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THE EFFECT OF DIFFERENT POLISHING SYSTEMS ON THE SURFACE ROUGHNESS OF A NANOCOMPOSITE AND A MICROHYBRID COMPOSITE

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ABSTRACT

Objectives: To evaluate the surface roughness of a nanocomposite and a microhybrid composite after polishing the composites with different polishing systems.

Key words: Polishing, surface roughness, microhybrid composite, nanocomposite, Sof-Lex XT, Spiral Wheels, Enhance, Intensiv UniglossCellbrush, Zircon-Brite, Dura-White stones, Mylar strips

Methods: The composites used in this study were Filtek Supreme XTE (3M ESPE, St Paul, USA) and Z100 (3M ESPE, St Paul, USA). Thirty-five composite samples were made from each of the two composites. Uncured composite was placed into an aluminium ring mould, 10mm X 2mm. Both the upper and lower surfaces of the composite were covered with Mylar strips and glass plates, before the specimens were cured for 40 seconds from both sides.

Samples were randomly divided into seven groups. The groups were:

1. Mylar polyester strip (control)
2. Sof-Lex XT finishing and polishing discs (3M ESPE, St Paul, USA)
3. Sof-Lex Spiral Wheels (3M ESPE, St Paul, USA)
4. Dura-White stones (Shofu Inc, Kyoto, Japan)
5. Intensiv UniglossCellbrush (Intensiv SA, Montagnola, Switzerland)
6. Enhance finishing and polishing system (Dentsply, Milford, USA)
7. Sof-Lex Spiral Wheels combined with Zircon-Brite (Dental Ventures of America, Corona, USA)

The polishing of the specimens was performed by a single operator according to manufacturer's instructions. The mean surface roughness of each specimen was determined using a profilometer (Surftest SJ 210, Mitutoyo, Tokyo, Japan). Three readings were collected from each specimen. Data was statistically analysed using ANOVA. Scanning

Electron Microscope (JEOL JSM-5800 LV, Tokyo, Japan) photos were taken of the representative samples.

Results: Statistically significant differences in surface roughness were observed between the following groups: Z100 and Filtek Supreme XTE with the polishing systems combined (p=0.005); Control group vs all the polishing systems; Sof-Lex XT finishing and polishing discs vs Dura-White stones, Intensiv UniglossCellbrush, Enhance finishing and polishing system (p < 0.0001); Sof-Lex Spiral Wheels vs Dura-White stones, Intensiv Unigloss Cellbrush, Enhance finishing and polishing system (p <0.0001); Dura-White stones vs Intensiv UniglossCellbrush, Enhance finishing and polishing system, Sof-Lex Spiral Wheels/Zircon-Brite (p <0.0001); Intensiv UniglossCellbrush vs. Spiral Wheels/Zircon-Brite (p<0.0001); Enhance finishing and polishing system vs. Spiral Wheels/Zircon-Brite
(p <0.0001).

Conclusion: Filtek Supreme XTE displayed significantly better polishability and lower surface roughness values after polishing than Z100. The composite samples cured against the Mylar polyester strip produced significantly smoother surface roughness values than all the polishing systems tested in this study. The following polishing systems led to the smoothest surfaces after polishing: Sof-lex Spiral Wheels in combination with Zircon-Brite, as well as the Sof-Lex Spiral Wheels and Sof-Lex finishing and polishing discs. These systems were significantly smoother than the Enhance system used in combination with Prisma Gloss polishing paste, and also the one-step polishing system Intensiv UniglossCellbrush. There was no statistically significant difference between Sof-Lex Spiral Wheels in combination with Zircon-Brite, the Sof-Lex Spiral Wheels and the Sof-Lex finishing and polishing discs.

DECLARATION

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and that I have not previously in its entirety or in part submitted it at any other university for the purposes of obtaining a degree.

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DATE

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LIST OF ABBREVIATIONS

SEM	-	Scanning Electron Microscope
ANOVA	-	Analysis of Variance
AFM	-	Atomic Force Microscopy
µm	-	Micro meter
Al_2O_3	-	Aluminum oxide
°	-	Degrees

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CHAPTER 1: Introduction and literature review

Resin composite is the material of choice for direct restorations in the anterior aesthetic zone of the mouth, and it is used daily in clinical practice around the world.[1] The introduction of bonded composite materials made it possible to conserve more tooth structure whilst still resulting in an aesthetically acceptable restoration.[2] After placement of a composite resin restoration, the restoration needs to be finished in order to remove overhangs, reduce excess material, create optimal tooth morphology and to restore function.[3, 4] During the process of finishing the composite, the restoration becomes rough and subsequently needs to be polished to reduce surface roughness.[4]

The surface roughness of composite restorations is of great importance in the ultimate success and longevity of these restorations.[5] It has an influence on plaque accumulation on the composite surface.[6] If the surface of the composite restoration is not smooth, the accumulation of plaque can have serious effects, for example secondary caries at the restoration-tooth interface.[6] A rough restoration can cause gingival irritation or periodontal disease.[7] Surface roughness also plays an important part in the aesthetics of the restoration.[5, 8] The smoother the restoration, the more aesthetically acceptable it will be.[8] A rough composite restoration is also more prone to discolouration and will be unacceptable and uncomfortable to the sensory feeling of the patient's tongue.[9, 10] The type of composite that is used and the surface roughness of that specific composite may also have an influence on the wear of the opposing dentition.[11] The polishing direction can also have an effect on the marginal adaptation of a restoration. Marginal adaptation and marginal integrity have been proven to be better when a restoration is polished from the composite restoration to the tooth surface.[5, 12]

When using a polishing system the aim should be to prepare the surface or the restoration to mimic the enamel's natural smooth surface.

There are different composite polishing systems on the market, and they all claim to give excellent polishing results.[4] There are also different composite materials available on the market, all with varying degrees of polishability, which is mostly determined by the type and composition of the filler and the size of the filler particles.[13]

Composite materials used in dentistry can be classified according to the type of filler particle used, and also the size of the filler particles.[14, 15] Depending on the type and size of filler particles, the surface roughness of the polished product will be influenced. During the process of finishing and polishing the composite, the resin matrix and the inorganic filler does not abrade uniformly due to differences in hardness, and this can lead to protruding filler particles and a rough composite surface.[16] A specific substrate (specific type of composite), used with a specific abrasive system, should lead to unique surface properties.[17]

It is difficult for a clinician to decide which polishing system will give optimal results with a particular type of composite material. In this study the effects of different polishing systems used on a nanocomposite and a microhybrid composite were compared. The results of this study may provide valuable information that can aid clinicians and dental teaching institutions to decide on the optimal polishing system to use with the two commonly used types of composite, namely a nanocomposite and a microhybrid composite. The composites included in this study were Z100 (3M ESPE, St Paul, USA) and Filtek Supreme XTE (3M ESPE, St Paul, USA). Z100 and Filtek Supreme XTE were chosen as both are available on the Gauteng National Tender, and readily available to the researcher. Z100 acted as the gold standard as there has been a lot of research done on Z100.

The products selected for use in this study were a combination of “older” and “new” commonly used products currently available on the South African market. The polishing systems chosen represent the types of products mostly used at South African dental schools and by private practitioners.

1.1 Surface roughness and its importance

Plaque accumulation is influenced by the surface roughness of the composite restoration.[1, 6, 18, 19] Plaque accumulation and the formation of a biofilm, which harbour many cariogenic bacteria, can cause secondary caries and subsequent failure of the composite restoration.[20, 21] In order for bacteria (*Streptococcus mutans, Lactobacillus spp, Actinobacillus actinomycetemcomitans, Porphyromonas gingivalis*) to survive in the oral environment, it needs to adhere to a surface.[6] A surface roughness threshold of below 0,2 µm is necessary to prevent bacterial adhesion and plaque accumulation.[6, 18] Mei, Busscher, Van der Mei and Ren showed that it was more difficult to remove *Streptococci* bacteria from a rougher composite surface, due to stronger adherence of the *Streptococci* bacteria to a rougher composite surface.[22] They concluded that the adherence strength of bacteria to a composite surface is dependent on the surface roughness of the composite. The rougher the composite surface, the larger the contact area for the adhesion of bacteria to the composite.[22] Unpolished rough restorations further lead to plaque accumulation which can cause gingival irritation, gingivitis and ultimately can lead to periodontitis.[5-7]

The surface roughness also plays an important part in the aesthetics of the restoration.[5, 9, 23] Composite surfaces which were only finished (not polished) discolour more that composite surfaces which were polished as well.[24] However, composites cured through a matrix discoloured more than a rougher polished surface, probably due to the amount of resin in the outer unpolished layer of the composite surface.[24] In contradiction to this statement Park, Noh, Ahn and Kim could not demonstrate any difference in discolouration between celluloid strip-finished surfaces and polished composite surfaces in microhybrid composites.[25] Other factors such as strain in the molecular arrangement also play an important role in the discolouration of a composite surface.[24] Composite restorations which were polished too early, before complete polymerization took place, can cause strain in the molecular arrangement of the resin, and therefore will be more prone to discolouration.[24] The composition of the composite will also affect the staining susceptibility and colour stability of the restoration.[9] The smoother the polished surface of a composite restoration, the more colour stable the restoration will be.[9]

A rough restoration is unacceptable to the sensory feeling of a patient's tongue. Patients use the tip of their tongues to detect any surface roughness.[10] A patient can detect any roughness in the surface of composite restorations greater than 0.50 µm.[10] In order for a patient not to "feel" the restorative material, the surface roughness should therefore be less than 0.50µm.[10] In a study conducted by Botta, Duarte, Paulin Filho, Gheno and Powers it was found that untreated buccal enamel surfaces of incisors exhibited a surface roughness of more or less 0.047µm.[26] Any polishing system should aim to produce surface roughnesses below the critical 0.2µm threshold to prevent plaque accumulation, and also below 0.5µm to be unnoticeable to a patient's sensory feeling.

Research has proven that the smoothest composite surface is obtained when the composite is cured under a Mylar polyester strip.[4, 27-29] However, this surface is a polymer rich layer, making it more unstable and more prone to discolouration.[24, 28] Most restorations need finishing after placement of the composite to remove overhangs and excess composite material to restore the occlusion and morphology.[4, 30] During the finishing process, the surface roughness increases above the acceptable threshold of under 0.2µm.[4] It is therefore necessary to polish restorations after the finishing process to reduce the surface roughness to an acceptable value of 0.2µm.[6]

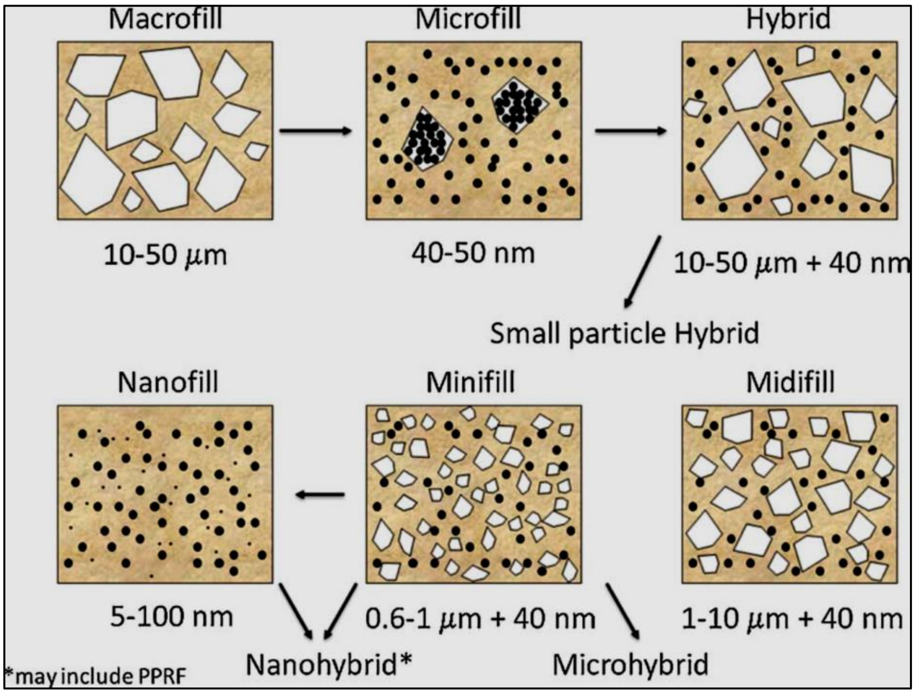
1.2 Influence of the composition of the composite resin restorative material on its surface roughness

Composites comprise of three main components: an organic matrix (resin), an inorganic phase (filler particles) and a interfacial phase (coupling agent) to bind the resin and filler.[15, 31] The coupling agent is a bipolar molecule that consists of silane groups at one end, and a methacrylate group at the other end (organosilane).[32]

The organic matrix consist of monomers such as Bisphehol-A-diglycidylmethacrylate (BIS-GMA) and urethane dimethacrylate (UDMA), ethylene glycol dimethacrylate (EGDMA), triethylene glycol dimethacrylate (TEGDMA), methyl methacrylate (MMA), a free radical polymerisation initiation system (such as camphoroquinone), an acceleration system dimethylaminoethyl methacrylate (DMAEM), a stabilizer (hydroquinone monomethyl ether) and absorbers of ultra-violet wavelengths (2-hydroxy-4-methoxybenzophenone).[15] There is always a certain degree of polymerisation shrinkage that takes place during and after curing of composites.[15]

It is mainly the inorganic fillers that determine the mechanical and physical properties of the composite material.[33] The aim is to obtain a high filler load into the resin matrix in order to reduce polymerisation shrinkage and to improve the mechanical properties of the composite.[33] Examples of inorganic fillers are silicon dioxide, boron silicates, lithium aluminium silicates, quartz, barium, strontium, zinc, aluminium or zirconium.[15]

Composites are classified according to the type and size of the filler particles.[14, 15, 33-36] Lutz and Phillips created a classification system, based upon the filler size of the particles, which is still used today. They classified composites into macro fillers, micro fillers and hybrid composites.[32, 34] Willems, Lambrechts, Braem, Celis and Vanherle developed a classification system that take not only the filler particle size into account, but also parameters such as The Young's modulus of elasticity, surface roughness of the material, and the hardness of the material.[37] Categories of composites described by Willems are Densified Composites, Microfine Composites, Miscellaneous Composites, Traditional Composites and Fiber-Reinforced Composites.[37] Figure 1 is a schematic presentation by Ferracane of the current classification of dental composites.[33]



*prepolymerised resin filler

Figure 1: The chronological development and classification of dental composites based on filler particle size[33]

The type, size and shape of filler material, and the filler load in the composite contribute to the physical characteristics of the composite material.[15, 38] The composition of the composite will influence the wear resistance and hardness of the composite, which in turn will determine the wear pattern when the composite is subjected to abrasion.[13, 33, 38]

Table 1: Summary of particle filler size, manufacturing process, filler load and mechanical properties of the different types of composites[13, 33]

1µm = 1000nm	**MICROFILLS**	**HYBRIDS** **MICROHYBRIDS** **NANOHYBRIDS**	**NANOCOMPOSITES**
Filler	Fumed silica	Zirconia/silica	Zirconia/silica
Particle size	0.04µm silica particles Aggregates	Broad distribution of particle sizes: • ≤0.1µm (nanohybrids) • 0.1µm • 0.2µm ≥1µm • ≥1µm	**Nanoparticles:** 20nm silica fillers 4 – 11 nm zirconia fillers **Nanoclusters** (loosely bound aggregates of nanoparticles) 0.6-10 µm zirconia/silica clusters
Manufacturing process	Pyrogenic process Add prepolymerised resin particles to increase filler load, mixture is polymerized and then ground to form particles.	Grinding/milling of larger particles into smaller particles Sintering process producing densified or compact fillers (Z100)	Sol-gel process (fillers are made from liquid precursors) Modified sintering process producing loosely agglomerated nanoparticles: nanoclusters
Filler load	Low	High	High
Mechanical properties	Weak strength Weak wear resistance	High strength High wear resistance	Strength = Hybrids Wear = Hybrids Polish retention > Hybrids

1.2.1 Nanocomposites

In their search for the optimal restorative material companies developed nanocomposites. Nanocomposites fulfil the aesthetic requirements of the anterior zone of the mouth with superior gloss and polish retention, and with excellent mechanical and wear properties for stress bearing areas in the posterior region of the mouth.[2, 35, 36] Nanotechnology produces structures in the nano range: 0.1 – 100nm.[2, 39] Nanocomposites have a higher filler load with a reduced resin content, which reduces polymerization shrinkage.[40]

The nanocomposite used in this study is Filtek Supreme XTE (3M ESPE, St. Paul, USA).[41] The inorganic filler load is 63.3% by volume for the dentine, enamel and body shades. The inorganic filler load is 55.6% by volume for the translucent shade. The fillers are a combination of the following: non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4 to 11 nm Zirconia filler and aggregated zirconia/silica cluster filler.[13] The dentine, body and enamel shade's cluster particle size range from 0.6 – 10µm. Filtek Supreme XTE contains BIS-GMA, UDMA, TEGDMA, PEGDMA and BIS-EMA resins.[13, 41]

1.2.2 Microhybrid composites

The microhybrid composite used in this study was Z100 (3M ESPE, St Paul, USA).[42] The filler is zirconia/silica and it has a particle size of between 0.01 to 3.5 µm.[42] The inorganic filler load is 66% by volume.[42] The resin used in Z100 is BIS-GMA and TEGDMA.[42]

Table 2: The composition and technical profile of the composites used in this study[13, 41, 42]

Material	**Resin Matrix**	**Type of filler**	**Filler vol. %**	**Mean particle size (µm)**	**Manufacturer**	**Batch no.**
Z100 (Shade A2)	BIS-GMA* TEGDMA§	Zirconia/silica	66%	0, 01 to 3, 5 µm	3M ESPE, St Paul, USA	LOT N585492
Filtek Supreme XTE (Shade A2B)	BIS-GMA* UDMA¶ TEGDMA§ PEGDMA # Bis-EMA †	Non-agglomerated/ non-aggregated silica fillers, non-agglomerated/ non-aggregated zirconia filler, aggregated zirconia/silica cluster filler	63.3%	i. 20nm silica ii. 4 to 11 nm zirconia iii. 0.6-10 µm zirconia/silica clusters	3M ESPE, St Paul, USA	LOT N596719

* Bis-GMA: Bisphenol A glycidyl dimethacrylate; § TEGDMA: Triethylene glycol methacrylate;
¶ UDMA: Urethane dimethacrylate; # PEGDMA: polyethylene glycol dimethacrylate; †BIS-EMA: Bisphenol A ethyl dimethacrylate

1.3 The effect of "finishing" and "polishing" on surface roughness

Finishing of a restoration is defined as the gross reduction of excess material to achieve the ideal morphology (contour and shape) and optimal function.[4] Finishing of a composite restoration is usually achieved by either using a fine and extra-fine diamond bur (different grits ranging from 7µm to 50µm), or with multifluted tungsten carbide burs (8-40 flutes).[5, 17]

Polishing of a composite is defined as the reduction of roughness and elimination of scratches which were created whilst finishing the composite.[4]

There are different types of abrasive systems used in dental finishing and polishing systems:

- Aluminum oxide (alumina) Al_2O_3, which is usually bonded to paper or polymer disks and strips, or impregnated into rubber wheels and points.[17]
- Carbide compounds, which can include silicon carbide, boron carbide, and tungsten carbide. Multi-fluted finishing burs are made of tungsten carbide. Silicon and boron carbide are used as discs, cups, points or wheels.[17]
- Diamond abrasives, which can be used in rigid diamond finishing burs, or in a elastomeric matrix (Intensiv UniglossCellbrush) or as a polishing paste.[17] Diamonds are the hardest substance known to mankind.[17]
- Silicon dioxide that is usually used in elastomeric cups and points.[17]
- Zirconium oxide.[17]
- Zirconium silicate, which is a natural mineral that can be used in elastomeric form, or as a polishing paste.[17]

There are different polishing systems on the market, and all claim to give excellent results.[4] Polishing can be achieved by different methods:[1, 43]

- Coated abrasive discs and strips: They are manufactured by means of bonding the abrasive particles onto a plastic polymer backing.[17] These discs and strips are single-use only. They are most often coated with aluminum oxide, but silicon carbide, garnet, emery and quartz can also be utilized.[17] Sof-Lex XT discs (3M ESPE, St Paul, USA) are an example of an abrasive disc system coated with aluminum oxide. Sof-

Lex XT discs are used in a sequence of course (55µm), medium (40µm), fine (24µm) and ultrafine (8 µm) discs.

- Stones: They are created during a sintering process. It is a combination of abrasive particles with an organic resin. The stones are usually colour coded: white stones: aluminum oxide, green stones: silicon carbide. Stones are manufactured as course, medium and fine grits.[17]
- Polishing pastes containing aluminum oxide or diamond abrasives are used with felt type wheels, prophy cups or rubber cups.[17]
- Soft or hard rubber cups, points, and wheels impregnated with various abrasives: These points contain abrasive particles imbedded in a softer, elastic matrix.[17, 44] There are different shapes and sizes available. The elastomeric matrix can be a synthetic rubber, silicon, or synthetic elastic polymer.[17] Enhance finishing system (Dentsply, Milford, USA) is an example that uses "urethane" elastic polymer with abrasive particles (Al_2O_3).[45]
- Abrasive impregnated brushes: These brushes can reach into difficult-to-reach fissures and grooves, and embrasure areas.[17] An example is Intensiv UniglossCellbrush (Intensiv SA, Montagnola, Switzerland) which is impregnated with ultra-fine diamond particles.[46]

Polishing systems can be further divided into one-step systems and multi-step systems.[44] There are various one-step and multi-step polishing systems on the market.[47] The use of one-step polishing systems have the advantage of taking less time, whereas multi-step polishing systems are more time consuming.[44] Intensiv UniglossCellbrush (Intensiv SA, Montagnola, Switzerland)is an example of a one-step polishing system, and Sof-Lex XT discs (3M ESPE, St Paul, USA) are an example of a multi-step system.

A specific substrate (different type of composite) used with a specific abrasive system will lead to unique surface properties.[4, 17] Different types of composite have different filler particle sizes and composition, which will abrade distinctively according to the type of abrasive system that is used to polish the composite.

Jefferies (2007) describes the different factors that can influence the effectiveness of a polishing system:[17]

- The composition, structure and mechanical properties of the substrate or composite that is being polished;
- The dissimilarity in hardness between the polishing system's abrading particles and the hardness of the composite or substrate;
- The hardness, shape and size of the abrasive particles used in the polishing system;
- The physical properties of the "carrier" of the abrasive particles, ie the structure of the polymer discs or strips, or the elastomeric cups or points (eg, rigidity, elasticity, flexibility, thickness, softness, porosity);
- The speed and the pressure of the abrasive polishing system being applied to the composite or substrate;
- The use of lubricants during the polishing process.

In this study we will evaluate the following polishing products (Table 3):

- Sof-Lex XT discs: Aluminum oxide coated abrasive discs of different grits: course (55µm), medium (40µm), fine (24µm) and superfine (8µm).[48]
- Sof-Lex Spiral Wheels: Sof-Lex Spiral Wheels are a two-step, single use finishing and polishing system. The spiral wheels are made of a thermoplastic elastomer that is impregnated with aluminum oxide particles.[49]
- Sof-Lex Spiral Wheels in combination with Zircon-Brite: Zircon-Brite is a polishing zirconium paste.[50]
- Dura-White stones: Dura-White stones are made of micro grained aluminum oxide grits.[51]
- Intensiv UniglossCellbrush: Intensiv UniglossCellbrush is a unique cellulose brush filled with ultra-fine diamond particles.[46]
- Enhance finishing and polishing system: Enhance finishers are available in discs, cups and points. Enhance finishers consists of cured urethane dimethacrylate resins impregnated with aluminum oxide (40µm).[45] The manufacturers recommend that Enhance finisher points, cups or discs are followed by Prisma Gloss composite polishing pastes. There are two pastes

available: the Prisma Gloss composite polishing paste, and the Prisma Gloss extra fine polishing paste.[45] The paste consists of aluminum oxide, glycerine and hydrophobic amorphous fumed silica and is water-soluble.[45]

Table 3: Product information about the finishing and polishing systems[45, 46, 48-52]

Surface treatment	Type	Composition	Manufacturer	Batch no.
Sof-Lex XT Polishing Discs - Course (2382C) - Medium (2382M) - Fine (2382F) - Superfine (2382SF)	Disc and mandrel	Polyester film, aluminum oxide Different grits: - Course: 55 µm - Medium: 40 µm - Fine: 24µm - Superfine: 8µm	3M ESPE, St Paul, USA	LOT N195023 LOT N164233 LOT N411740 LOT P070516
Sof-Lex Spiral Wheels	Finishing wheel Polishing wheel	Thermoplastic elastomer impregnated with aluminum oxide particles	3M ESPE, St Paul, USA	LOT N485117 LOT N496319
Dura White stones	Stone	aluminum oxide	Shofu Inc., Kyoto, Japan	LOT 0514382
Intensiv Unigloss Cellbrush	Cellulose Brush	Ultrafine diamond particles	Intensiv SA, Montagnola, Switzerland	LOT 271127
Enhance finishing and polishing system	Finisher discs, points, cups.	Cured urethane methacrylate resin impregnated with aluminum oxide	Dentsply, Milford, USA	LOT 1106071 LOT 140619
	Prisma Gloss Composite Polishing Paste	Water soluble Aluminum oxide paste		
Zircon-Brite polishing paste	Polishing paste	Zirconium silicate	Dental Ventures of America, Corona, USA	Not available

1.4 Examples of polishing studies in the literature

Research has proven that the smoothest composite surface is obtained when the composite is cured through a Mylar polyester strip.[4, 27-29, 53]

A study by Quirz and Lentz demonstrated that ultrafine diamond finishing burs caused an uneven and rough surface in hybrid composites, and that the ultrafine diamond burs damaged the enamel surface.[54]

Goldstein and Waknine found that carbide burs caused more damage than diamond burs. They concluded that the damage caused by diamond burs could more easily be polished out using a polishing system, than damage caused by a carbide bur.[55]

Joniot, Gregoire, Auther and Roques also concluded that it was harder to polish out the irregularities that were caused by tungsten carbide finishing burs, than those caused by diamond finishing burs.[56] Both tungsten carbide and diamond finishing burs left the surface rough. They found that Enhance (Dentsply, Milford, USA) and Sof-Lex discs (3M ESPE, St Paul, USA) gave good polishing results when polishing hybrid composites Charisma (Heraeus Kulzer, South Bend, USA), Z100 (3M ESPE, St Paul, USA) and Prisma TPH (Dentsply, Milford, USA).[56]

Senawongse and Pongprueksa compared different surface treatment protocols: i. composite cured under mylar strip, ii. Composite polished with Sof-Lex discs (3M ESPE, St Paul, USA), iii. Composite polished with Astropol (Vivadent, Schaan, Liechtenstein) and iv. composite after brushing with Oral B Conture or Colgate on nanocomposites Filtek Supreme XT (3M ESPE, St Paul, USA) dentine shade and transparent shade, Filtek Z350 (3M ESPE, St Paul, USA), and Estelite Sigma (Tokuyama Dental Co, Tokyo, Japan); microhybrids Filtek Z250 (3M ESPE, St Paul, USA), Tetric Ceram (Vivadent, Schaan, Liechtenstein) and Clearfil AP-X (Kuraray, Osaka, Japan) and nanohybrids Tetric EvoCeram (Vivadent, Schaan, Liechtenstein), Ceram X (Dentsply, Konstanz, Germany) and Premise SDS (Kerr, Orange, USA). They demonstrated that nanocomposites with nanoclusters resulted in the smoothest surface after polishing.[28]

Jung, Eichelberger and Klimek compared a one-step polishing system OptiShine (Kerr, Bioggio Switzerland) and three multi-step polishing systems Astropol (Vivadent, Schaan, Liechtenstein), Enhance/PoGo (Dentsply, Konstanz, Germany) and Sof-Lex discs (3M ESPE, St Paul, USA) on four nanocomposites. These were Premise (Kerr, Bioggio Switzerland), Tetric

EvoCeram (Vivadent, Schaan, Liechtenstein), Filtek Supreme (3M ESPE St. Paul, USA) and Ceram X Duo (Dentsply, Konstanz, Germany) and a hybrid composite Herculite XRV (Kerr, Bioggio Switzerland). The composite discs that were polished with Astropol, OptiShine and Enhance/PoGo were first finished with diamond finishing burs before the polishing system was used. The Sof-Lex group was not finished with a finishing diamond bur prior to polishing. They concluded that the polishing results of three-step polishing systems (Astropol and Sof-Lex) were superior to the results of one-step (OptiShine) and two-step (Enhance/PoGo) polishing systems on nanocomposites and hybrid composites. They determined that only two of the four nanocomposites that were polished achieved better results than polished hybrid composites, namely Premise and Tetric EvoCeram.[57] The study found that the method of finishing the composite prior to polishing had a greater effect on the surface roughness with one-step polishing systems compared to multi-step polishing systems.[57]

Korkmaz, Ozel, Attar and Aksoy evaluated the following polishing systems PoGo one step (Dentsply, Milford, USA), OptraPol one step (Vivadent, Schaan, Liechtenstein) and Sof-Lex multi-step (3M ESPE, St Paul, USA) on different composite materials: Filtek Supreme XTE (3M ESPE, St Paul, USA), Grandio (Voco, Cuxhaven, Germany), Ceram X (Dentsply, Konstanz, Germany), Aelite Aesthetic Enamel (BISCO, Schaumburg, IL, USA), Tetric EvoCeram (Vivadent, Schaan, Liechtenstein) and Filtek Z250 (3M ESPE, St Paul, USA). A group cured against a Mylar polyester strip with no polishing application acted as control group. All the other specimens were wet ground with 1200 grit silicon carbide paper on a metallurgical finishing wheel before using the polishing systems. They concluded that the smoothest surfaces were obtained using the polyester strip, and that there were no statistical significant differences between the one-step and multi-step polishing systems for Filtek Supreme XTE (3M ESPE, St Paul, USA), Ceram X (Dentsply, Konstanz, Germany) , Aelite Aesthetic Enamel (BISCO, Schaumburg, IL, USA), and Grandio (Voco, Cuxhaven, Germany).[58]

In a study by Ergücü and Türkün it was concluded that the one-step polishing system PoGo (Dentsply, Milford, USA) could be used effectively to polish the nanocomposites Filtek Supreme XTE (3M ESPE, St Paul, USA), Grandio (Voco, Cuxhaven, Germany), Tetric EvoCeram (Vivadent, Schaan, Liechtenstein), Premise (Kerr, Bioggio Switzerland) and the nanohybrid

Ceram X (Dentsply, Konstanz, Germany) with reduced chair-time.[23] For all the composites tested in this study, OptraPol (Vivadent, Schaan, Liechtenstein) and One Gloss (Shofu, Kyoto, Japan) gave statistically significant higher surface roughness values than PoGo (Dentsply, Milford, USA).[23] SEM studies revealed an uneven surface due to the plucking of filler particles by OptraPol (Vivadent, Schaan, Liechtenstein) and One Gloss (Shofu, Kyoto, Japan) polishing systems, causing damage to the composite and creating surface irregularities and scratches. Profilometer readings were confirmed by SEM analysis.[23]

Erdemir, Sancakli and Yildiz showed that the nanocomposite Filtek Supreme XTE (3M ESPE, St Paul, USA) and the nanohybrid Ceram-X (Dentsply, Konstanz, Germany) had better polishing results and a smoother surface than the nanohybrid Grandio (Voco, Cuxhaven, Germany), irrespective of the polishing system that had been used. Both the one-step polishing systems PoGo (Dentsply, Milford, USA) and Sof-Lex (3M ESPE, St Paul, USA) multi-step polishing system produced surface roughness values below 0.3 µm.[4]

Da Costa, Ferracane, Paravina, Mazur and Roeder demonstrated that Z100 (3M ESPE, St Paul, USA) had a statistically significant higher surface roughness value after polishing compared to Filtek Supreme (3M ESPE, St Paul, USA). PoGo (Dentsply, Milford, USA) showed the best result for both Z100 and Filtek Supreme XTE, with Sof-Lex (3M ESPE, St Paul, USA) in the second place. However, the difference in surface roughnesses obtained after polishing with PoGo (Dentsply, Milford, USA) and Sof-Lex (3M ESPE, St Paul, USA) was not statistically significant.[47]

Da Costa, Goncalves and Ferracane also evaluated a two-step polishing system Enhance Flex NST-EF (Dentsply, Milford, USA) with a four-step polishing system Sof-Lex (3M ESPE, StPaul, USA) and SuperSnap-SS (Shofu Dental, San Marcos, USA) on a nanocomposite Filtek Supreme Plus (3M ESPE, St Paul, USA), a nanohybrid composite Premise (Kerr, Orange, USA), microfill composites Durafill VS (Kulzer, Hanau, Germany), Minifill Hybrids Filtek Z250 (3M ESPE, St Paul, USA) and Esthet-X (Dentsply, Milford, USA). They demonstrated that the two-step polishing system achieved almost equal surface roughness values when compared to the four-step polishing system. The four-step system still produced a better surface gloss and a lower surface roughness value for three of the five composites that were used in the study.[44]

Antonson SA, Yazici, Kilinc, Antonson DE and Hardigan investigated the surface roughness of a nanocomposite Filtek Supreme (3M ESPE, St Paul, USA) and a microhybrid composite Esthet-X (Dentsply, Milford, USA) after polishing with the following polishing systems: Astropol (Vivadent, Schaan, Liechtenstein), Enhance/PoGo (Dentsply, Milford, USA) and Sof-Lex (3M ESPE, St Paul, USA). Sof-Lex (3M ESPE, St Paul, USA) produced the smoothest surface for both composites, although not statistically significant from the other polishing systems used in their study.[59]

A study by Koh, Neiva, Dennison and Yaman demonstrated that Sof-Lex discs (3M ESPE, St Paul, USA) produced the smoothest surface for the composites Filtek Supreme (3M ESPE, St Paul, USA) and Gradia Direct (GC America, Alsip, USA), when compared to Astropol (Vivadent, Schaan, Liechtenstein), OptiDisc (Kerr, Bioggio, Switzerland) and PoGo/Enhance (Dentsply, Milford, USA).[60]

Chung demonstrated that the surface roughness of a microfilled composite Heliomolar (Vivadent, Schaan, Liechtenstein) was significantly smoother than the surface roughness of hybrid composites Prisma APH (Dentsply, Milford, USA), P-50 (3M ESPE, St Paul, USA), Herculite XR (Kerr, Romulus, USA) after being polished with different polishing systems: Enhance (Dentsply, Milford, USA), Sof-Lex medium, fine and superfine discs (3M ESPE, StPaul, USA); and Premier Two Striper MPS diamond polishing system.[16]

Yap A, Yap S, Teo and NG tested different polishing systems on a composite Z100 (3M ESPE, St Paul, USA) and a compomer F2000 (3M ESPE, St Paul, USA). The baseline reading for Z100 cured through a Mylar strip was 0.04µm and the surface roughness for Z100 after polishing with Sof-Lex (3M ESPE, St Paul, USA) was 0.22µm. When they compared the composite with the compomer, they concluded that the effect of polishing systems was dependent on the type of material that was used; ie composite or compomer.[53]

In a study by Scheibe, Almeida, Medeiros, Costa and Alves the surface roughness of Z100 (3M ESPE, St Paul, USA) microhybrid composite was evaluated after being polished by three different polishing regimes: Sof-Lex discs (3M ESPE, St Paul, USA), Enhance combined with PoGo diamond polishing system (Dentsply, Milford, USA), and felt discs in combination with a diamond paste (Excel diamond paste, FGM Ind. Brasileira, Brazil). The results showed that Sof-Lex (3M ESPE, St Paul, USA) produced rougher surfaces than the other two systems. The fact that PoGo (Dentsply, Milford, USA) was used in combination with Enhance (Dentsply, Milford, USA) was discussed as a possible explanation for this result.[61]

In a study by Kaplan, Goldstein, Vijayaraghavan and Nelson the polishability of four composites, Pertac (ESPE/Premier, Norristown, USA), APH (LD Caulk, Milford, USA), Herculite (Kerr, Romulus, USA) and Z100 (3M ESPE, St Paul, USA) were compared after being polished by three different polishing systems: Enhance (Dentsply, Milford, USA), Kerr polishing kit and MFS/MPS (ESPE/Premier, Norristown, USA) polishing kit. The study concluded that MFS/MPS (ESPE/Premier, Norristown, USA) gave superior polishing results, with the lowest surface roughness for Z100 (3M ESPE, St Paul, USA), Herculite (Kerr, Romulus, USA) and Pertac (ESPE/Premier, Norristown, USA). The poorest results for all four composites were obtained with Enhance. No statistical difference was found between the four different composites when polished with the respective polishing systems, ie the composites behaved similarly when treated with each polishing system.[30]

In a study by Janus, Fauxpoint, Arntz, Pelletier and Etienne, three nanocomposites, Filtek Supreme XT (3M ESPE, St Paul, USA), Grandio (Voco, Cuxhaven, Germany), Synergy (Coltene, Altstatten, Switzerland) and one hybrid composite, Tetric Ceram (Vivadent, Schaan, Liechtenstein) were evaluated for surface roughness after treatment with two polishing systems, Sof-Lex (3M ESPE, St Paul, USA) and CompoSystem (Komet, Lemgo, Germany). Filtek Supreme XT (3M ESPE, St Paul, USA) exhibited the smoothest surface when polished with any of the polishing systems. Sof-Lex produced superior polishing results when compared with CompoSystem (Komet, Lemgo, Germany). SEM studies revealed that the smoothest surface was obtained for Filtek Supreme XT, with only a few voids visible. Scratch lines, surface irregularities and voids were present in all of the composite samples, and Grandio (Voco, Cuxhaven, Germany) showed filler particle dislodgement.[62] In addition to SEM, they also used Atomic Force Microscopy to assess the surface morphology of the polished composite samples. They concluded that surface roughness was related to the surface morphology of the composites samples, and to the size of the filler particles.[62]

Different polishing motions have been classified: planar motion, rotary motion and reciprocal motion.[1, 63] A planar motion is where the axis of rotation of the abrasive disc is perpendicular to the substrate, for example the motion used with Sof-Lex discs (3M ESPE, St Paul, USA). A rotary motion is where the axis of rotation is parallel to the substrate, for example the motion used with diamond finishing burs and Dura-White stones (Shofu Inc, Kyoto, Japan).[63] And a reciprocation motion is a two-way bidirectional motion, for example the motion used with a finishing strip.[63] In a study by Fruits, Miranda and Coury, they concluded that the smoothest surface was obtained with a planar motion for both amalgam and composite restorations.[63]

Higher speed and increased pressure influence the rate at which the material is removed, ie the wear of the material. The higher the speed, and the higher the pressure that is applied by the abrasive onto the substrate, the higher the rate of removal of the substrate will be.[59] A study by Xie and Bhushan investigated the influence of abrasive particle size, the structure of the polishing pad (the carrier of the abrasive particles), and contact pressure in free abrasive polishing of copper and Ni-Zn Ferrite.[64] They demonstrated that an increase in pressure increased the wear rate of the substrate.[64] They concluded, however, that contact pressure had little effect on surface roughness.[64]

1.5 Measuring surface roughness

Profilometry is a very good and acceptable method to study the surface roughness of composite samples.[1, 56, 65] A profilometer gives information of the topography of a specimen based on a mean line drawn between the peaks and valleys of the roughness profile.[65, 66] The average surface roughness (Ra) is the arythmic mean of the absolute values of the evaluation profile deviation from the mean line.[63, 65, 66]

A Scanning Electron Microscope is an additional method to evaluate the surfaces of polished composite discs.[1, 14, 16, 47, 65]

1.6 Limitations of this study

- This was an in vitro study, and thus not a true reflection of the clinical situation.
- The polishing results in this study is true for Z100 (3M ESPE, St Paul, USA) and Filtek Supreme XTE (3M ESPE, St Paul, USA) and the conclusion about polishing systems is limited to use on Z100 and Filtek Supreme XTE. Both composites are a 3M ESPE product. No other composites from other companies were included in this study.
- The polishing systems that were chosen are only representative of different polishing systems used and available in South Africa.
- The hand piece that was used could not measure speed accurately, therefore the rpm's mentioned in this study is an approximation.

CHAPTER 2: Aim and objectives

2.1 Aim

The aim of this study was to evaluate and compare the surface roughness of a nanocomposite (Filtek Supreme XTE) and a microhybrid composite (Z100) after polishing the composites with different polishing systems.

2.2 Objectives

The objectives of this study were to:

- Polish two different composites with six different polishing systems;
- Measure the surface roughness for each group with a profilometer;
- Compare the different polishing techniques per composite;
- Compare the two composites for polishability;
- Obtain scanning electron microscope images of the polished surfaces; and compare it to the profilometer readings.

2.3 Hypothesis

Null hypothesis: There will be no difference in surface roughness between the different polishing systems used on the same composite, and there will be no difference in surface roughness after polishing between the two different composites used in this study.

Alternative hypothesis: Differences in surface roughness will be detected after using different polishing systems on each composite and differences in surface roughness will be observed between the two composite groups, ie the one composite will have superior polishability compared to the other composite.

CHAPTER 3: Materials and methods

3.1 Standardisation of composite discs

Two types of composite were used in this study: a nanocomposite Filtek Supreme XTE (shade A2B) (3M ESPE, St Paul, USA), and a microhybrid composite Z100 (shade A2) (3M ESPE, St Paul, USA). Shade A2 was chosen as it was easily available. Research has shown that resin shade had no significant influence on curing at 2mm depth.[67] The source intensity and exposure duration are the main factors that influence curing of a resin composite at 2mm depth.[67] The composition and technical profile of the composites used in this study are represented in Table 2. Thirty-five composite samples were made for each of the two composites, by placing the uncured composite into an aluminum ring mould. The ring moulds were 10mm in diameter and 2mm in height. Each ring mould was cut from an aluminum pipe using an ISOMET low speed saw (Buehler, Lake Bluff, USA) (Fig 2). The moulds were 2mm in height as composite needs to be placed and cured in 2mm increments.[67, 68]

Figure 2: ISOMET low speed saw

A Mylar polyester strip (Du Pont Co, Wilmington, USA) was placed against both sides of the uncured composite. Using light finger pressure, the uncured composite inside the ring mould was pressed between two glass plates (1mm thick) that were placed on a flat surface to extrude excess material (Fig 3). The tracing length of the profilometer was 4mm and the centre of the each sample were evaluated (the margins of the samples were not evaluated with the profilometer). This was in accordance with the methods used by previous researchers.[4, 23, 28, 62]

Figure 3: The uncured composite placed inside the ring mould, between Mylar strips and two glass plates (top and bottom)

The composites were cured through Mylar (Du Pont, Wilmington, USA) polyester strips and glass plates, as research has proven that the smoothest composite surface is obtained when the composite is cured through a Mylar strip.[4, 27] This was done in order to standardize the composite samples. The composite was cured with a curing light (Valo, Ultradent, South Jordan, USA) from both sides for 40 seconds with the curing light tip held at right angles and at a 1mm distance from the composite surface.[68, 69] The intensity of the curing light was tested after curing every composite sample with a Bluephase radiometer (Ivoclar Vivadent, Schaan, Liechtenstein). After curing, the composite samples were removed from the ring mould (Fig 4). When the samples were removed from the aluminum ring mould, cured excess composite material chipped off the samples.

Figure 4: Composite sample being removed from the ring mould, after being cured between two glass plates through a Mylar strip

The composite samples were then bonded with Pattex glue (Henkel, Düsseldorf, Germany), onto a transparent plastic backing, marked with an arrow to indicate the direction and orientation for polishing, and direction for profilometer readings. Care was taken so no superfluous Pattex came into contact with the polishing surface. The backing served to stabilize and hold the samples during polishing (Fig 5). A study done by Da Costa, Goncalves and Ferracane used double-sided adhesive tape to adhere the samples to a metal ring backing to facilitate the polishing procedure.[44]

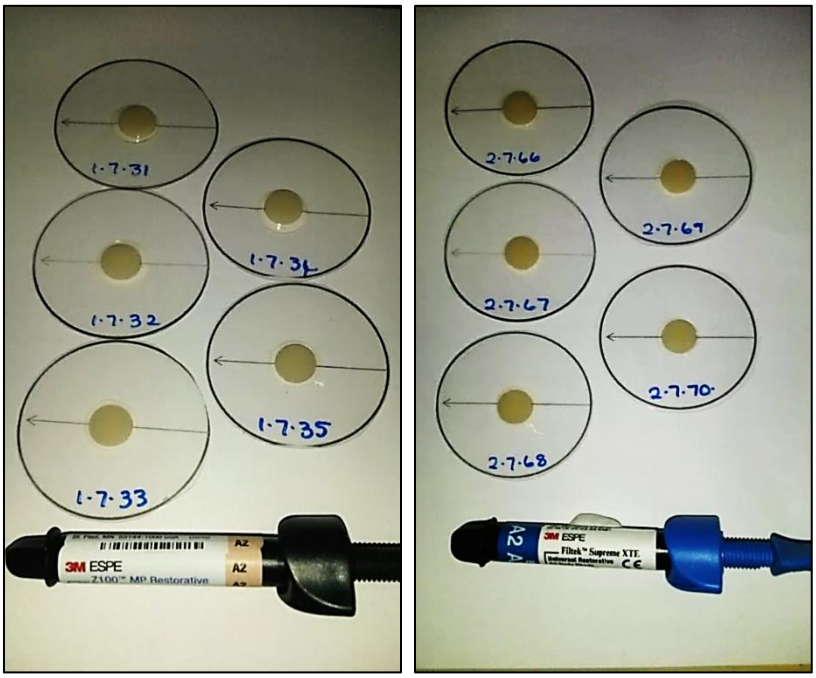


Figure 5: The composite samples fixed onto a marked transparent backing

After curing of the composite samples, all the samples, except for the control groups, were finished with a red stripe, flame shape finishing diamond bur ISO 806 314 249 514 012 (Dentsply/Maillefer, Ballaigues, Switzerland), followed by a yellow stripe, flame shape finishing diamond bur ISO 806 314 249 504 012 (Dentsply/Maillefer, Ballaigues, Switzerland) (Fig 6) using a fast hand piece under copious water spray for five seconds each. The samples were finished in the direction of the arrow on the transparent backing. A study done by Senawongse and Pongprueska also polished all samples in one direction.[28] This was done in order to aid standardizing the finishing of the composite samples. A new bur was used on every new composite sample.

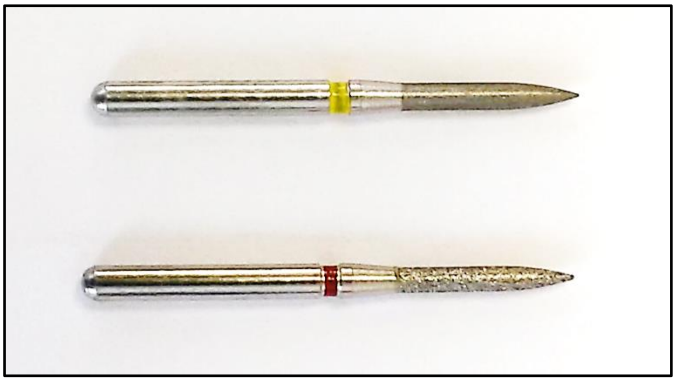


Figure 6: Red and yellow stripe finishing diamond burs

For this research project the following hand pieces were used: Sirona T4 Racer fast hand piece and Sirona T4 Line B 40 slow hand piece (Sirona Dental, Bensheim, Germany). The maximum speed of the Sirona T4 Line B 40 slow hand piece is 40 000 rpm.[70] Speed and rotation direction can be adjusted with the ring at the bottom of the hand piece. All the samples were finished before polishing, as most composite restorations need finishing to obtain proper morphology and function after placement.[1, 44] This finishing procedure creates a rough composite surface.[1] A single operator performed both the finishing and polishing steps in order to reduce variability. The polishing of all the samples was done in the Skills laboratory, Oral and Dental Hospital, University of Pretoria at the demonstration station (Westar, Mukilteo, USA). The polishing of all the samples was done at the demonstration station in the Skills laboratory, Oral and Dental Hospital, University of Pretoria (Westar, Mukilteo, USA).

Subsequently the specimens were randomly allocated to the seven different groups. There were 35 samples per composite, and this was further divided into seven groups for the polishing technique (n=5 per polishing group for each composite) (Table 4).

Table 4: Study design showing the distribution of the polishing systems per composite.

Z100 (35 samples: n=5 per group)							Filtek Supreme XTE (35 Samples: n= 5 per group)						
Mylar Polyester Strip	Sof-Lex XT Discs	Spiral Wheels	Dura White Stones	Intensiv UniglossCellbrush	Enhance Polishing System	Spiral Wheels + Zircon Brite	Mylar Polyester Strip	Sof-Lex XT Discs	Spiral Wheels	Dura White Stones	Intensiv UniglossCellbrush	Enhance Polishing System	Spiral Wheels + Zircon Brite

3.2 Polishing of composite discs

The specimens were polished according to the manufacturer's instructions. A single operator performed the polishing of the specimens in order to reduce variability. The following techniques were performed on the microhybrid composite Z100 (3M ESPE, St Paul, USA) and on the nanocomposite Filtek Supreme XTE (3M ESPE, St Paul, USA).

1. **Control**

Group 1 acted as the control group for both composite materials. No finishing or polishing was done after curing the composite on both sides through a Mylar (Du Pont Co, Wilmington, USA) polyester strip that was pressed between two glass plates.

For groups 2 to 7 the finishing procedure was done as follows: Dentsply/Maillefer fine finishing burs (red stripe ISO 806 314 249 514 012) and Dentsply/Maillefer extra fine finishing burs (yellow stripe ISO 806 314 249 504 012) were used in a Sirona T4 Racer fast hand piece under copious water spray for five seconds each in the direction of the arrow on the transparent backing. This is described as a rotational clockwise motion.[63] Time was kept using a Samsung Galaxy S4 cell phone timer (Samsung, Seoul, South Korea).

2. Sof-Lex XT finishing and polishing discs (3M ESPE, St Paul, USA)

After finishing of the composite discs, they were polished using the Sof-Lex XT finishing and polishing discs (coarse 55µm, medium 40 µm, fine 24 µm and superfine 8 µm) according to manufacturer's instructions (Fig 7). The Sof-Lex XT polishing discs were used sequentially in a low-speed hand piece with intermittent, light pressure without water, polished according to the manufacturer's instructions. The coarse-grit disc was used at approximately 10 000 rpm for 5 seconds. After polishing the composite disc with the coarse Sof-Lex XT disc the composite disc was rinsed with water and dried with the 3-in-1 air syringe. Following the coarse disc, the medium-grit disc was used without water at approximately 10 000 rpm for 15 seconds. The composite disc was rinsed and dried. After the final contouring with the medium grit Sof-Lex XT disc, the fine grit Sof-Lex XT disc was used at high speed (approximately 30 000 rpm) for 15 seconds. The composite disc was rinsed with water and air dried with the 3-in-1 syringe. Final polishing was done using the superfine grit Sof-Lex XT disc at approximately 30 000 rpm for 15 seconds.[48] The powder/debris was washed away with water, and the discs were then evaluated using the Profilometer (SJ 210 Surftest, Mitutoyo, Tokyo, Japan). After polishing each composite sample, the Sof-Lex XT discs were discarded.

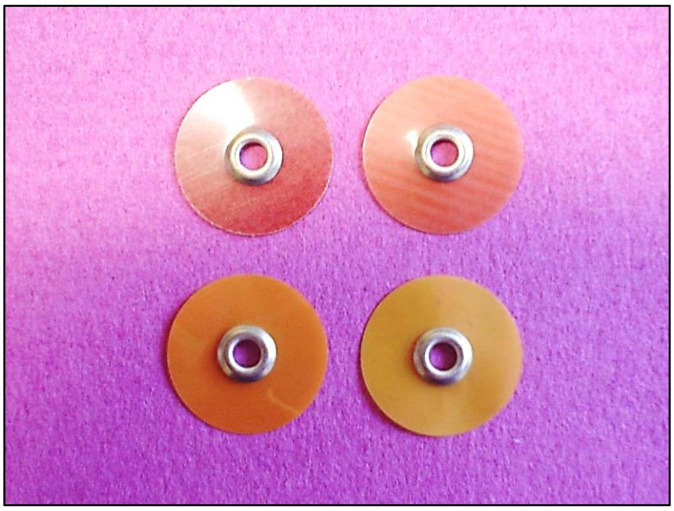


Figure 7: Sof-Lex XT finishing and polishing C, M, F, SF discs

3. Sof-Lex Spiral Wheels (3M ESPE, St Paul, USA)

After the finishing with the fine and extra fine diamond burs, the composite was finished with a medium grit Sof-Lex XT polishing disc according to the manufacturer's instructions. This was done at approximately 10 000 rpm for 15 seconds. The disc was rinsed with water and dried with a 3-in-1 syringe. The discs were subsequently polished using the Sof-Lex Spiral Wheels in a slow hand piece, polished according to the manufacturer's instructions (Fig 8). The beige finishing Sof-Lex Spiral Wheel was attached to the mandrel and placed in a slow hand piece. Polishing of the composite disc was done in the forward motion with light pressure at a speed of approximately 15 000 rpm for 15 seconds. The Spiral Wheel was in constant motion over the composite surface. Debris was rinsed off from the composite surface with water and dried with the 3-in-1 air syringe. The composite samples were subsequently polished with the white polishing Sof-Lex Spiral Wheel using the same procedure.[49] The discs were then evaluated using the Surftest SJ 210 profilometer (Mitutoyo, Tokyo, Japan).

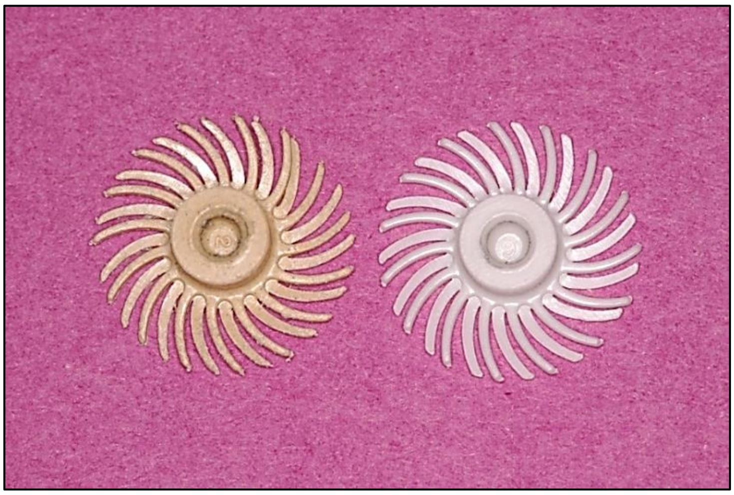


Figure 8: Sof-Lex Spiral Wheels (beige – finishing; white – polishing)

4. Shofu Dura-White stones (Shofu Inc., Kyoto, Japan)

After finishing the composite the Dura-White stones were used to polish the composite according to the manufacturer's instructions (Fig 9). Shofu Dura-White stones were used in a fast hand piece under copious water spray to polish the composite disc for 10 seconds.[51]

The surface was rinsed with water and air-dried. The discs were then evaluated using the Surftest SJ 210 (Mitutoyo, Tokyo, Japan) profilometer.

Figure 9: Dura-White stone

5. Intensiv UniglossCellbrush (Intensiv SA, Montagnola, Switzerland)

After finishing the composite, Intensiv UniglossCellbrushes were used to polish the composite according to the manufacturer's instructions (Fig 10). The Intensiv UniglossCellbrush was first used dry with the hard filaments for 15 seconds, under light pressure and at approximately 5000 rpm. Water spray was subsequently added for a few seconds. The filaments changed from hard to soft filaments. The final polishing was done for a further 15 seconds in a wiping motion, with minimal pressure being applied to achieve the final gloss.[46] The surface was rinsed with water and dried. The discs were then evaluated using the Surftest SJ 210 (Mitutoyo, Tokyo, Japan) profilometer.

Figure 10: Intensiv UniglossCellbrush

6. Enhance finishing and polishing system (Dentsply, Milford, USA)

After finishing the composite, Enhance finishing and polishing system were used to polish the composite according to the manufacturer's instructions (Fig 11). An Enhance finishing disc was inserted into the slow speed hand piece. Moderate to light, intermittent pressure was used in a buffing motion. The Enhance finishing disc was used on a dry surface for 15 seconds using a Sirona T4 Line B 40 slow hand piece at approximately 20 000 rpm.[45] After the composite was finished using the Enhance finishing disc, Prisma Gloss polishing paste was dispersed into a dappen dish and the polishing paste was applied to the polishing cup. The composites samples were then polished for 15 seconds using light pressure, with circular overlapping motions. A small amount of water was added to the polishing paste to increase surface lustre of the polished composite surface. The composites were polished with the paste for a further 15 seconds using light pressure at approximately 20 000 rpm in a buffing motion. The excess debris and polishing paste was rinsed off with water and the surfaces were air-dried.[52] The discs were then evaluated using the Surftest SJ 210 (Mitutoyo, Tokyo, Japan) profilometer.

Figure 11: Enhance finishing and polishing system

7. Sof-Lex Spiral Wheels (3M ESPE, St Paul, USA) in combination with Zircon-Brite polishing paste (Dental Ventures of America, Corona, USA)

After finishing the composite discs with the red and yellow label finishing burs, the discs were polished using the Sof-Lex Spiral Wheels with a slow hand piece, polished according to the manufacturer's instructions. The composites were first finished with a medium grit Sof-Lex XT polishing disc, before using the Sof-Lex Spiral Wheels, as per manufacturer's instructions. This was done at approximately 10 000 rpm for 15 seconds. The disc was rinsed with water and then dried with a 3-in-1 syringe. The beige finishing Spiral Wheel was attached to the mandrel and placed in a slow hand piece. Polishing of the composite disc was done in a forward motion with light pressure at approximately 15 000 rpm for 15 seconds.[49] The Spiral Wheel was in constant motion over the composite surface. Debris was rinsed off the composite surface with water and dried with the 3-in-1 air syringe. This process was then repeated with the white polishing Spiral Wheel. This step was followed by a further polishing sequel using a felt wheel and Zircon-Brite polishing paste to polish the composite samples for a further 10 seconds (Fig 12).[50]

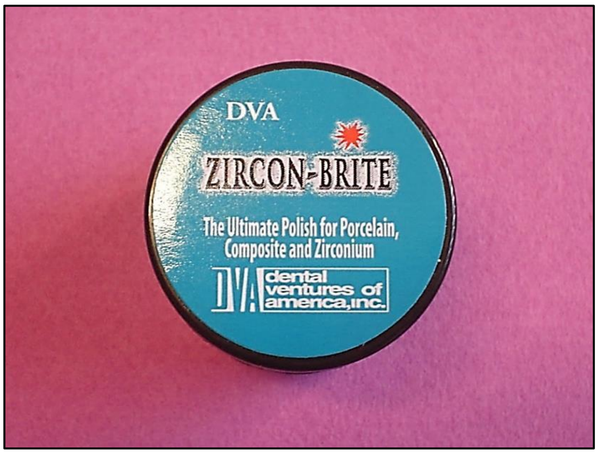


Figure 12: Zircon-Brite polishing paste

3.3 Profilometer readings: Surftest SJ 210 (Mitutoyo, Tokyo, Japan)

A Surftest SJ 210 profilometer (Mitutoyo, Tokyo, Japan) was used to determine the surface roughness of each of the groups.[66] The cut-off value was 0.8mm, the evaluation length was 4mm and the speed 0.5mm/s.[66] After polishing, the composite samples were mounted on a wheel template with three markings: 0˚, 120˚ and 240˚ (Fig 13). Three readings, in the different directions, were taken on each sample, resulting in 15 readings per group. This was done to standardize the readings on all the different composite samples, and also to compensate for possible different surface roughness values on the polishing disc due to different measuring directions. Measuring the surface roughness in different directions was done in accordance with previous studies.[44, 58, 61] By doing this the researcher ensured that a representative surface roughness value of the whole sample was obtained, and not just the roughness of a certain area on the sample. The average surface roughness of the three readings per disc was taken as the average surface roughness value for each disc.

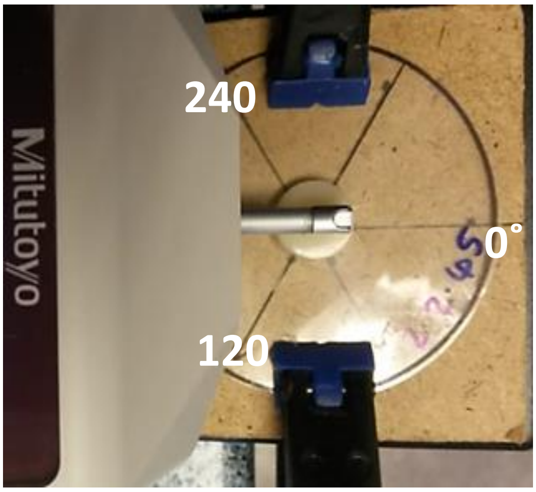


Figure 13: Wheel template with markings at 0˚, 120˚ and 240˚

After every three readings (per composite sample) the profilometer was calibrated using the precision specimen (Fig 14).[66]

Figure 14: The profilometer SJ 210 Surftest being calibrated with the precision specimen on the left, and a composite disc that is being evaluated on the right

3.4 Scanning Electron Microscope

After profilometry, one sample per group was evaluated in the SEM to visually examine and compare the surface topography of some of the composite surfaces after polishing with the different polishing systems (Fig 15). This was done to compare the SEM images with the profilometry results.

Figure 15: Scanning Electron Microscope (JEOL JSM-5800 LV, Tokyo, Japan)

The samples were first gold sputtered (Fig 16), after which the samples were investigated and photographed under 500 X magnification, and 1000 X magnification. A study done by Senawongse and Pongpresksa evaluated samples under 750X magnification.[28] A study done by Berger, Palialol, Cavalli and Giannini, evaluated samples at 700 X magnification.[14]

Figure 16: Composite samples being gold sputtered in preparation for viewing in the Scanning Electron Microscope

3.5 Statistics

The statistical planning and analysis for this study was performed with the assistance of a biostatistician employed by the University of Pretoria.

3.5.1 Study design

The study design for this study was a two-factor experimental study design. The two factors were composites and polishing systems.

3.5.2 Sample size

In order to perform the data analysis, an appropriate Analysis of Variance (ANOVA) was employed. In this study readings were taken at three positions on each of the five discs per treatment. By convention a sample size is regarded adequate if the residual degrees of freedom exceed 30˚ or more. With a five discs per treatment modality and with three readings on each disc there were 100 residual degrees of freedom. The sample size was therefore deemed adequate. A total of 210 readings on 70 composite discs were analysed.

3.5.3 Data analysis

Summary statistics included the mean, standard deviation (SD) and 95% confidence interval. Data summary was done for surface roughness in micrometers (µm) as dependent variable set against the two factors ie composite (two groups) and polishing system (seven groups) individually, and for the combined composite (the average surface roughness of the two combined composites for each polishing system) and combined polishing system (the average surface roughness of the combined polishing systems for each composite group) as independent variables.

Data analysis: Data for this two-factor experimental design was analysed using a two-way ANOVA at the 0.05 level of significance. A two-way ANOVA is an extension of the one-way ANOVA that examines the influence of two different categorical independent variables (main factors) on one continuous dependent variable.[71] This study compared the surface roughness (continuous data, measured in µm as dependent variable) for different polishing systems (seven categories/levels as independent variable 1) used on two different composites (two categories/levels as independent variable 2).

When using a two-way ANOVA, a test for possible interactions between the main factors (composites and polishing systems) on the dependent variable (surface roughness in µm), must be examined. If there is an interaction between the independent variables (main factors), it means that they are not independent, and have a complex interactive influence on the dependent variable. This possible interaction between the independent variables (composite and polishing) will mean that the main effects (the effect of one independent variable ie composite on the dependent variable ie surface roughness) do not collectively explain all of the influence of the Independent variables on the dependent variable (µm).[72]

If there is no interaction between the independent variables, the main effects of each independent variable (composites and polishing systems) on the dependent variable (surface roughness) can be interpreted with confidence.

In this study, both composites performed parallel when polished by the individual polishing systems. No significant interactions between composite and polishing system were found and hence the final ANOVA included only the main factors (combined composite and combined polishing systems) to interpret the main effects (the influence of composite or polishing systems on the surface roughness). As ANOVA just show that there is a difference in the independent variables, but not exactly where those differences are within the independent variables, further pairwise comparisons were done to identify between which polishing groups those differences were. A problem with multiple comparisons is that the number of hypotheses being tested increases, so the likelihood of a rare event is higher; therefore the likelihood of incorrectly rejecting a true null hypothesis (Type 1 error) is higher. The Bonferroni correction method was therefore used to counteract this problem as it maintains and protects family wise type 1 error (family wise error represents the probability that any one of a set of comparisons is a Type I error).[71]

CHAPTER 4: Results

4.1 Profilometer

The mean surface roughness values (± SD) for all experimental conditions are presented in Table 5. Analysis by two-way ANOVA indicated that there were no significant interactions between the composites and polishing systems (p=0.4450). Therefore the average results of the polishing procedures, as well as of the two composites could be combined (Table 5, end column and end row).

Table 5: Mean surface roughness (± Standard Deviation)(±SD) for the two composites and the different polishing systems

Polishing system	Composites: Mean surface roughness (µm ± SD)		Combined composite: mean surface roughness (µm ± SD)
	Z100	Filtek Supreme XTE	
Mylar Strip – Control	0.059 (0.012)	0.050 (0.008)	0.055 (0.11)[a]
Sof-Lex XT Discs C, M, F, SF	0.263 (0.044)	0.211 (0.042)	0.237 (0.049)[b]
Sof-Lex Spiral Wheels	0.255 (0.027)	0.211 (0.019)	0.233 (0.032)[b]
Dura-White stones	1.284 (0.162)	1.162 (0.183)	1.223 (0.175)[d]
Intensiv UniglossCellbrush	0.644 (0.101)	0.473 (0.138)	0.558 (0.145)[c]
Enhance + PrismaGloss Paste	0.555 (0.183)	0.483 (0.519)	0.519 (0.133)[c]
Spiral Wheels + Zircon-Brite	0.218 (0.047)	0.216 (0.023)	0.217 (0.035)[b]
Combined polishing system mean surface roughness (in µm)	0.468 (0.399)A	0.401 (0.357)B	

Different lower case letters indicate statistically significant differences for the combined composite mean surface roughnesses. Uppercase letters indicate statistically significant differences among the two composites for the combined polishing systems mean surface roughnesses.

As individual polishing systems differed significantly (p<0.001), pairwise comparisons were done to identify between which polishing groups those differences were. Table 6 lists the results of the pairwise multiple comparisons, while Figure 19 illustrates the differences between the polishing systems to achieve a polished surface.

Table 6: Results of pairwise comparison to identify significant differences between polishing systems

	Comparison Polishing Groups	Mean surface roughness in µm	Bonferroni Adjusted p-value
1	Mylar vs Sof-Lex XT polishing discs	0.055 vs 0.237	0.002
2	Mylar vs Sof-Lex Spiral Wheels	0.055 vs 0.233	0.003
3	Mylar vs Dura-White stones	0.055 vs 1.223	<0.0001
4	Mylar vs Intensiv UniglossCellbrush	0.055 vs 0.558	<0.0001
5	Mylar vs Enhance + Prisma Gloss polishing paste	0.055 vs 0.519	<0.0001
6	Mylar vs Spiral Wheel + Zircon Brite polishing paste	0.055 vs 0.217	0.009
7	Sof-Lex XT polishing discs vs Sof-Lex Spiral Wheels	0.237 vs 0.233	1 (not significant)
8	Sof-Lex XT polishing discs vs Dura-White stones	0.237 vs 1.223	<0.0001
9	Sof-Lex XT polishing discs vs Intensiv UniglossCellbrush	0.237 vs 0.558	<0.0001
10	Sof-Lex XT polishing discs vs Enhance + Prisma Gloss polishing paste	0.237 vs 0.519	<0.0001
11	Sof-Lex XT polishing discs vs Spiral Wheel + Zircon Brite polishing paste	0.237 vs 0.217	1 (not significant)
12	Sof-Lex Spiral Wheels vs Dura-White stones	0.233 vs 1.223	<0.0001
13	Sof-Lex Spiral Wheels vs Intensiv UniglossCellbrush	0.233 vs 0.558	<0.0001
14	Sof-Lex Spiral Wheels vs Enhance + Prisma Gloss polishing paste	0.233 vs 0.519	<0.0001
15	Sof-Lex Spiral Wheels vs Spiral Wheel + Zircon Brite polishing paste	0.233 vs 0.217	1 (not significant)
16	Dura-White stones vs Intensiv UniglossCellbrush	1.223 vs 0.558	<0.0001
17	Dura-White stones vs Enhance + Prisma Gloss polishing paste	1.223 vs 0.519	<0.0001
18	Dura-White stones vs Spiral Wheel + Zircon Brite polishing paste	1.223 vs 0.217	<0.0001
19	Intensiv UniglossCellbrush vs Enhance + Prisma Gloss polishing paste	0.558 vs 0.519	1 (not significant)
20	Intensiv UniglossCellbrush vs Spiral Wheel + Zircon Brite polishing paste	0.558 vs 0.217	<0.0001
21	Enhance + Prisma Gloss polishing paste vs Spiral Wheel + Zircon Brite polishing paste	0.519 vs 0.217	<0.0001

Combined composite: mean surface roughness

Statistical significant differences were found between the seven experimental groups (p<0.001) (Table 6 – lower case letters and Table 7). For the combined composite surface roughness values the Mylar strip gave the smoothest finish and was significantly different from the Sof-Lex XT discs, the Sof-Lex Spiral Wheels and the Spiral Wheels + Zircon Brite, which, in turn, gave a significantly smoother finish than the Intensiv UniglossCellbrush and Enhance + Prisma Gloss Paste. Dura-White stones provided for the roughest finish and was significantly different from all other groups. These differences are illustrated graphically in Figure 17 where polishing systems under the same black line are not statistically different from each other, while those that do not share a common line differ statistically significantly from each other.

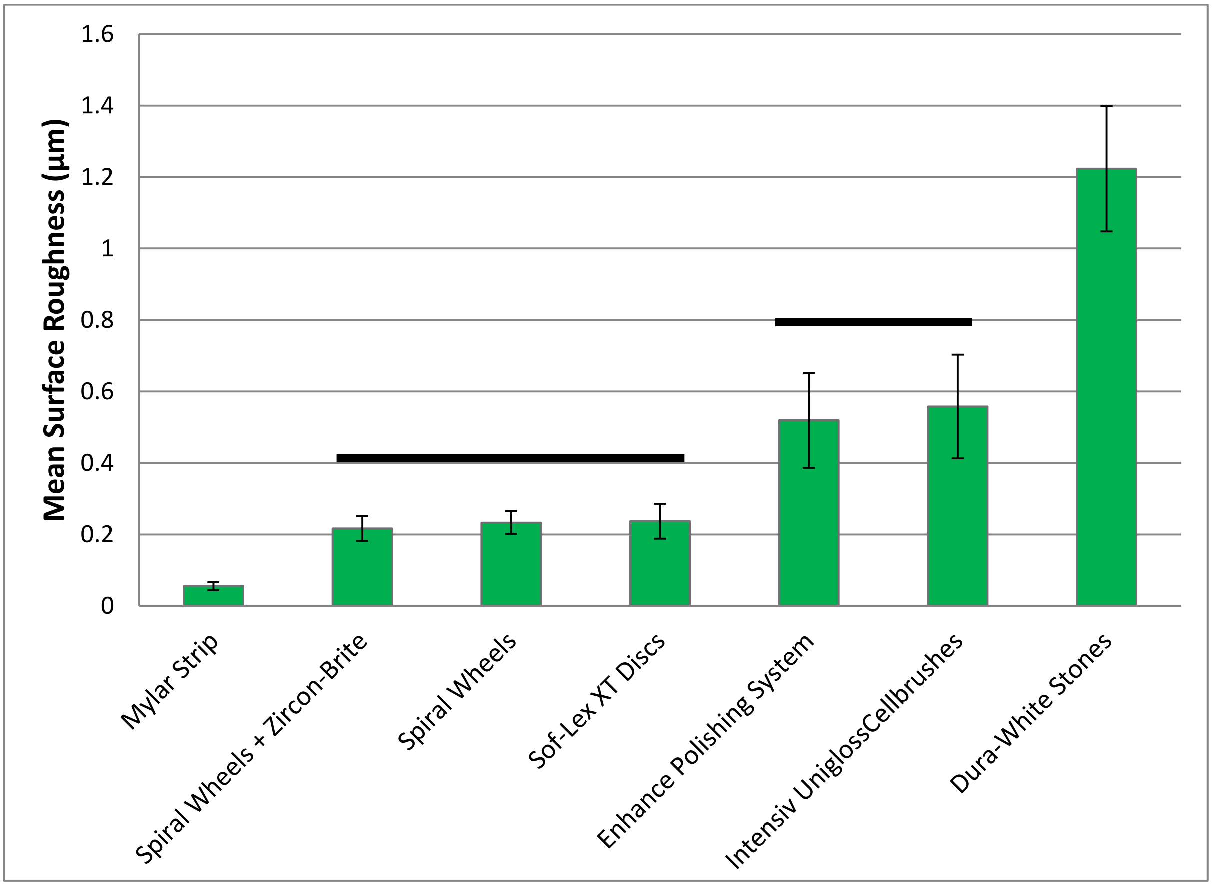


Figure 17. Bar graph of the combined mean composite surface roughnesses in micrometers (µm) for the polishing systems tested

Combined polishing: mean surface roughness

When comparing the combined polishing procedures, the mean surface roughness of Z100 was higher than, and significantly different from, the mean surface roughness of Filtek Supreme XTE ($p=0.005$), indicated with A and B in Table 6.

Figure 18 illustrates the differences in mean surface roughness in µm between the two composites after statistically combining the polishing procedures.

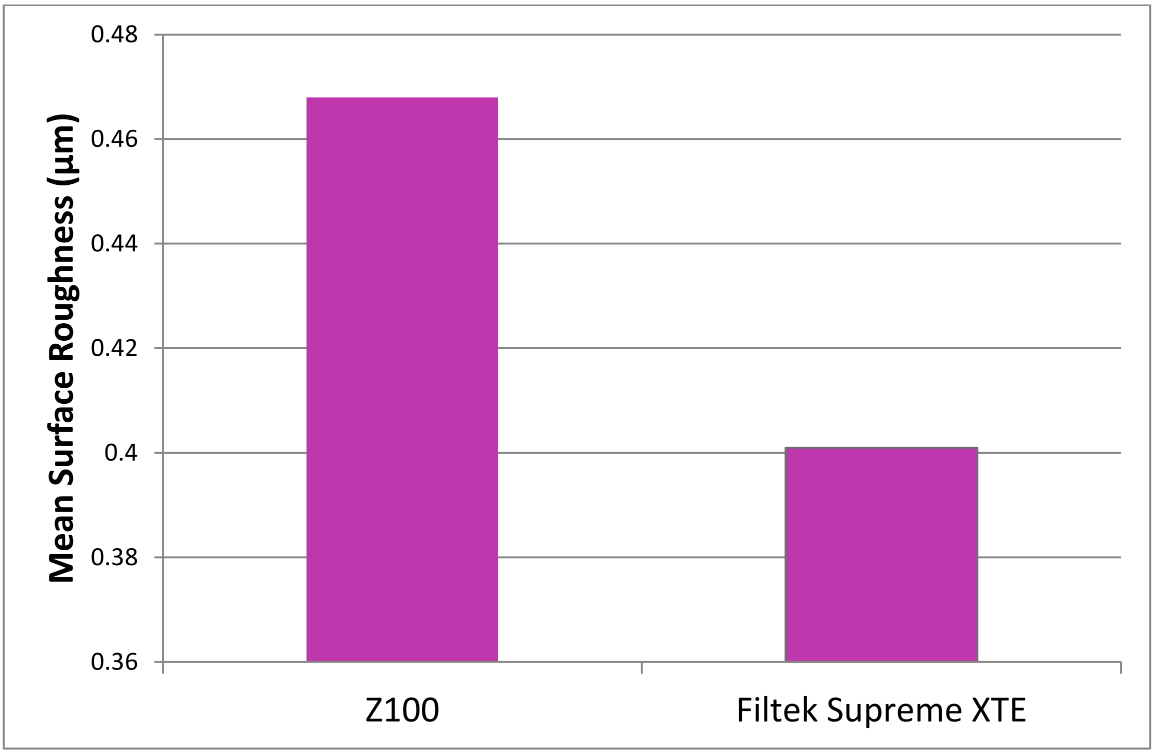


Figure 18. Bar graph of the combined polishing mean surface roughnesses in micrometers (µm) for Z100 and Filtek Supreme XTE

Figure 19 illustrates the different, yet almost parallel performance of Z100 and Filtek Supreme XTE when polished with the individual polishing systems, with Z100 having rougher surfaces after polishing than Filtek Supreme XTE.

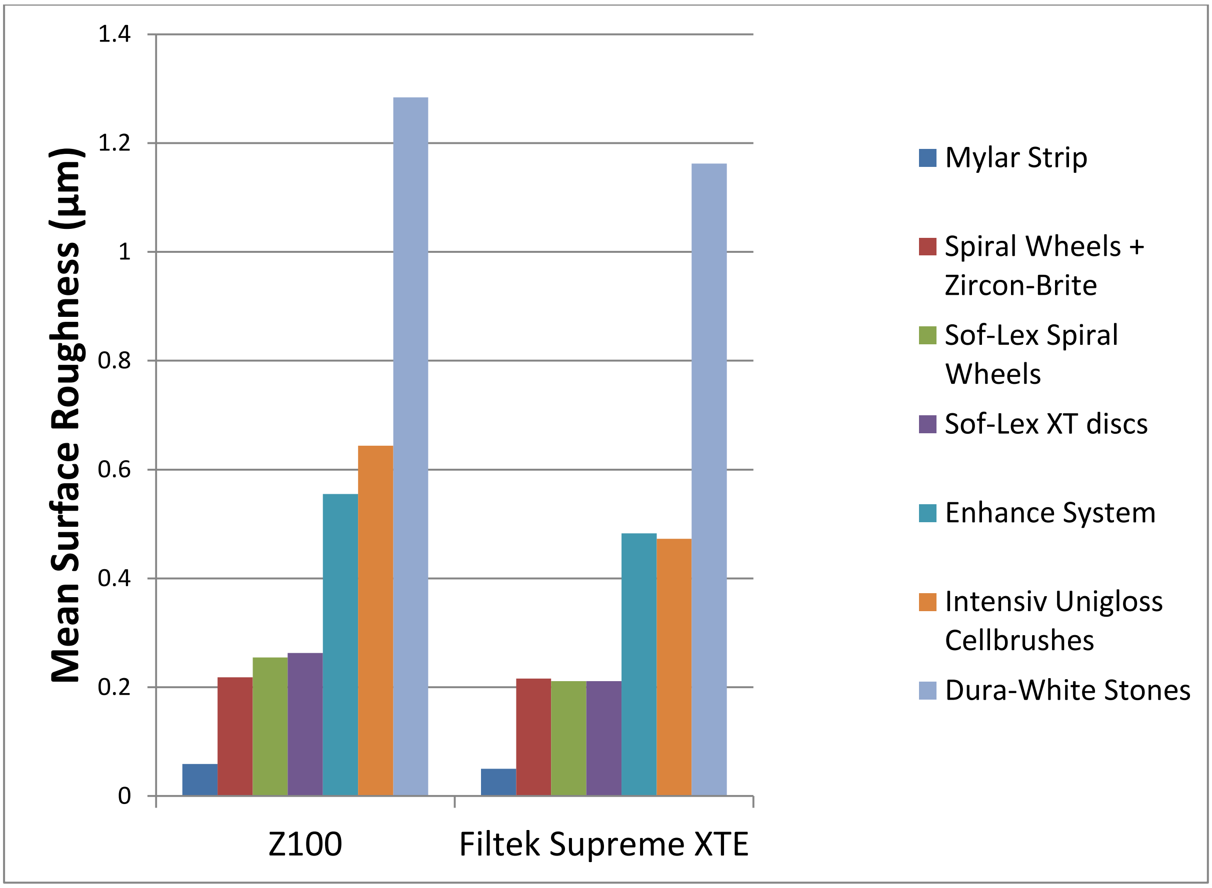


Figure 19: Bar graph of the surface roughness (µm) obtained on Z100 and Filtek Supreme XTE with the different polishing systems

4.2 Scanning Electron Microscope (SEM)

One representative sample per polishing group was evaluated under the SEM (JEOL JSM-5800 LV, Tokyo, Japan). Some of the significant SEM findings (images at 500 X and 1000 X magnification) are shown in Figures 20 – 47.

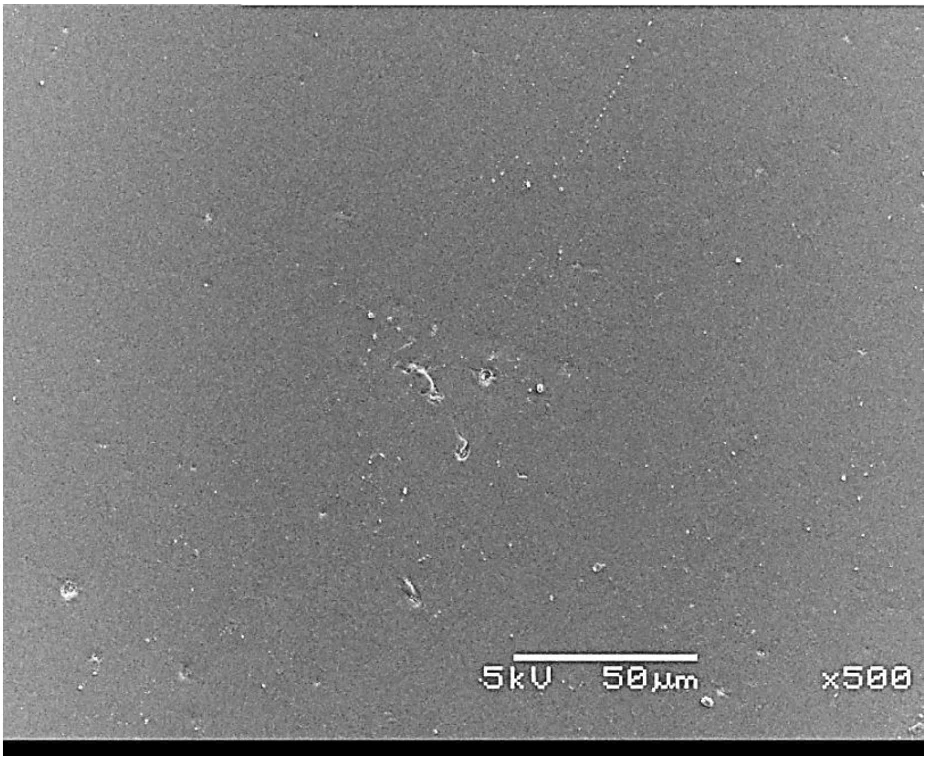


Figure 20: SEM image at 500 X magnification of Z100 cured through a Mylar polyester strip

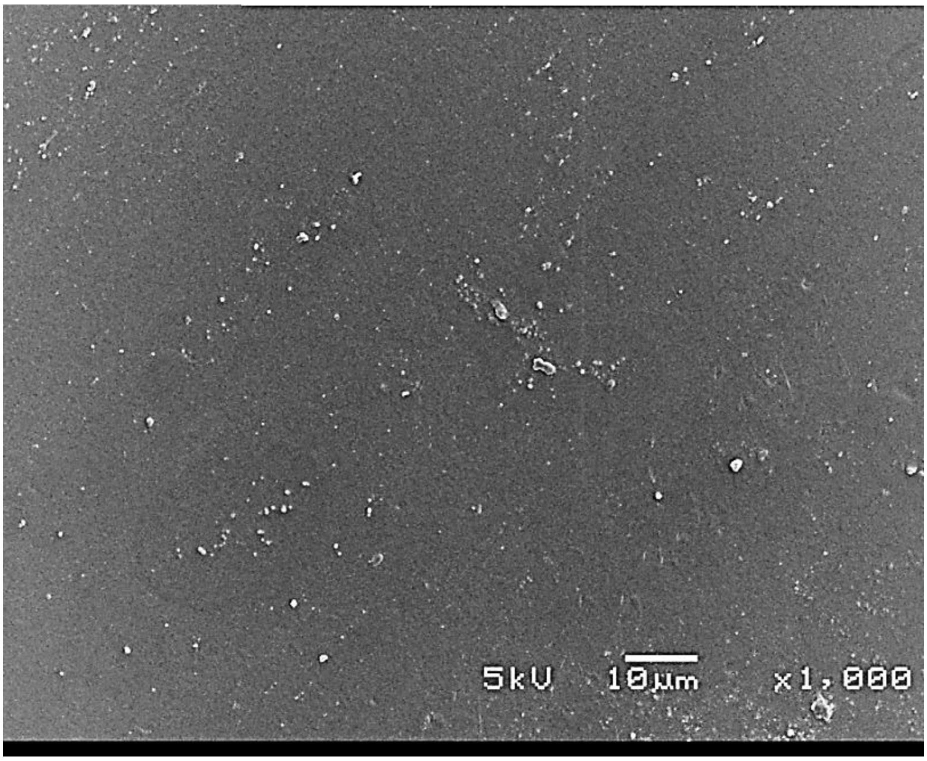


Figure 21: SEM image at 1000 X magnification of Z100 cured through a Mylar polyester strip

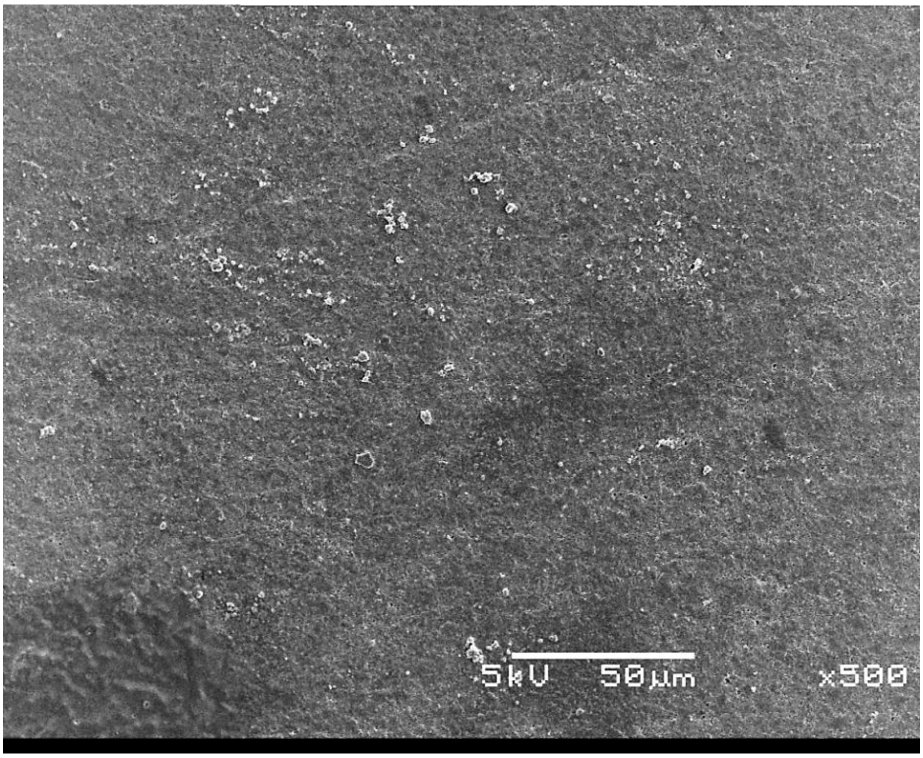


Figure 22: SEM image at 500 X magnification of Z100 after being polished with Sof-Lex XT discs (Coarse, Medium, Fine, Superfine)

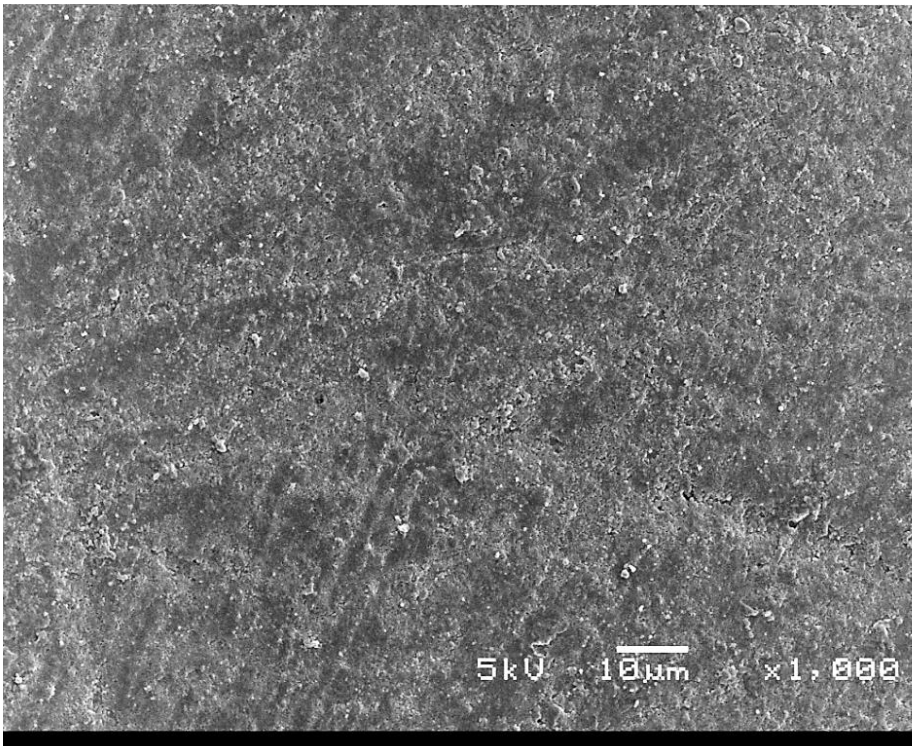


Figure 23: SEM image at 1000 X magnification of Z100 after being polished with Sof-Lex XT discs (Coarse, Medium, Fine, Superfine)

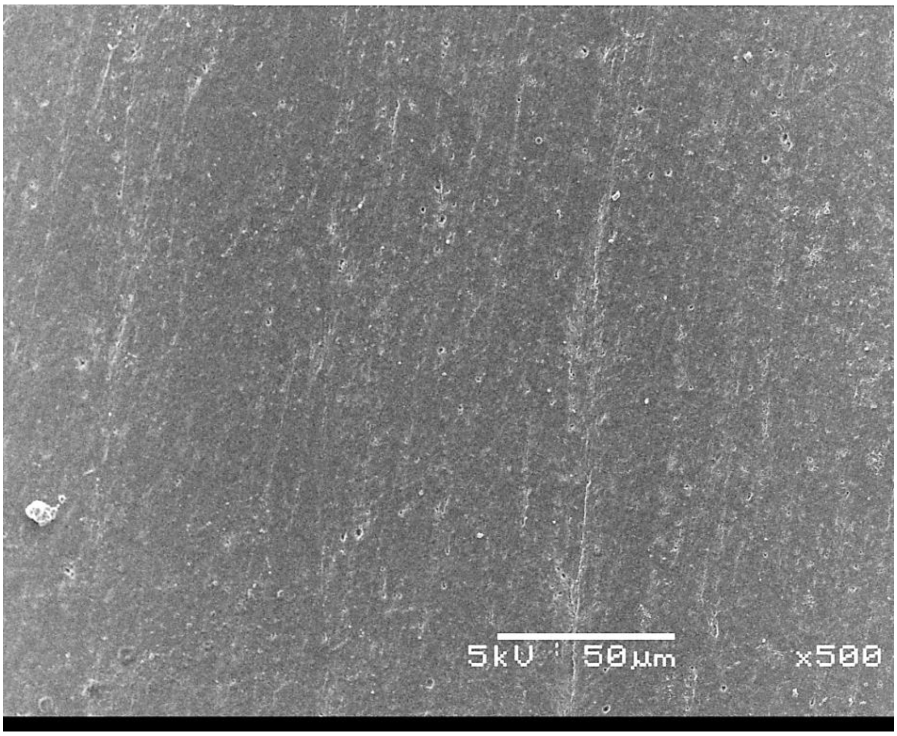


Figure 24: SEM image at 500 X magnification of Z100 after being polished with Sof-Lex Spiral Wheels

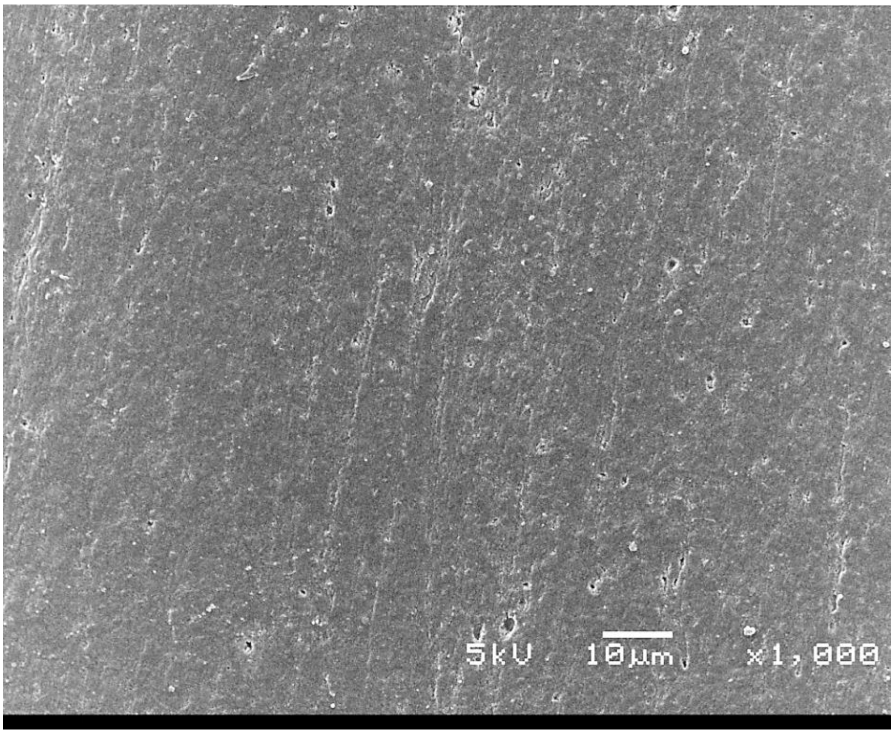


Figure 25: SEM image at 1000X magnification of Z100 after being polished with Sof-Lex Spiral Wheels

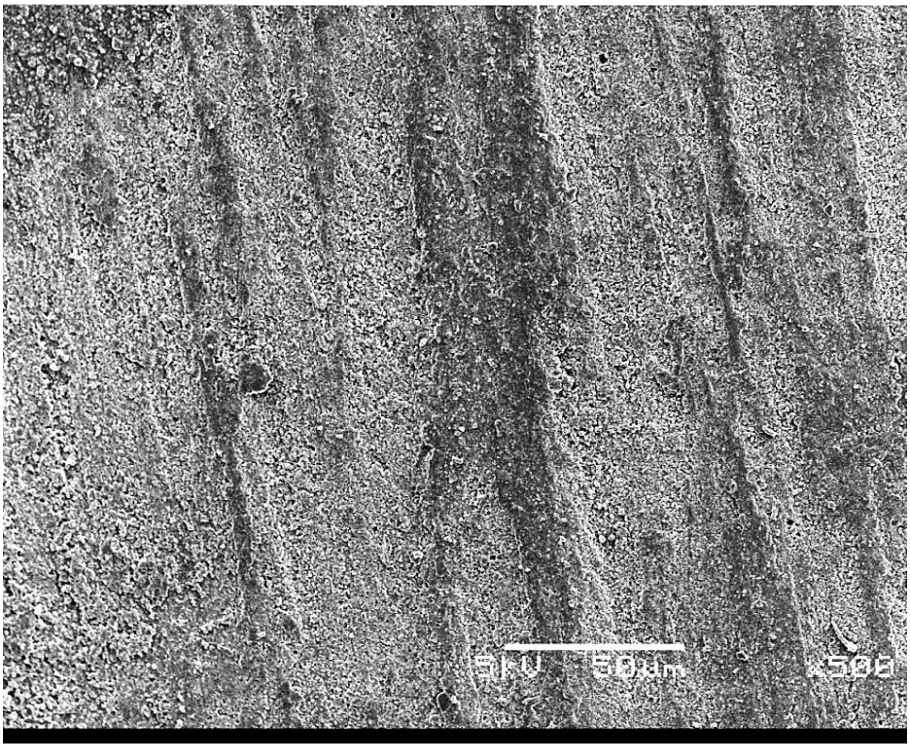


Figure 26: SEM image at 500 X magnification of Z100 after being polished with Dura-White stone

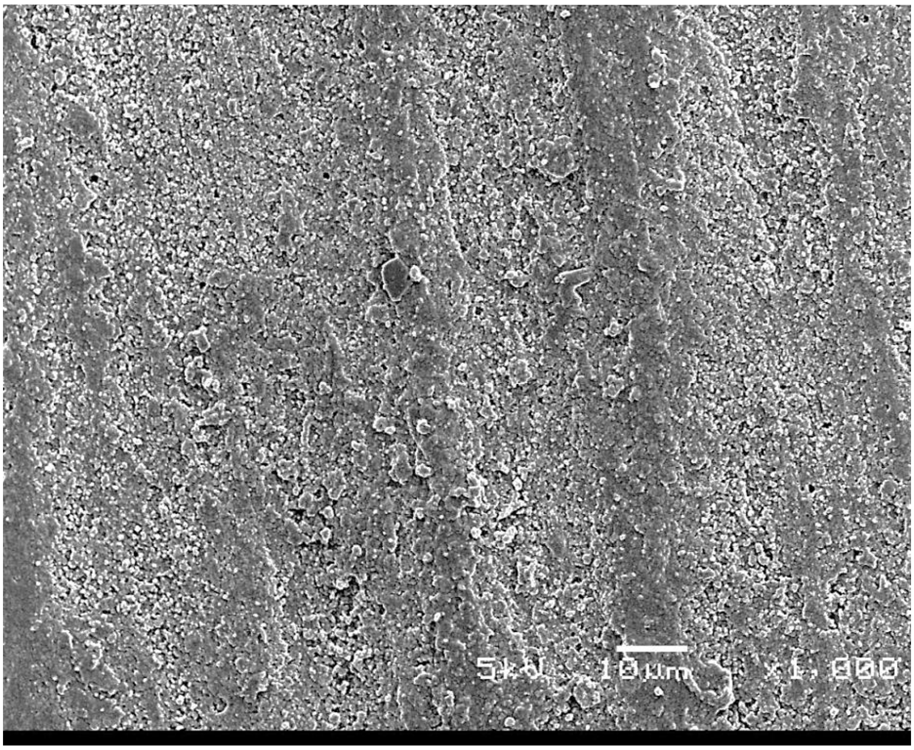


Figure 27: SEM image at 1000 X magnification of Z100 after being polished with Dura-White stone

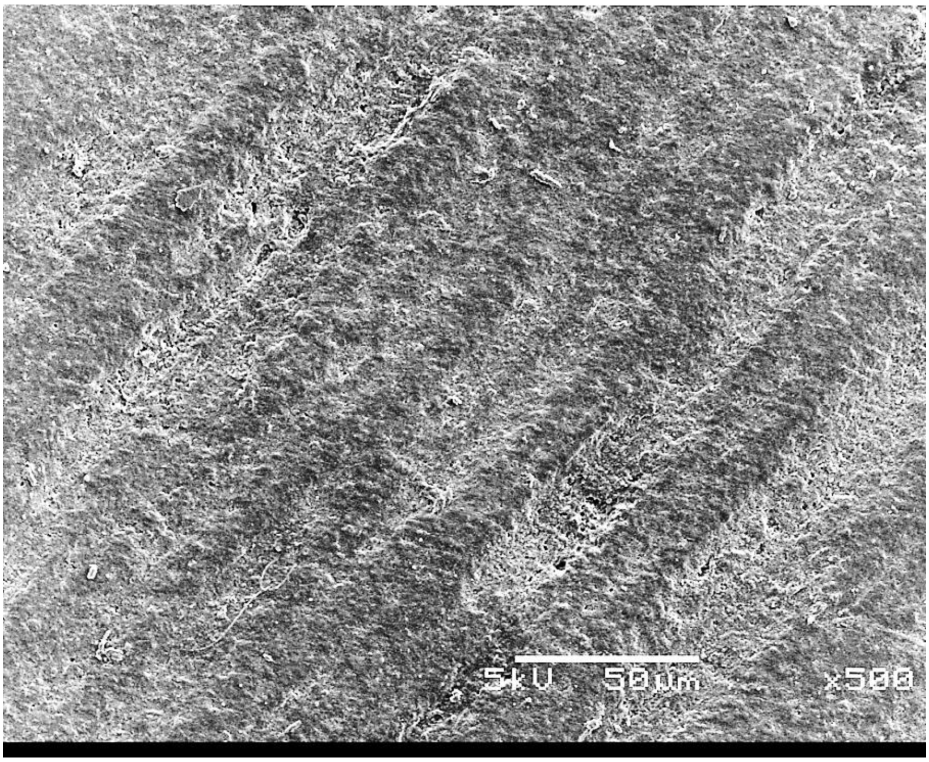


Figure 28: SEM image at 500 X magnification of Z100 after being polished with Intensiv UniglossCellbrush

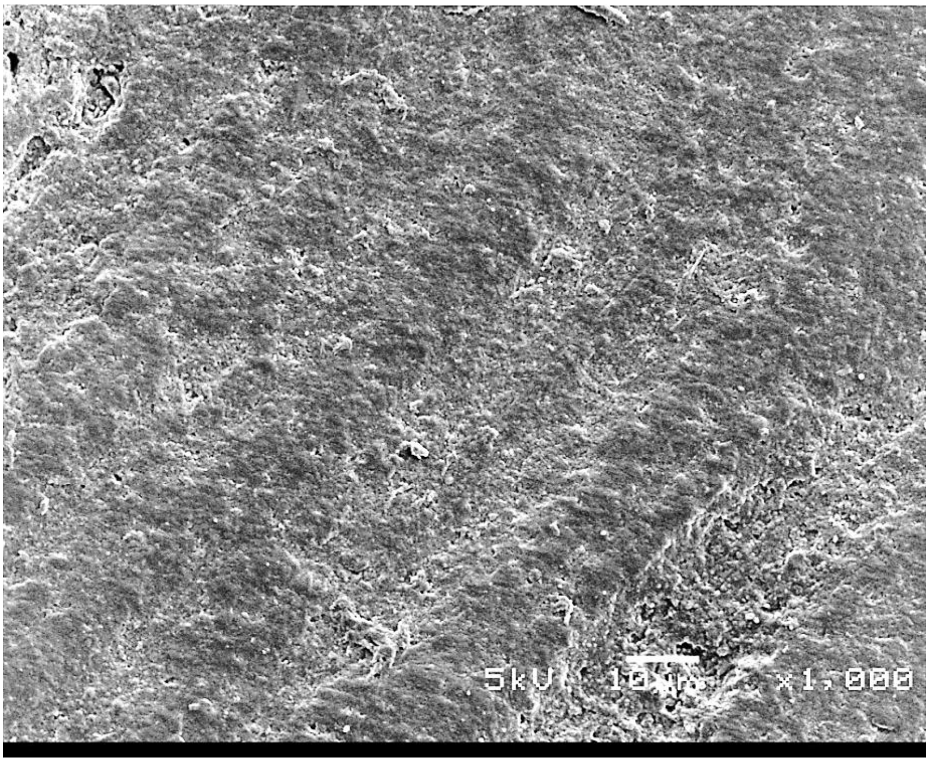


Figure 29: SEM image at 1000 X magnification of Z100 after being polished with Intensiv UniglossCellbrush

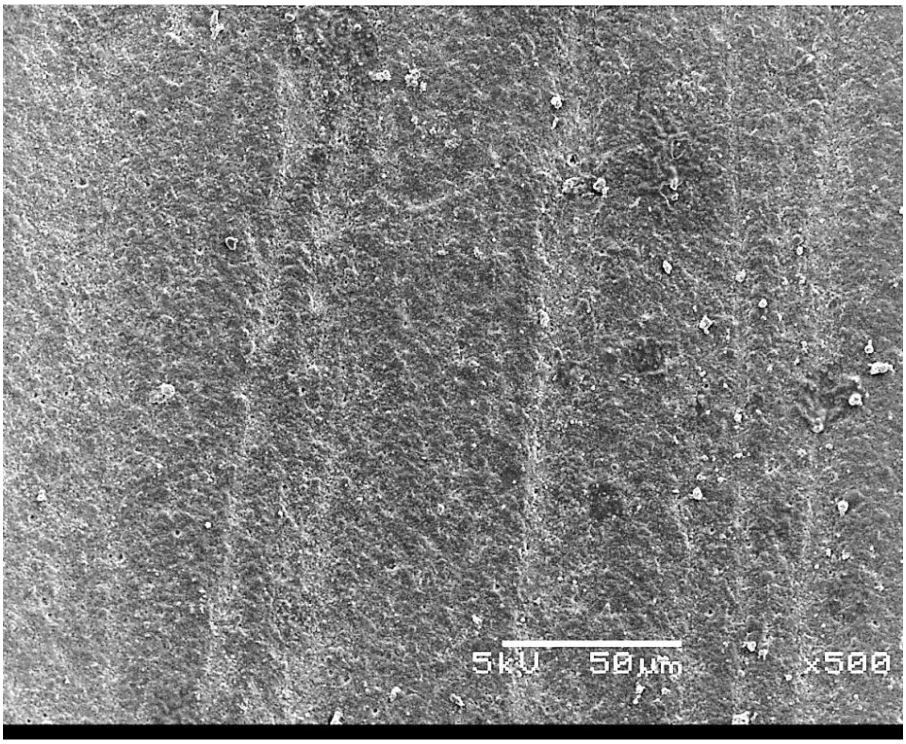


Figure 30: SEM image at 500 X magnification of Z100 after being polished with Enhance Finishing and Polishing System and Prisma Gloss polishing paste

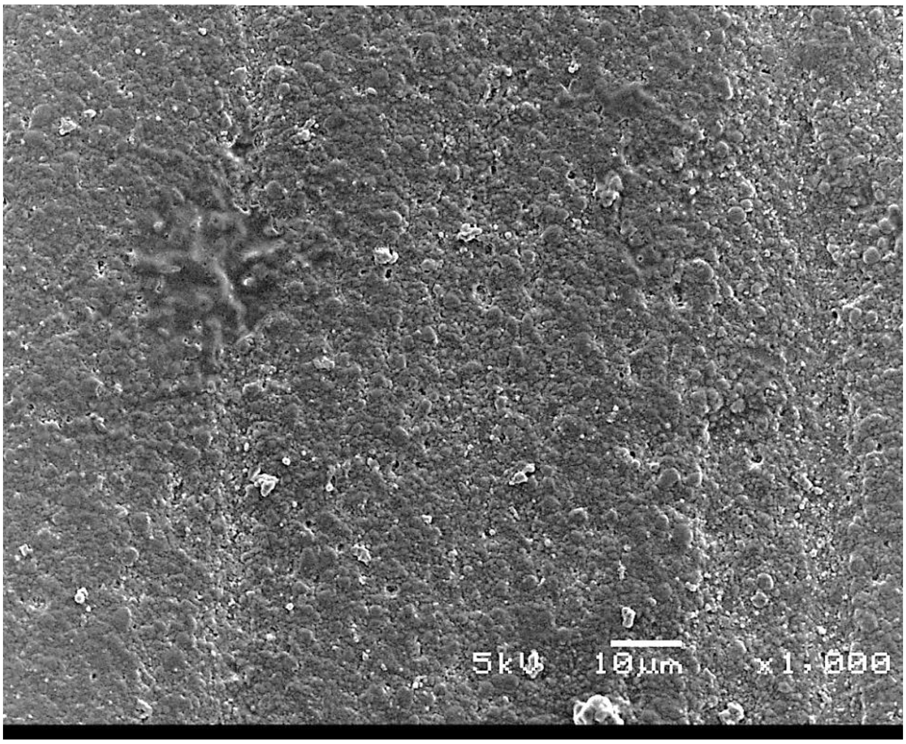


Figure 31: SEM image at 1000 X magnification of Z100 after being polished with Enhance Finishing and Polishing System and Prisma Gloss polishing paste

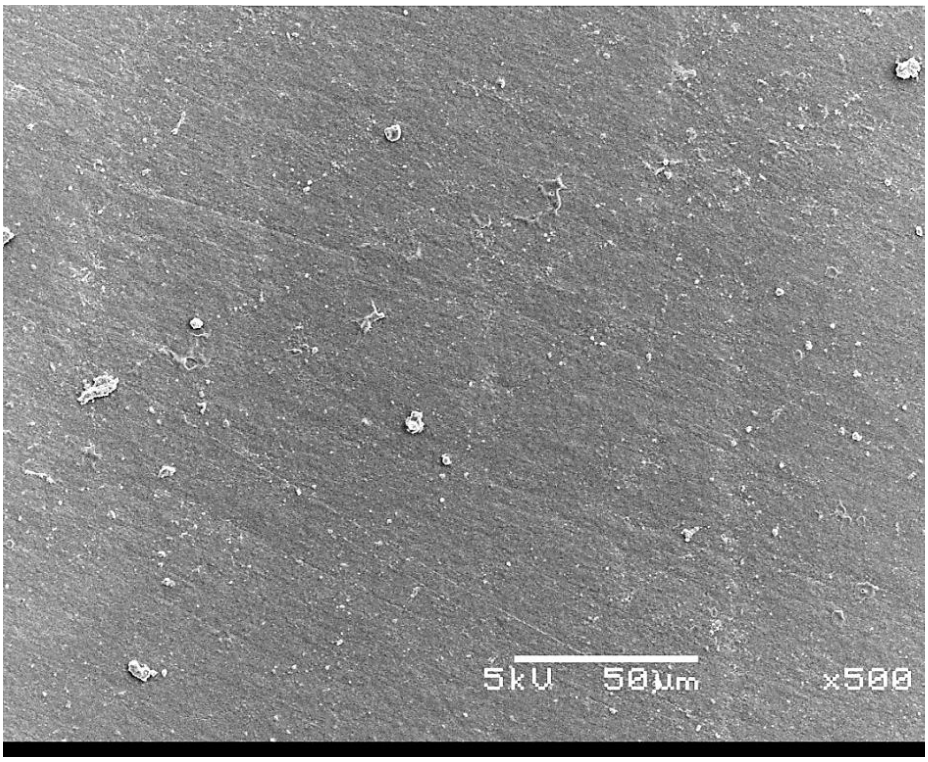


Figure 32: SEM image at 500 X magnification of Z100 after being polished with Sof-Lex Spiral Wheels, followed by Zircon-Brite

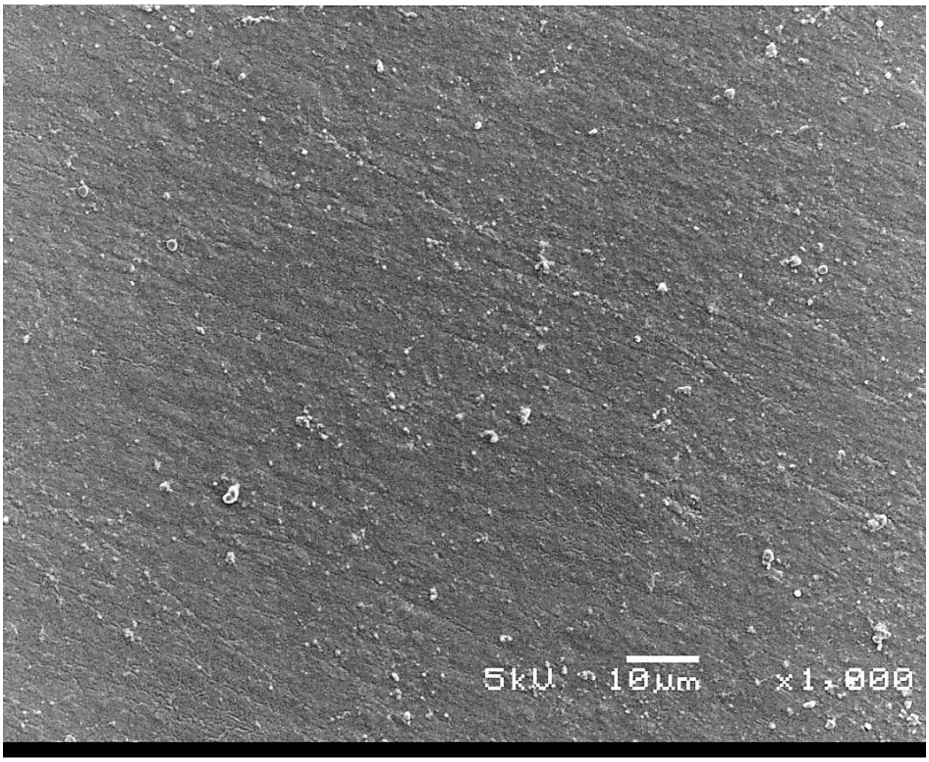


Figure 33: SEM image at 1000 X magnification of Z100 after being polished with Sof-Lex Spiral Wheels followed by Zircon-Brite.

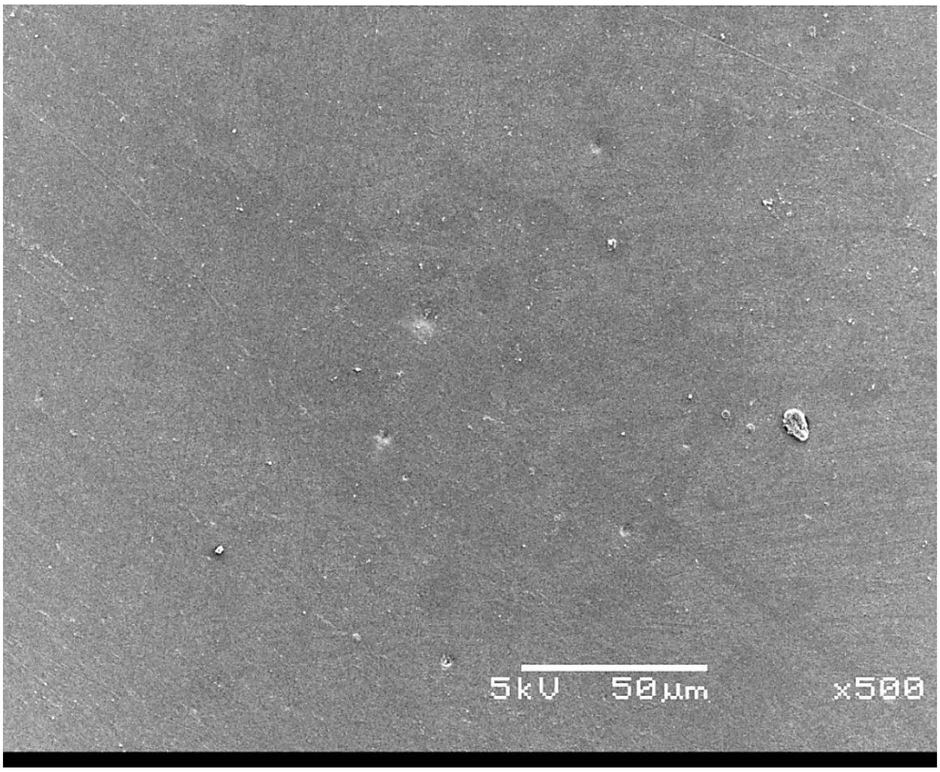


Figure 34: SEM image at 500 X magnification of Filtek Supreme XTE after being cured through a Mylar polyester strip

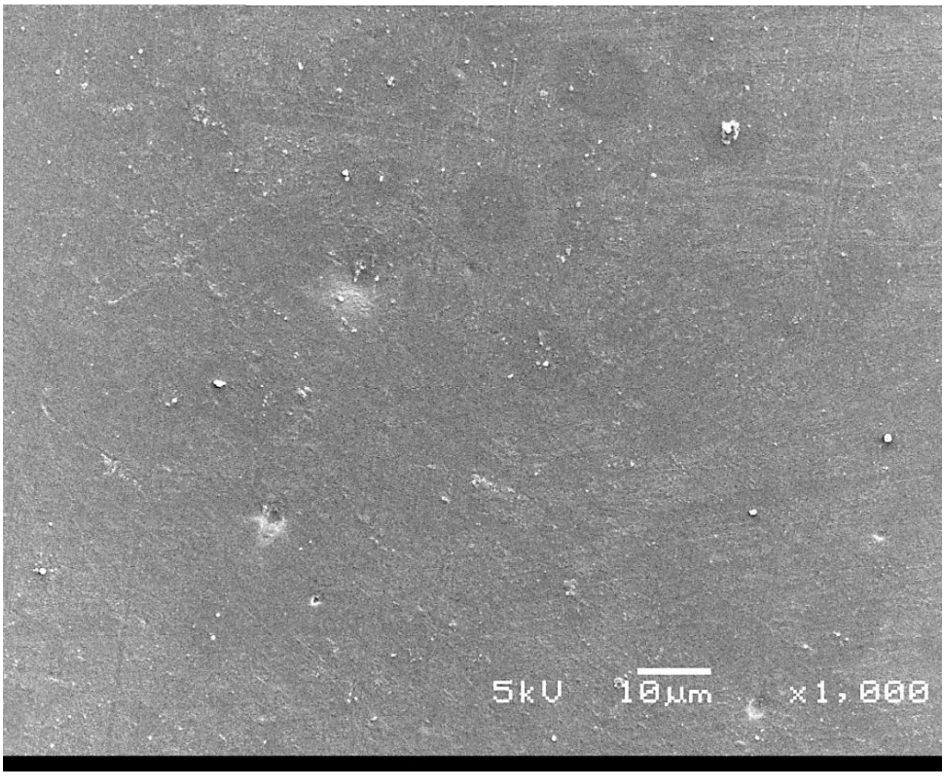


Figure 35: SEM image at 1000 X magnification of Filtek Supreme XTE after being cured through a Mylar polyester strip

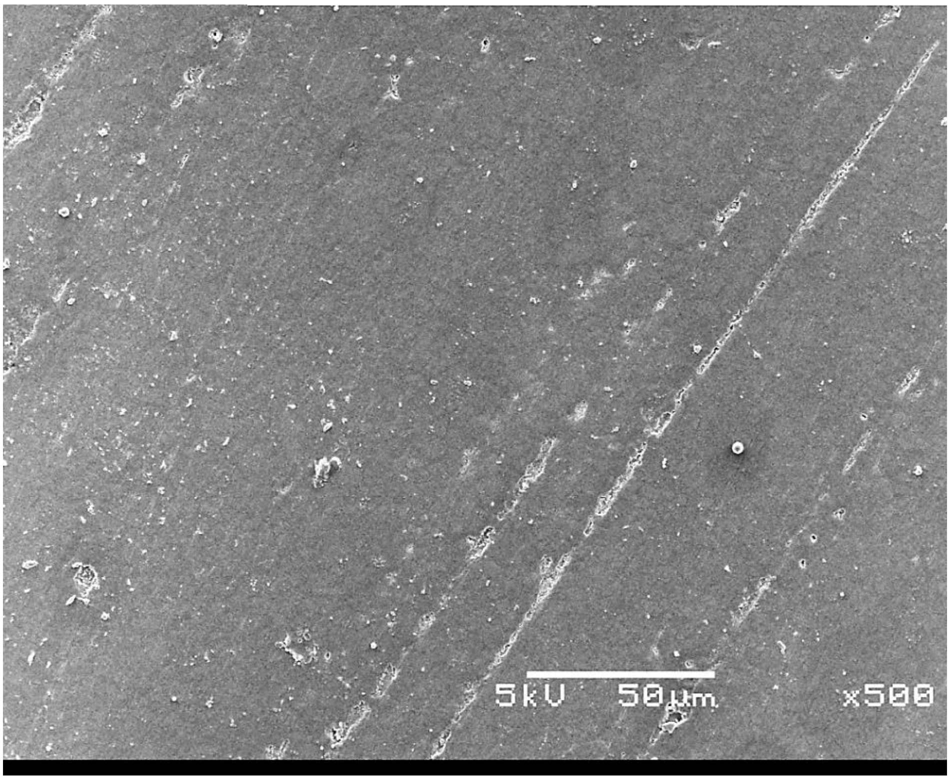


Figure 36: SEM image at 500 X magnification of Filtek Supreme XTE after being polished with Sof-Lex XT discs (Coarse, Medium, Fine, Superfine)

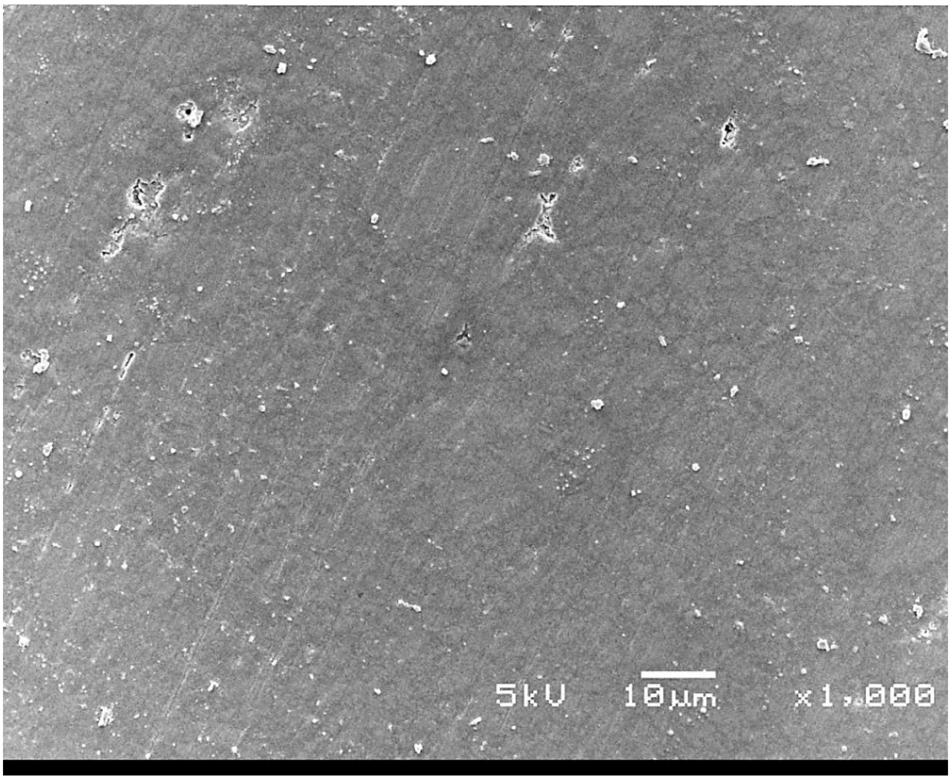


Figure 37: SEM image at 1000 X magnification of Filtek Supreme XTE after being polished with Sof-Lex XT discs (Coarse, Medium, Fine, Superfine)

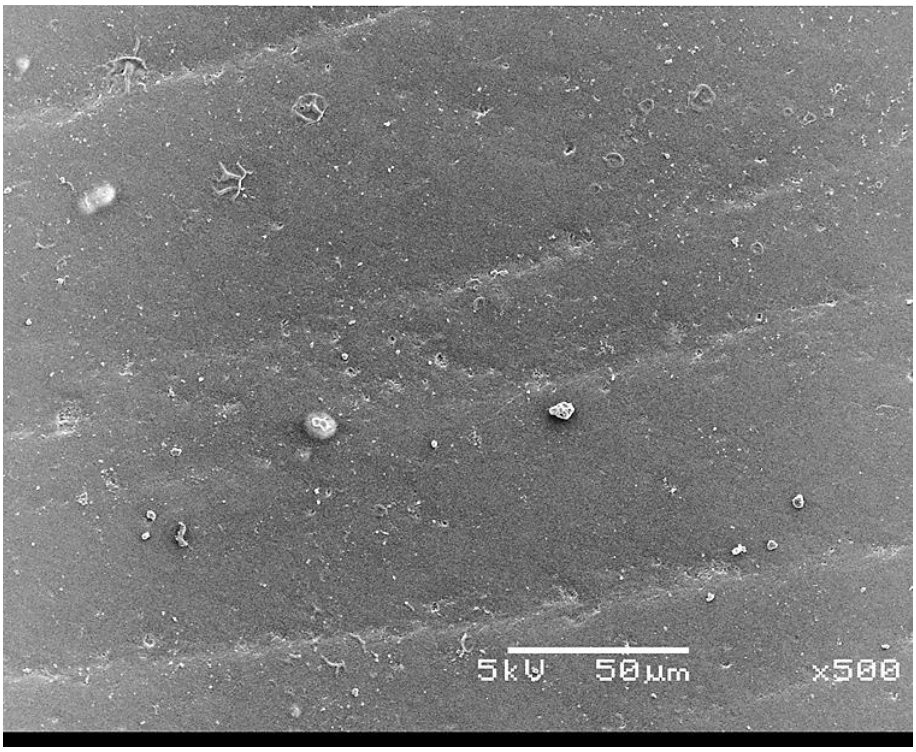


Figure 38: SEM image at 500 X magnification of Filtek Supreme XTE after being polished with Sof-Lex Spiral Wheels

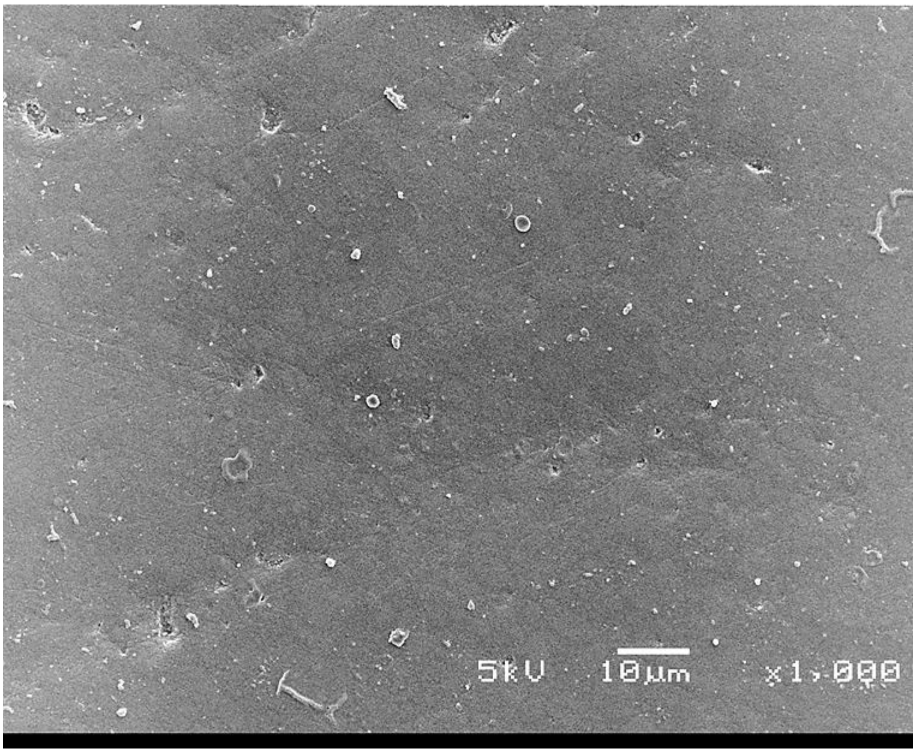


Figure 39: SEM image at 1000 X magnification of Filtek Supreme XTE after being polished with Sof-Lex Spiral Wheels

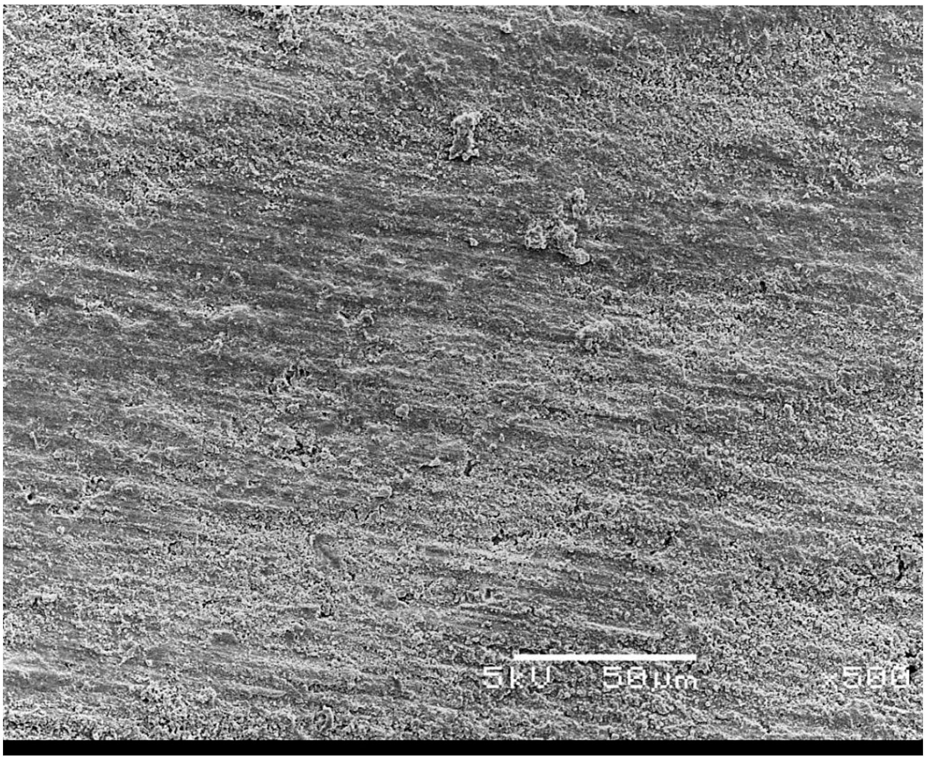


Figure 40: SEM image at 500 X magnification of Filtek Supreme XTE after being polished with Dura-White stone

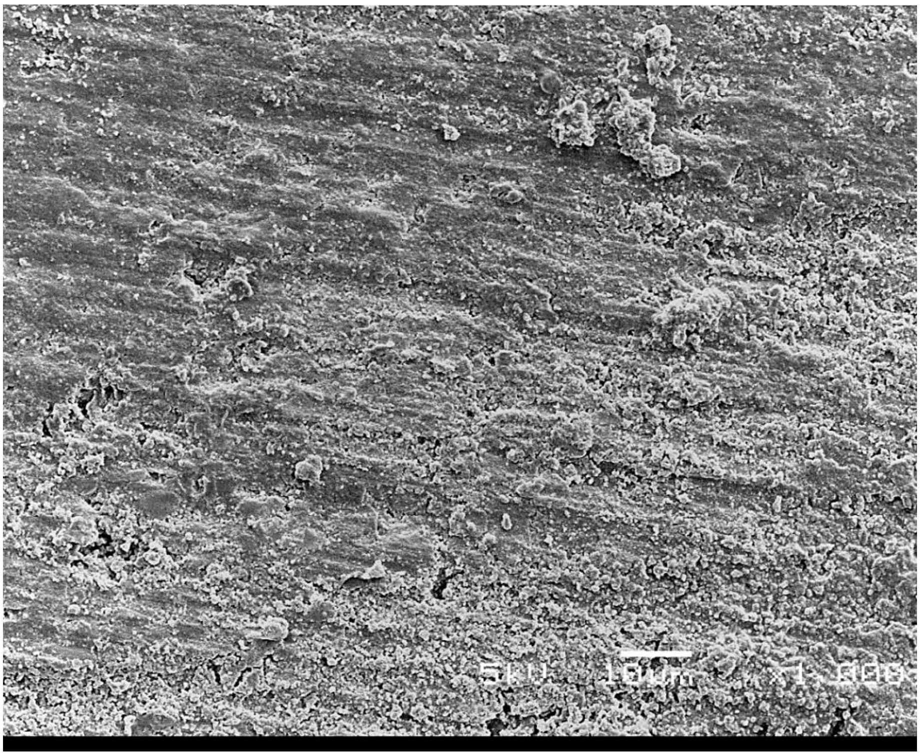


Figure 41: SEM image at 1000 X magnification of Filtek Supreme XTE after being polished with Dura-White stone

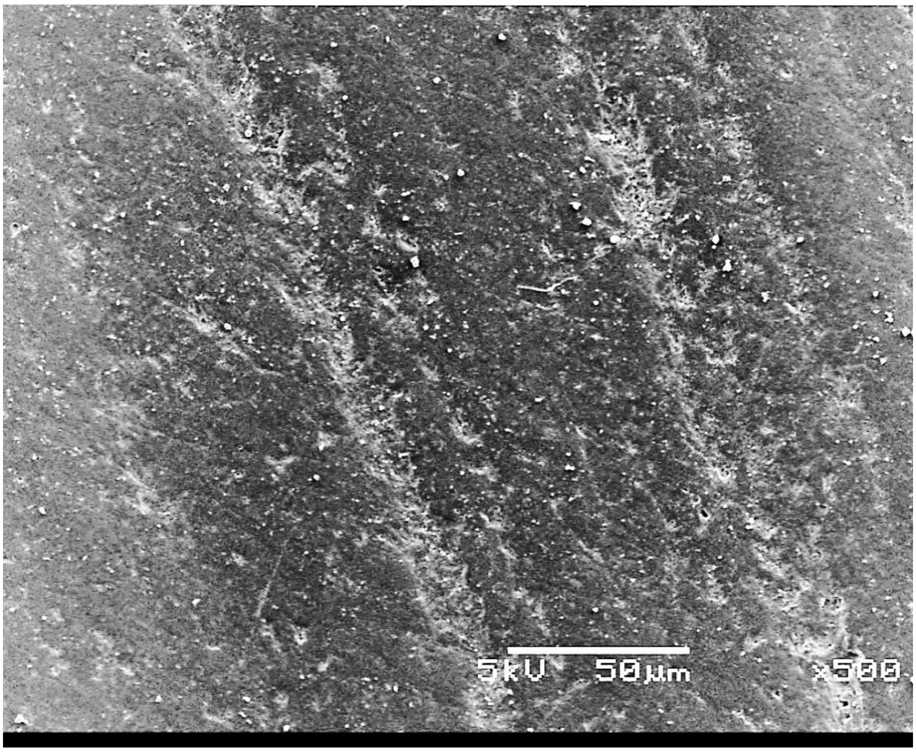


Figure 42: SEM image at 500 X magnification of Filtek Supreme XTE after being polished with Intensiv UniglossCellbrush

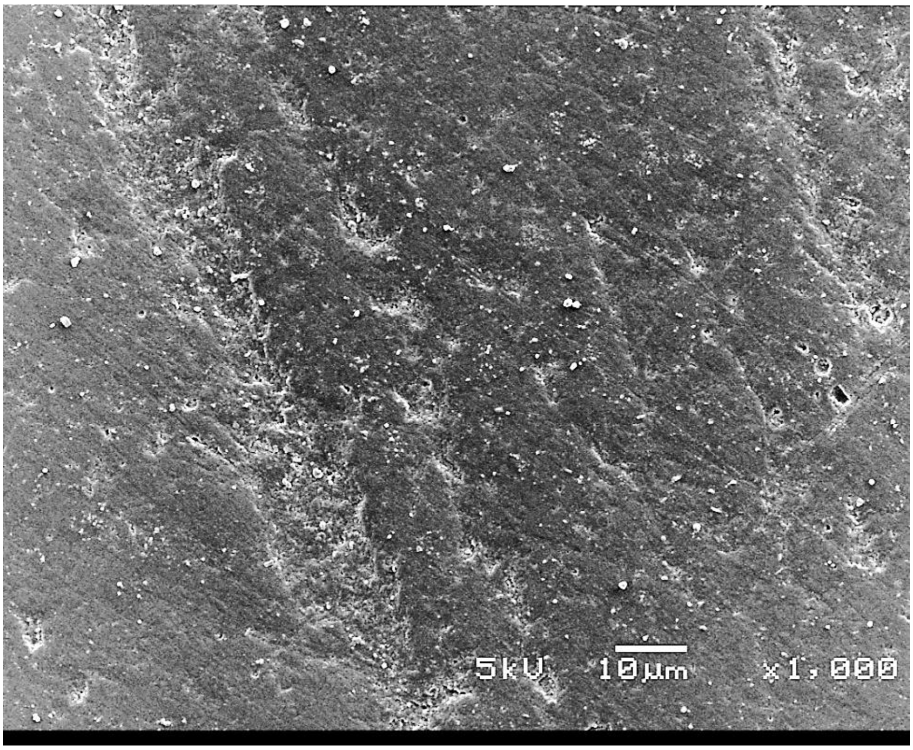


Figure 43: SEM image at 1000 X magnification of Filtek Supreme XTE after being polished with Intensiv UniglossCellbrush

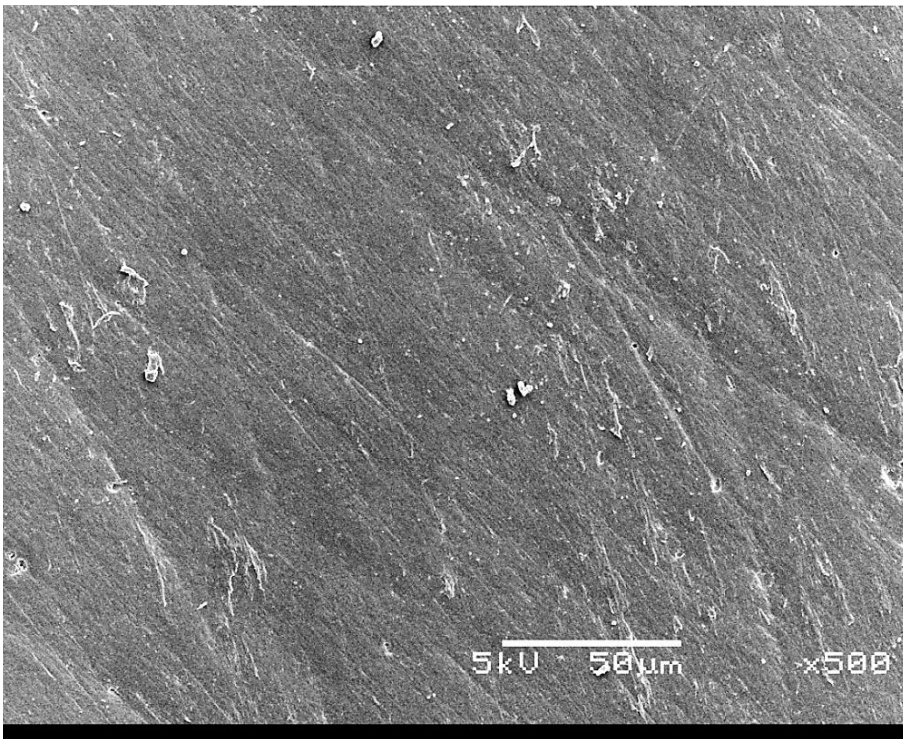


Figure 44: SEM image at 500 X magnification of Filtek Supreme XTE after being polished with Enhance Finishing and Polishing System and Prisma Gloss polishing paste

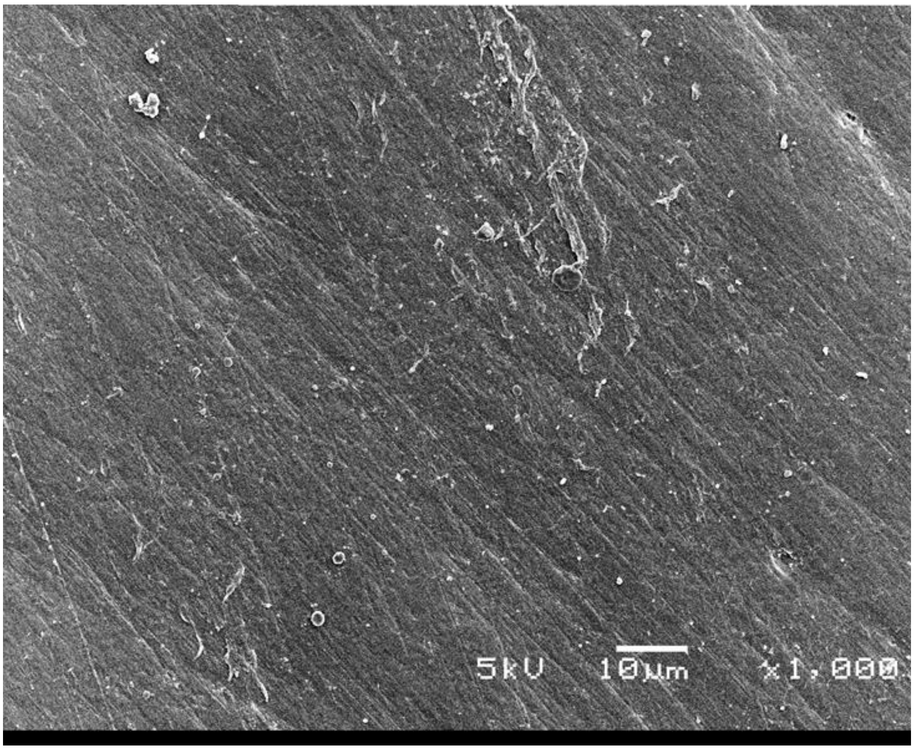


Figure 45: SEM image at 1000 X magnification of Filtek Supreme XTE after being polished with Enhance Finishing and Polishing System and Prisma Gloss polishing paste

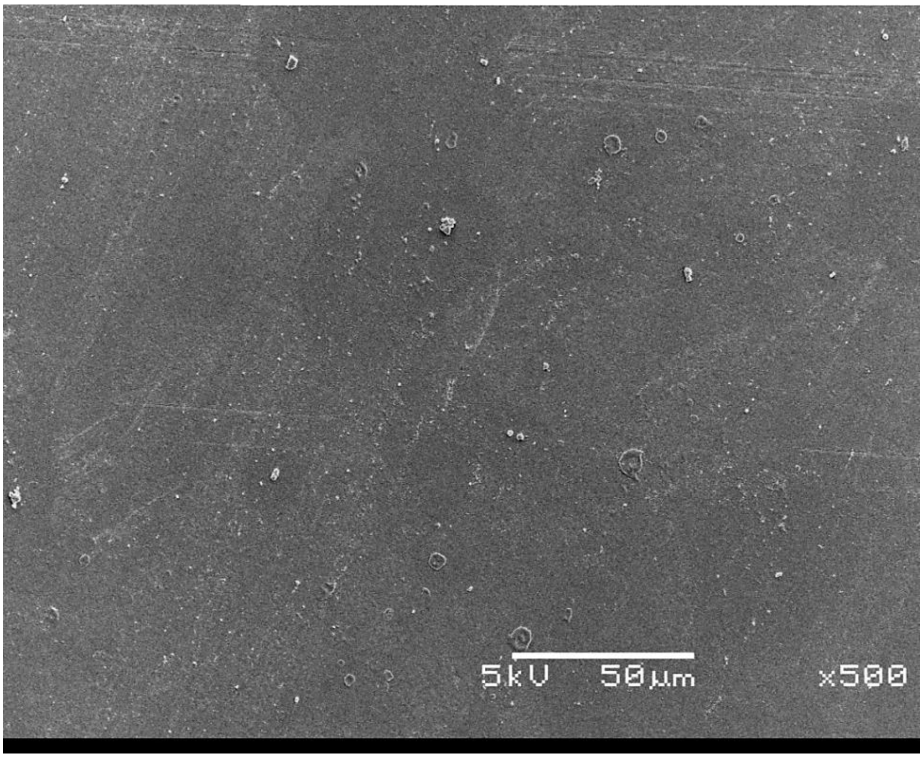


Figure 46: SEM image at 500 X magnification of Filtek Supreme XTE after being polished with Sof-Lex Spiral Wheels followed by Zircon-Brite

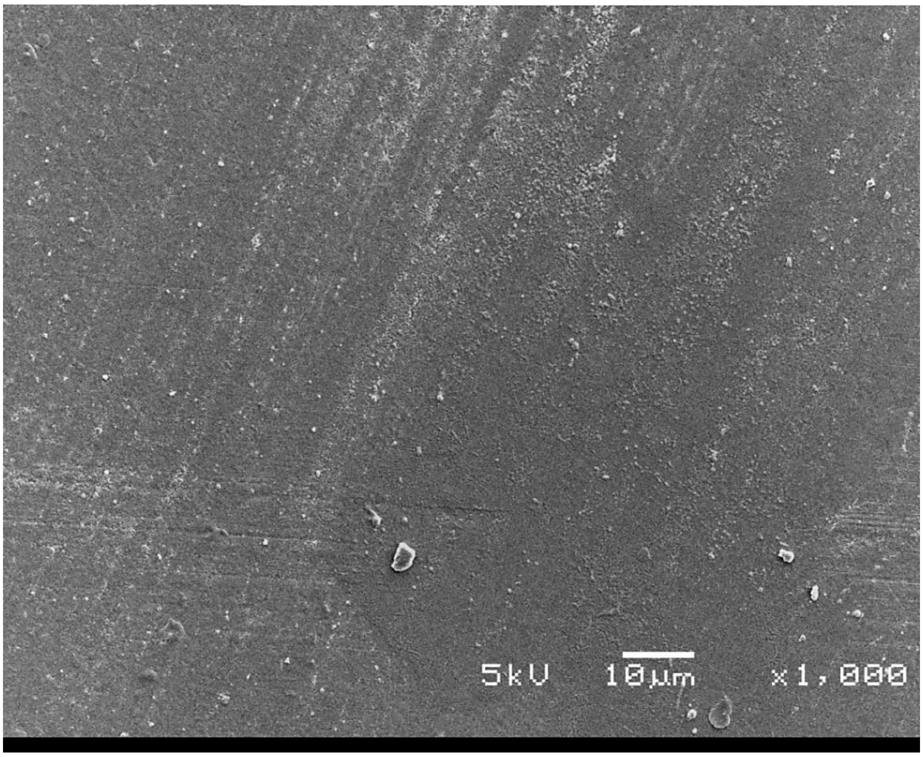


Figure 47: SEM image at 1000 X magnification of Filtek Supreme XTE after being polished with Sof-Lex Spiral Wheels followed by Zircon-Brite

CHAPTER 5: Discussion

The two composites used in this study represent two types of composite often used by private dentists. Z100 is an older, conventional micro-hybrid composite, and Filtek Supreme XTE a more modern composite representing the latest technology in the field of nanocomposites.

The polishing systems were carefully chosen, so that most of the major groups of polishing systems used in South Africa were represented in this study:

- *One-step polishing systems* Dura-White stone and Intensiv UniglossCellbrushes vs *multi-step polishing systems* Sof-Lex XT polishing discs, Sof-Lex Spiral Wheels and Enhance in combination with Prisma Gloss polishing paste.
- Different abrasives were included in this study:[17]
  - Al_2O_3: Sof-Lex XT Polishing discs, Sof-Lex Spiral Wheels, Dura-White stones and Enhance
  - *Diamond abrasives*: Intensiv UniglossCellbrushes
  - *Zirconium abrasive*: Zircon-Brite polishing paste
- Different carrier products:[17]
  - Coated abrasive discs: Sof-Lex XT polishing discs
  - Stones: Dura-White stones
  - Polishing pastes: Prisma Gloss composite polishing paste
  - Elastic Polymer: Enhance
  - Brushes: Intensiv UniglossCellbrushes
  - Wheels: Sof-Lex Spiral Wheels

Clinically, most composite restorations need to be subjected to some finishing and contouring in order to obtain the correct shape and morphology before polishing.[1] Therefore, to mimic the clinical situation, all the composite samples were first finished with a red stripe finishing diamond bur, followed by a yellow stripe finishing diamond bur.

In this study diamond finishing burs were chosen over carbide finishing burs, because the literature showed that carbide burs cause more damage than diamond burs during the finishing procedure, and that the damage caused by diamond burs could more easily be rectified by a good polishing system.[55, 56]

The results obtained from this study confirmed that the smoothest composite surface is obtained when the composite is cured through a Mylar polyester strip. These samples were statistically smoother than the surface roughnesses obtained for any of the polishing systems tested in this study. This result is in accordance with previous studies.[4, 27, 29, 58, 73]

The surface roughness of Z100 cured through a Mylar polyester strip in this study was 0.059 µm. This result compares favourably with the Jones study who also found the surface roughness to be 0.06 µm for Z100 cured through a Mylar polyester strip.[10] The surface roughness of Filtek Supreme XTE cured through a Mylar polyester strip in this study was 0.050 µm. This result also compares favourably with the surface roughness of 0.040 µm for Filtek Supreme XTE cured through a Mylar polyester strip, as noted in the study by Baseren.[73]

The surface roughness of Z100 before polishing was higher than the surface roughness of Filtek Supreme XTE (Table 5). The lower surface roughness value for Filtek Supreme XTE can be explained by the smaller filler particles (nano particles and clusters of nano-sized fillers) which are incorporated into Filtek Supreme XTE.[13] The average particle size of the fillers in Z100 is 0.01 – 3.5 µm.[42] Filtek Supreme XTE has a combination of different size particles: i. 20nm silica fillers; ii. 4 to 11 nm zirconia fillers; iii. 0.6-10 µm zirconia/silica clusters.[13]

In this study there was no statistical interaction between the composites and the different polishing systems. The polishing systems acted in a parallel manner on the Z100 and Filtek Supreme XTE meaning that the polishing systems that differed significantly from each other when used on Z100, also differed significantly when used on Filtek Supreme XTE. The two different composites did not affect the main effect of the different polishing systems. This is in accordance with a study by Da Costa, Ferracane, Paravina, Mazur and Roeder that also found no significant interaction between the type of composite used, and the particular polishing system.[47]

A study by Kaplan, Goldstein, Vijayaraghavan and Nelson investigated the polishability of four different composites with three different polishing systems. A two-way ANOVA also demonstrated a highly significant effect for the respective polishing systems, but with no interaction between the composites and the polishing systems.[30] This finding of no interaction between composites and different polishing systems, but a highly significant effect for the individual polishing systems in that particular study is in accordance with the findings of this study.[30]

After polishing with the different polishing systems, Filtek Supreme XTE had a statistical significant smoother surface when compared to Z100 ($p=0.005$). This means that Filtek Supreme XTE has better polishability than Z100. This is in accordance with several studies in the literature:

- Senawongse and Pongprueksa demonstrated that nanocomposites with nanoclusters had a smoother surface after polishing, compared with microhybrid- and nanohybrid composites.[28]
- Da Costa, Ferracane, Paravina, Mazur and Roeder demonstrated that Z100 had a statistically significantly higher surface roughness after polishing compared to Filtek Supreme XTE.[47]

A surface roughness threshold of below 0,2µm is necessary to prevent bacterial adhesion and plaque accumulation.[6, 18] A patient can detect roughnesses in the surface of composite restorations that is greater than 0,5 µm.[10] Enamel surface roughness at enamel-to-enamel occlusal contact areas is 0.64±0.25µm.[74] Z100 and Filtek Supreme XTE displayed surface roughnesses of 1.284µm and 1.162µm respectively after being polished with Dura White stones. This is above the 0, 2 µm threshold for surface roughness for plaque adhesion, and much higher than the 0, 5 µm that a patient can detect with their tongue.[6, 18]

The following polishing systems provided the smoothest surfaces after polishing: Sof-Lex Spiral Wheels in combination with Zircon-Brite, as well as the Sof-Lex Spiral Wheels and Sof-

Lex finishing and polishing discs. These systems created significantly smoother surface composite surfaces than the Enhance system, used in combination with Prisma Gloss polishing paste, and also the one-step polishing system Intensiv UniglossCellbrush. There was no statistically significant difference between Sof-Lex Spiral Wheels used in combination with Zircon-Brite; Sof-Lex Spiral Wheels and also Sof-Lex XT discs. The fact that Sof-Lex XT discs produced some of the smoothest surfaces after polishing is in accordance with previous studies done.[59, 60, 62] Yap, Yap, Teo and NG found that the surface roughness for Z100, after polishing with Sof-lex XT discs, was 0.22µm.[53] This value is comparable to the value obtained in the current study, ie 0.26µm.

Enhance in combination with Prisma Gloss polishing paste, and in combination with Intensiv UniglossCellbrush, did not differ significantly from each other. Both were over the 0, 2µm thresholds for plaque accumulation. Enhance performed poorly not only in this study but also in a study done by Kaplan, Goldstein, Vijayaraghavan and Nelson.[30]

The surface roughness values obtained for all the polishing systems in this study were the lowest when they were used on Filtek Supreme XTE. The fact that the polishing systems gave better results when used on a nanocomposite compared to a microhybrid composite is in accordance with a study done by Senawongse and Pongprueksa.[28]

The surface roughness values for Sof-Lex Spiral Wheels and also for Sof-Lex XT finishing and polishing discs, when used on Filtek Supreme XTE, were 0.211µm. This is acceptable for the plaque accumulation threshold and the patient’s sensory feeling threshold.

The smoothest surface for Z100 was obtained with a combination of Sof-Lex Spiral Wheels and Zircon-Brite. No previous studies could be found where Zircon-Brite was used in combination with Sof-Lex Spiral Wheels. This combination, although proving to create the smoothest surface, was not statistically different compared to the Sof-Lex Spiral Wheels or the Sof-Lex finishing and polishing discs groups. When Zircon-Brite, in combination with Sof-Lex Spiral Wheels, was used on Filtek Supreme XTE there was no difference in surface roughness compared with Sof-Lex Spiral Wheels alone. This can be attributed to the nano filler particles of Filtek Supreme XTE.[13]

The operator found that using Zircon-Brite in addition to the Sof-Lex Spiral Wheels was time consuming and more costly than just using the Sof-Lex Spiral Wheels alone - all in order to achieve a result that was smoother, but not statistically significantly different.

The Sof-Lex XT discs and the Spiral Wheels, as well as the Spiral Wheels combined with the Zircon-Brite showed a lower variability in polishing end-result than the Enhance and Unigloss Cellbrush systems, as well as the Dura White stone as indicated by the standard deviations of each system (Fig 17). Clinically, this may mean that the Sof-Lex XT discs and the Spiral Wheels, as well as the Spiral Wheels combined with the Zircon-Brite may provide a less technique-sensitive polishing sequence to the dental operator.

The SEM images for both Z100 and Filtek Supreme XTE showed the smoothest composite surface when the composite was cured through a Mylar polyester strip (Fig 20, 21, 34, 35). The composite surfaces appeared quite smooth, but showed small protruding particles and irregularities on the surface, possibly small filler particles that protruded from the resin matrix. Visually there were no obvious differences between the Z100 and Filtek Supreme XTE surfaces. These SEM images are in agreement with the profilometer readings that were obtained during this study.

For both composites the images for Dura-White stones under the SEM after polishing appeared very rough, and had a wavy and uneven appearance (Fig 26, 27, 40, 41). Clear crests and valleys were visible. This may be attributed to the rotational polishing motion of the Dura-White stone. Fruits, Miranda and Coury showed that a planar polishing motion resulted in smoother polished surfaces than a rotational motion.[63] These images also correspond to the high profilometer readings.

The SEM images for both Z100 and Filtek Supreme XTE showed relatively smooth surfaces with only a few scratch lines and irregularities visible after polishing with Sof-Lex XT discs (Fig 22, 23, 36, 37). Protruding filler particles are visible on the surface, as well as a few voids. The voids or pits may be attributed to the dislodgement of filler particles.[30, 62] These images correspond to the profilometer readings obtained in this study.

For both composites the SEM images for Sof-Lex Spiral Wheels alone, and Zircon-Brite combined with Sof-Lex Spiral Wheels, appeared reasonably smooth with a few scratch lines and voids that were present (Fig 24, 25, 32, 33, 38, 39, 46, 47). Protruding filler particles were also noted. The protruding particles indicate resin removal during the polishing procedure, and also the non-uniform abrasion of resin vs filler particles.[17, 30]

The SEM images for both Z100 and Filtek Supreme XTE showed a very wavy appearance with distinct crests and valleys, after being polished with Intensiv UniglossCellbrush and Enhance in combination with Prisma Gloss polishing paste (Fig 28, 29, 30, 31, 42, 43, 44, 45). There were voids and surface irregularities visible, possibly due to the plucking effect of the polishing systems.[30] Protruding filler particles and debris were also visible on the surface.

CHAPTER 6: Conclusion

Filtek Supreme XTE displayed significantly better polishability than Z100. Some polishing systems produced statistically smoother surfaces than others. The smoothest surface was obtained after curing through a Mylar strip. The smoothest surface after polishing was the Zircon-Brite/Spiral Wheel combination, followed by Sof-Lex Spiral Wheels and Sof-Lex XT polishing discs. These systems did not differ significantly from each other, but did produce significant smoother surfaces than Enhance, Intensiv UniglossCellbrush and Dura-White stone.

For this study the null hypothesis is rejected and the alternative hypothesis is accepted. Filtek Supreme XTE had statistically significant better polishability than Z100. The different polishing systems gave different surface roughness values when used on each composite, ie, there were statistically significant differences between the different polishing systems.

Regarding polishability the author would recommend the use of a Filtek Supreme XTE above Z100 due to better polishability.

The author would further recommend the use of Sof-Lex Spiral Wheels or Sof-Lex XT finishing and polishing discs, above the use of Dura-White stone, Enhance in combination with Prisma Gloss polishing paste, and Intensiv UniglossCellbrushes for the polishing of Z100 and Filtek Supreme XTE restorations.

CHAPTER 7: References

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ETHICAL CLEARANCE

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.
- FWA 00002567, Approved dd 22 May 2002 and Expires 20 Oct 2016.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 22/04/2017.

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Faculty of Health Sciences Research Ethics Committee

26/06/2014

Approval Certificate
New Application

Ethics Reference No.: 197/2014

Title: The effect of different polishing systems on the surface roughness of a nanocomposite and a microhybrid composite.

Dear Dr Dorette Kritzinger

The **New Application** as supported by documents specified in your cover letter for your research received on the 30/05/2014, was approved, by the Faculty of Health Sciences Research Ethics Committee on the 25/06/2014.

Please note the following about your ethics approval:
- Ethics Approval is valid for 2 years
- Please remember to use your protocol number (**197/2014**) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, or monitor the conduct of your research.

Ethics approval is subject to the following:
- The ethics approval is conditional on the receipt of 6 monthly written Progress Reports, and
- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Dr R Sommers; MBChB; MMed (Int); MPharMed.
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

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