numerical data of various research can be difficult because of numerous factors that can influence the outcomes.

This study aims to evaluate any differences in the surface roughness of a composite resin material that may arise when polished by using 5 different polishing systems to provide information to clinicians regarding the efficacy of the 5 different 2-step polishing systems when using a sub-micron hybrid composite as an example. This study standardised as many variables as possible to allow a more accurate comparison of different polishing systems on one type of composite. The focus was on any potential differences in the polishing systems rather than the impact of the type of composite, hence a single composite was selected for the study. Contact profilometry was used to quantitatively analyse the surface roughness and

scanning electron microscopy to visualise the surface topography produced by the polishing systems. The combined use of the scanning electron microscope (SEM) images can help the reader understand the type of surface morphology that would be expected from different polishing systems based on their surface roughness results

Methods

Five commercially available composite polishing systems were selected as shown in Table 1. All the polishing systems used were composed of either diamond or Al₂O₃, silicone impregnated 2-step polishers. Everglow Brilliant (Coltene Whaledent, AG, Alstatten, Switzerland) is a commercially available submicron hybrid resin composite commonly used by clinicians, hence used in this study.

Composite resin blocks of similar and uniform roughness were prepared by placing the composite in round silicone moulds, which were covered with a Mylar strip (Hawe Transparent Strip, Kerr Hawe, Switzerland), compressed between two glass slabs and light cured (light intensity > 800 mW/cm²) using a cordless LED curing light (Dentsply, Smartlite TM PS) for 20 seconds through each side. The composite blocks were 1cm in diameter and 2mm. These were polished in an automatic polisher using 180 grit paper for 25 seconds in wet conditions. The samples were numbered 1-200 using adhesive labels and randomised into 5 groups A-E.

In each group the composite blocks were polished using light pressure in wet conditions using a slow-speed handpiece. The 5 groups received the polishing treatment shown in Table 2. The samples were polished for a total of 20 seconds each. After each polishing, the samples were rinsed under running cold water and allowed to dry for 24 hours before profilometry was completed.

A contact profilometer (Tesa Rugosurf 10g Surface Roughness Gage) was used to measure the surface roughness of the composite blocks. The stylus was placed away from the edge of the composite block to avoid any areas that may have not been reached by the polisher. The cut off length was 8mm, a tracing length was 5mm and a stylus speed of 0.1mm/s was used to measure the surface roughness.

Statistical analysis was completed using SSPS software to calculate each group's mean and standard deviation. Following completion of the profilometry analysis, two samples from

each group, that mirrored the group's mean surface roughness values, were selected for scanning electron microscopy (JCM-6000 PLUS NeoScope Benchtop SEM, JEOL USA, Inc) in order to compare the surface morphology and compare to the results of profilometry.

Results

The mean surface roughness and standard deviation of each group are presented in Table 3. The data was found to be normally distributed and therefore, a one-way analysis of variance test was completed to investigate whether there were any statistically significant differences between the means of the 5 independent groups.

The result was significant at $p < 0.05$ and demonstrates that there are differences between the groups and the null hypothesis can be rejected.

The post-hoc Tukey test investigated where the differences between groups lies and showed the following results;

- The Diatech Shapeguard and Komet Spirals groups had the lowest surface roughness values, $0.23\mu\text{m}$ (SD 0.09) and $0.26\mu\text{m}$ (SD 0.08) respectively and were statistically different to all other groups but not each other.
- The Compomaster group had the highest surface roughness $0.55\mu\text{m}$ (SD 0.19) and significantly different to all other groups
- The Sof-Lex Spiral ($0.33\mu\text{m}$ SD 0.13) and the Venus spiral ($0.42\mu\text{m}$ SD 0.07) groups were significantly different to the all groups except each other

Two SEM images from each group are shown in Figures 1-5 and illustrate the surface finish achieved after polishing. All images show varying degrees of white scratches or voids where filler particles have been plucked from the surfaces.

Discussion

The primary objective in this study was to assess whether the polishing systems yielded composite surfaces that differed in terms of the surface roughness. The polishers were of similar composition, a 2-step polishing system using diamond impregnated silicone materials and although all of the manufacturers did not provide information about the abrasiveness of the individual polishers, the expectation was that the polishers would provide similar surface polish and be measured as residual surface roughness. Therefore, the null hypothesis is that there are no differences between the polishing systems. After analysing the results of the

study, the null hypothesis is rejected because there were significant differences found between various polishing systems. A secondary aim was to identify which polishing system generated the smoothest surface.

The Diatech Shapeguard polishers produced the lowest mean surface roughness of 0.22 μ m (SD 0.08), however this was not significantly different to Komet Spiral polishers which produced a mean surface roughness of 0.26 μ m (SD 0.08). Both these polishers had significantly lower surface roughness values compared to the other polishers. It can therefore be said that within the limits of this study, these two polishing systems are the most effective when used on a submicron hybrid composite resin.

It has been demonstrated that filler particles only fall away when the surrounding resin has worn away. Therefore, in order to produce more uniform polishing, it is more ideal to increase the hardness of resin rather than filler particles. Additionally, Tjan and Chan recommended that the abrasive particles in the polishers should be harder than the composite resin filler particles otherwise only the soft resin will be removed leaving the filler particles protruding from the surface.²² Despite being similarly described by the manufactures, the difference in results may be because of the way the abrasive particles are bound within the polisher's silicone matrix or the composition of the silicone matrix differs between systems and this influenced their polishing proficiency. Furthermore, if the polisher's matrix wears at a similar rate to the polishing particles, it's less likely to extrude from the matrix and create deeper scratches in the composite resin.

The aim of the pre-polishing stage was to create a uniform baseline from which to begin the polishing and to mimic clinical conditions and effectively focus on the effect of the polishing system. It has been shown that the mean surface roughness of composite resins can differ based on the polishing bur used and a recent study reported that the mean surface roughness of a microhybrid composite resin was 2.82 μ m after polishing with a fine diamond bur however it was 0.26 μ m when using tungsten carbide.²³ The 180 Sic paper that was utilised in this study produced a mean value of 1.5 μ m. Kaizer *at al* reports a wide range of surface roughness values for various SiC papers but the values differ greatly and appear to be related to the various composite resin used rather than the abrasiveness of the paper.²¹

It was therefore acknowledged by the author that the replication of the clinical situation is extremely difficult and instead, the emphasis in this study was in the creation of a uniform smooth baseline.

Another parameter of importance was the standardisation of the force applied on the surface during polishing. In this study, to minimise the variation in the force applied, a single operator applied a light force. This is a potential source of bias to the study. Alternatives such as a mounted hand-piece was considered, which would have been able to provide a more uniform force, but this was beyond the means of this study.

The amount of time polishing was standardised to avoid bias. This however, made comparison to other studies difficult because the most relevant research used 20-30 seconds per polisher and may account for the difference in result regarding the Venus polishers which have several studies that used 20 seconds and more for the polishing time.^{24,25}

Frictional heat generated during polishing can cause damage to the pulp²⁶ and affect the mechanical properties of the composite resin.²⁷ In this study, manufacturers guidelines on speed were followed for each type of polisher and this varied from 6000-15000ppm as detailed in Table. However, this variation in speed could be a potential source of bias to the study. These guidelines on speed may be set arbitrarily and can often be difficult to follow in a clinical setting. Increased speeds can result in increased heat generation which could in turn could cause localised softening of the composite resin matrix and result in a smoothening affect. To counteract the potential increase in temperature the samples in this were polished in wet conditions with the polisher being moved over the surface.

Although all data was considered normally distributed, both the Sof-Lex Spirals and Compomaster groups exhibited large standard deviations. Compared to the other groups, there is more variation in the surface roughness achieved by these polishers which we would not expect when using the same type of composite resin. One reason for this may be the formation of scratches or grooves on a relatively smooth surface giving these outlying surface roughness values. Additionally, these outer lying results could be a result of debris on the surface of the sample or a defect on the surface in one area.

Overall, the SEM images are consistent with the results of the profilometry testing. The samples that were chosen had a surface roughness that was very close to the mean of their group to ensure that a representative image could be achieved for each group. All of the images have a similar appearance with regards to the small voids in the surface of composite resin with the largest of these being approximately 5-10µm in diameter. This is considerable larger than the filler particles that are used in this submicron hybrid composite resin. These larger voids may represent agglomerates of filler that have been plucked from the matrix during polishing.

The existing literature has many studies examining the surface roughness of various polishing systems, none of which looked concurrently at all of the polishers included in this study. However, Sof-Lex Spirals and Venus Supra polishers were examined in several studies.

Sof-Lex spirals produced similar surface roughness values in this study when compared to the results of Pala *et al.*¹⁷ After a total of 40 seconds polishing, mean surface roughness values were 0.32µm (SD .09) and 0.3µm (0.8) when tested on Majesty Posterior and Z550, two nanohybrid composite resins. However, this was not corroborated by another study by Kemaloglu *et al.*²⁴ which reported a surface roughness mean of 0.21µm (SD 0.01).

The mean surface roughness values of Venus Supra polishers in this study produced higher results when compared to another investigation by Say *et al.*²⁵ with similar methodology which reported surface roughness values of 0.147µm (SD 0.04), 0.112µm (0.01) and 0.14µm (SD 0.03) when applied to three nanohybrid composite resins. This is corroborated by another study which found similar surface roughness.²⁸ The lower surface roughness reported in these two studies may be explained by the longer polishing time used (60 seconds in total) but there are other interplaying factors such as the composite resin composition and force applied that could affect the resulting surface roughness.

When considering the clinical relevance of this study, it is useful to consider a threshold value that a polishing system should produce to ensure good aesthetics and oral health. Several authors suggest a threshold surface roughness value of 0.2µm for intra-oral materials with respect to biofilm formation.^{7,29}

Both the Diatech Shapeguard and Komet Spirals groups were approximately at the threshold value at 0.2µm after 20 seconds of polishing. Lu *et al* reported that up until 0.07µm, staining did not occur in a microfill composite resin but this was not found in other types of composite

resin where there was a positive linear relationship with surface roughness and staining.¹¹ However, Karamen *et al* did not find a difference in the amount of surface staining with surface roughness values of between 0.9 to 1.3µm.¹² It is therefore difficult to extrapolate a threshold value that is necessary to achieve with regards to surface roughness and the ability to increase surface staining however, all of the results found in this study are considerably greater than the results cited and therefore, may be more likely to accumulate surface staining.

When considering patient comfort, the level of surface roughness detected by patients has been observed to be 0.3µm. Diatech Shapeguard, Komet Spirals and Sof-Lex Spirals polishing systems produced surface roughness within acceptable limits of this result. Additionally, all of the polishing systems produced mean surface roughness below 1µm which has been reported by Chung to produce optically smooth composite resin surfaces well below this value.²⁰

In-vitro research cannot reproduce the dynamic oral environment and therefore there are other factors that can influence the amount of the immediate surface roughness of a finished restoration namely the type of composite and polishing system, the force applied and the amount of time spent polishing. This study examined a specific protocol and resin composite material. Care should be taken when extrapolating the results of this study and the findings should be limited in particular, to resin composite materials with a similar filler particle size and geometry.

Conclusion

Within the limits of this in vitro analysis of the efficacy of these diamond impregnated 2-step polishing systems, it appears that the Diatech Shapeguard and Komet Spiral polishing systems produced the lowest surface roughness values. These polishers produce acceptable surface roughness values with regards to the oral health and patient comfort. However, the results of these polishers were much higher than surface roughness levels needed to reduce the risk of surface staining. The worst performance was found in the CompoMaster group which produced values more than twice that on the Diatech Shapeguard and Komet Spiral polishers.

The polishing time in this study was relatively short and further sequences of polishing would allow the efficacy of the polishers to be fully assessed. This would be particularly relevant in helping clinicians choose a polishing system based on the overall performance but also the time required to achieve it.

Caution must be taken when extrapolating the results from this study. This in vitro investigation is unable to recreate the oral environment and there are many interplaying factors that can affect the final surface roughness of a polished restoration namely the type of composite resin, the finishing sequence and the method of polishing.

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Tables

Table 1 Details of the materials

Material	Matrix	Abrasive	Manufacturer
Sof-Lex Spiral	Elastomer	Al ₂ O ₃ and Diamond particles	3M ESPE, USA
Venus Supra	Urethane Polymer	Diamond particles	Heraeus Kulzer Germany
Komet Spirals	Synthetic Rubber	Diamond particles	Komet, Germany
CompoMaster	Synthetic Rubber	Diamond particles	Shofu INC, Japan
Diatech Shapeguard	Silicone	Diamond Particles	Coltene, Switzerland

Table 2 Polishing Protocols.

Group	Surface treatment allocated to each group
A	Sof-Lex spiral (Yellow) polisher followed by the 2nd (Pink) polisher for 10 seconds each with the speedset at 15,000 rpm
B	Venus Supra (Red) polisher followed by the 2nd (Grey)polisher for 10 seconds each with the speed set at 10,000 rpm
C	Komet Spiral Pink (94028F) polisher followed by the 2nd Grey polisher (94028) polisher for 10 seconds each with the speed set at 6,000 rpm
D	CompoMaster Coarse (Yellow) polisher followed by the CompoMaster (Blue)polisher for 10 seconds each with the speed set at 10,000 rpm
E	Diatech Shapeguard Blue polisher followed by the Purple Polisher for 10 seconds each with the speed set at 10,000 rpm

Table 3 Surface Roughness Values (Ra μm)

	N	Mean	Std. Deviation	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Sof-Lex Spirals	40	0.35	0.13	0.31	0.39
Venus Supra	40	0.42	0.07	0.40	0.45
Komet Spirals	40	0.26	0.08	0.24	0.29
CompoMaster	40	0.55	0.19	0.49	0.61
Diatech Shapeguard	40	0.23	0.09	0.20	0.25
Total	200	0.36	0.17	0.34	0.39

Figures

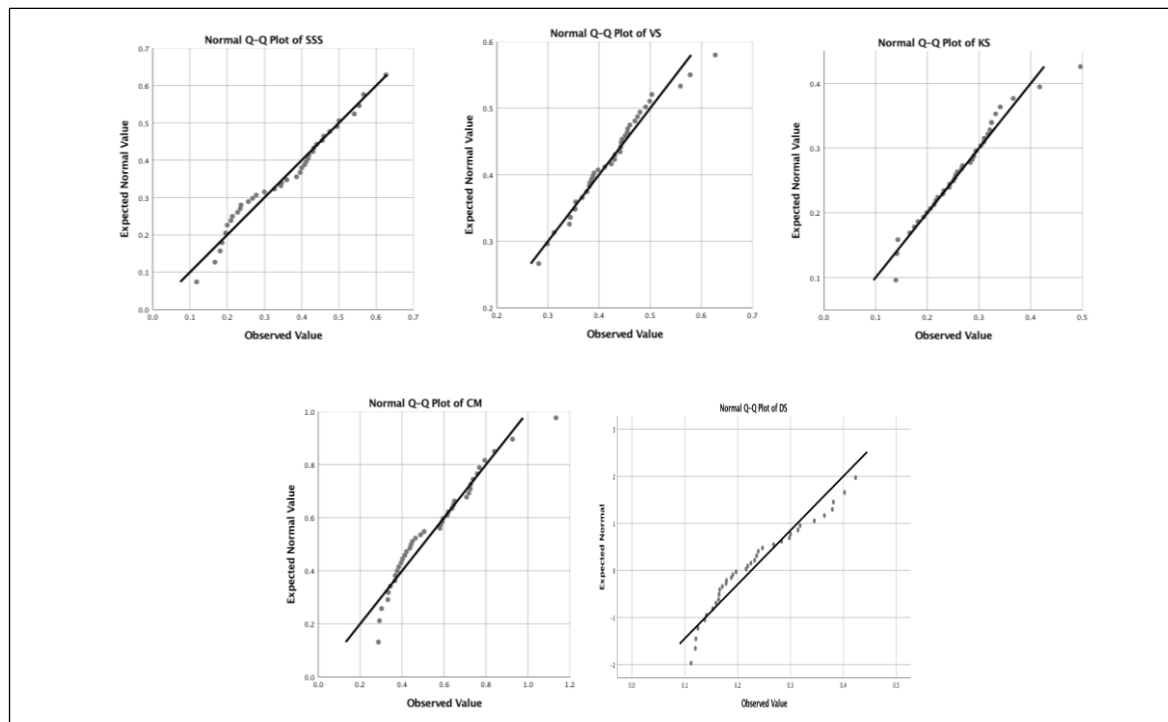
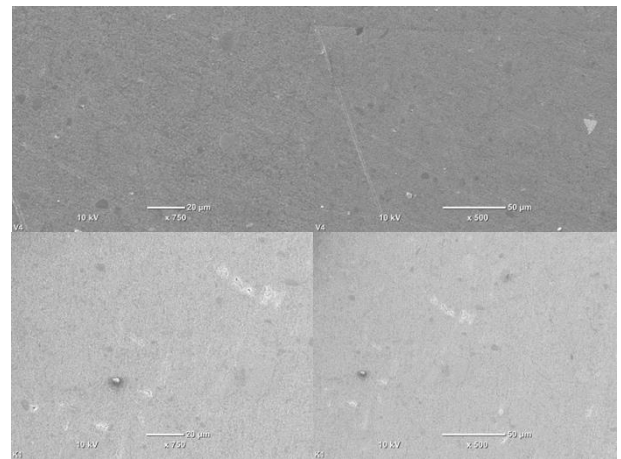
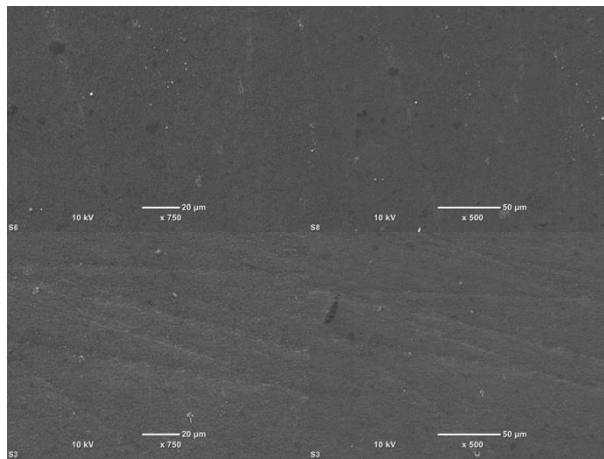
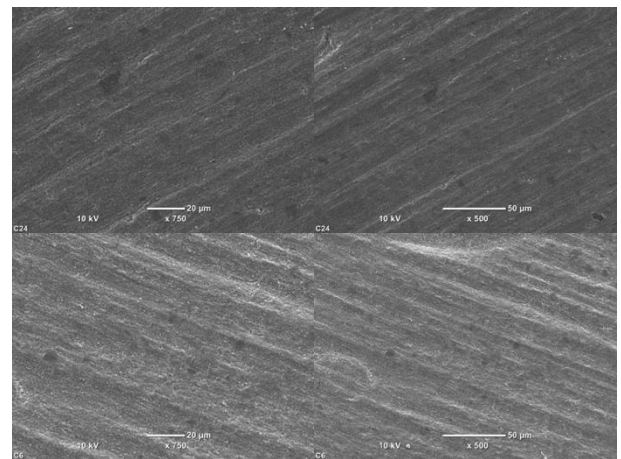
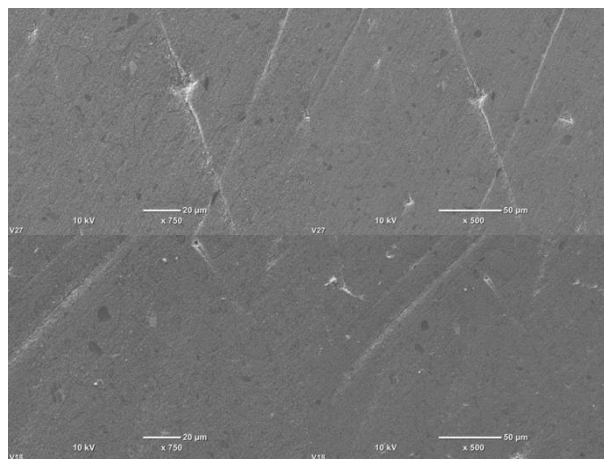


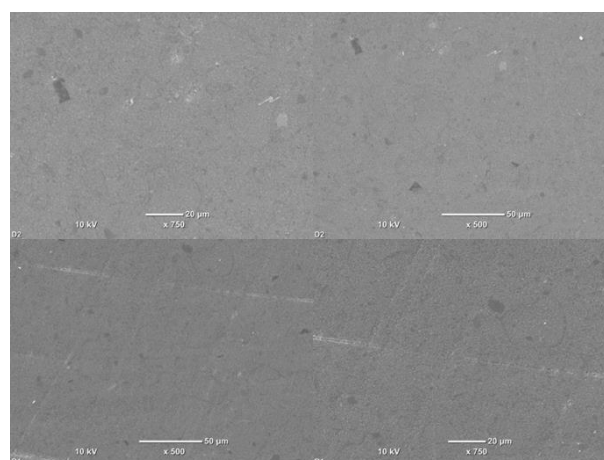
Figure 1: Clockwise from top left; Q-Q graph of surface roughness values for A) Sof-Lex Spirals, B) Venus Supra, C) Komet Spirals, D) Compomaster, E) Diatech Shapeguard



Figures 2-6 showing SEM images of two samples of composite resin from each group after under magnification x750 and x500. 2(a-d) Sof-Lex Spirals samples showing small amounts of filler particles that have been plucked from the surface and white scratches visible at higher magnification. 1(a-d): Komet Spirals samples showing minimal areas of filler particles missing and the surface is resin rich and relatively homogenous.



2(a-d): Venus Supra samples showing more obvious scratches and deeper voids where the filler particles have been plucked from the surface in Figure 14(c). In Figure 14(a-b), there is a higher incidence of smaller filler particle removal. 3(a-d): Compomaster samples showing a less uniform pattern compared to the other surfaces and white lines in one direction can be observed. These appear to be scratches from the polishers and would indicate that the polisher was applied using a reciprocating motion and minimal evidence of filler particle removal.



4(a-d): Diatech Shapeguard samples showing relatively uniform surface with some small scratches, filler voids and debris on the surface.