

Surface Roughness of Tooth Coloured Restorative Materials

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Mohd Shahminan Ibrahim¹, Yap Kai Wen¹, Maria Angela Garcia Gonzalez², Noor Azlin Yahya^{2*}

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KEYWORDS

Tooth-coloured restorative, Surface roughness, Polishing, Profilometry, Thermocycling, Bulk-fill restorative

ABSTRACT

This study compared the surface roughness of selected tooth coloured restorative materials that were polished according to manufacturers' instructions and Sof-Lex. It also assessed the surface roughness of polished materials after thermocycling. Filtek Z350XT, Beautifil-Bulk Restorative and Cention N, were used in this study. A stainless steel mould (10mm diameter x 2mm height) was used to fabricate 75 cylindrical specimens: 15 Filtek Z350XT (FZ), 30 Beautifil-Bulk Restorative (BB) and 30 Cention N (CN). All 15 FZ specimens were polished with Sof-Lex. Fifteen BB and CN specimens were polished according to manufacturers' instructions. The remaining fifteen BB and CN specimens were polished using Sof-Lex. All the specimens were subjected to thermocycling (1000 cycles). Surface roughness was assessed quantitatively with profilometry after specimen preparation (Mylar stage), polishing and thermocycling. Data were analysed using SPSS version 25.0 at $\alpha=0.05$. When polished according to manufacturers' instructions, BB had the lowest mean surface roughness (Ra) values ($0.13\pm 0.01\mu\text{m}$) followed sequentially by CN ($0.14\pm 0.03\mu\text{m}$) and FZ ($0.15\pm 0.02\mu\text{m}$). The differences were not statistically significant. When polished with Sof-Lex, BB exhibited the smoothest surface ($0.116\pm 0.03\mu\text{m}$) followed sequentially by and FZ ($0.150\pm 0.02\mu\text{m}$) and CN ($0.157\pm 0.02\mu\text{m}$). Thermocycling caused an increase in the Ra. The differences were statistically significant. All materials tested had Ra values below the threshold value of $0.2\mu\text{m}$ at Mylar stage and after polishing with their recommended polishing system and Sof-Lex. Thermocycling produced rougher surfaces that did not exceed the threshold Ra value. Polishability was material dependent.

INTRODUCTION

Polishing a restoration involves smoothing the surface with a series of abrasives to create the lowest surface roughness and a high surface lustre or polish. The advantages of finishing and polishing include minimising plaque accumulation at margins and on surfaces of restorations, minimising the risk of surface staining, surface degradation or wear and maximising the aesthetics of the restoration.

A rough restoration surface accumulates plaque. This is true for all restorative materials. Rough restoration surfaces near the gingiva are usually associated with inflamed bleeding gingiva, and increased crevicular fluid production. Rough surfaces will easily trap debris and make removal difficult even with toothbrushing. As the debris is retained, the restoration tends to take up the colour of the staining agent which may be removed or, in a worst-case scenario, become permanent. This obviously affects the aesthetic value of the restoration and defeats the main purpose of having a tooth coloured aesthetic restoration [1].

There are several tooth-coloured restorative materials which include composite resin, glass ionomer cement, giomer and alkasite. Nanofilled

¹Faculty of Dentistry, University of Malaya, Kuala Lumpur, Malaysia.

²Department of Restorative Dentistry, Faculty of Dentistry, University of Malaya, Kuala Lumpur, Malaysia.

*Correspondence: nazlin@um.edu.my

composites use nanosized particles throughout the resin matrix whereas nanohybrid is a combination of nanomeric and conventional fillers to maximise durability and polishability [2]. There are studies which state that Filtek Z350XT produce the smoothest surface finish in relation to filler particle size [3,4]. The term "Giomer" refers to any product containing Shofu's proprietary Surface Pre-Reacted Glass, or "S-PRG" filler particles. S-PRG filler uniquely releases six ions: Fluoride, Sodium, Strontium, Aluminum, Silicate, and Borate. S-PRG filler has been shown to inhibit plaque formation and possess remarkable acid neutralization capabilities. There are numerous studies used to evaluate the clinical performance or clinical longevity as well as biological properties of composite resin. In comparison, available studies on surface finish of giomer are relatively limited. An alkasite is essentially a subgroup of the composite material class. It utilizes an alkaline filler which is a calcium fluorosilicate glass [5]. It is capable of releasing acid-neutralizing ions. Parth et al concluded that Cention N is equally good in gross fracture and marginal integrity as nanohybrid composite but exhibit poorer surface characteristics [6]. Cention N was introduced as

- 1) To compare surface roughness of Filtek Z350XT, Beautifil-Bulk Restorative and Cention N polished according to manufacturers' recommendation.
- 2) To compare surface roughness of Filtek Z350XT, Beautifil-Bulk Restorative and Cention N polished with Sof-Lex
- 3) To investigate the effect of thermocycling on the surface roughness of polished Filtek Z350XT, Beautifil-Bulk Restorative and Cention N

the alternative to amalgam and, as a new material, studies on its surface roughness are limited.

Once a restorative material is exposed to the oral environment for a period of time, degradation in the aesthetic value due to staining, plaque accumulation, gingival irritation, recurrent decay, discoloration is unavoidable. There are in vitro studies which support the idea that the formation of plaque and bacterial adhesion on intraoral hard surface, such as a restoration, is greatly affected by its surface roughness. The threshold value of surface roughness suggested by a study on bacterial adhesion is $0.2\mu\text{m}$ [7, 8]. Aykent et al concluded that there is positive correlation between surface roughness and vital *S. mutans* adhesion [9]. After polishing, a restoration is expected to exhibit low surface roughness value (Ra). However, studies looking at whether surface smoothness can be maintained after days, months and years are limited. One of the most used ageing test protocol for dental materials is thermocycling. Thermocycling is more effective than other methods for simulation of aging of composite resins and creates more challenging conditions for composite resin restorations [10]. Hence the objectives of this study were:

MATERIALS AND METHODS

Materials selected for this study included Filtek Z350XT (FZ), Beautifil-Bulk Restorative (BB) and Cention N (CN). Details of the materials and their technical profiles are shown in Table 1.

Table 1: Technical profile and manufacturers of the materials evaluated

Material	Manufacturer	Type & method of curing	Resin	Filler	Filler content
Filtek Z350XT (FZ)	3M ESPE, St Paul, MN, USA	Nano-hybrid composite (Light cured)	Bis-GMA Bis-EMA UDMA	Non aggregated 20nm Silica filler, non aggregated 4-11nm zirconia filler and aggregated silica/zirconia cluster filler	78.5/59.5
Beautiful-Bulk Restorative (BB)	Shofu, Kyoto, Japan	Giomer (Light cured)	Bis-GMA UDMA Bis-MPEPP TEGDMA	S-PRG filler based on fluoroboroaluminosilicate glass and nano filler(10-20nm)	83.3/69
Cention N (bulk fill) (CN)	Ivoclar, Vivadent Inc., NY, USA	Alkasite (Self curing powder/ liquid with optional additional light curing)	UDMA DCP Aromatic aliphatic-UDMA PEG-400 DMA	Br-Al-Si glass filler, ytterbium trifluoride, and Isofiller(copolymer), a calcium barium aluminium fluorosilicate glass filler and a calcium fluorosilicate (alkaline) glass filler (0.1–35 µm)	75/61

Specimen Preparation

Fifteen FZ, 30 BB and 30 CN cylindrical specimens were fabricated using a stainless steel mould (10mm diameter x 2mm height) covered with a 10mm wide Mylar Strip which was pressed against a 1mm thick glass slide to extrude the excess with constant finger pressure. The specimens were light cured for 20 seconds at the top and bottom surfaces with light curing unit (LCU), (Bluephase N, Ivoclar Vivadent, Schaan, Liechtenstein, high power, wavelength of 1200mW/cm²). Five experimental groups with 15 specimens were formed based on the materials to be tested and polishing system (Table 2) to be used. They were named as Filtek (FZS), Beautiful Manufacturer (BBM), Beautiful Sof-Lex (BBS), Cention N Manufacturer (CNM) and Cention N Sof-Lex (CNS). All specimens were stored dry at room temperature (200C - 250C) when not in use.

Table 2: Polishing system used in this study.

Polishing system	Manufacturer	Type of abrasive
Sof-Lex disc	3M ESPE, St Paul, MN, USA	Aluminum oxide
One Gloss	Shofu, Kyoto, Japan	Silicone polishers impregnated with alumina
Optrapol	Ivoclar, Vivadent Inc., NY, USA	Silicone polishers with micro-fine diamond crystallites

Ra Measurement

Mean surface roughness (Ra) for each specimen was measured with optical profilometry (ALICONA, Infinite Focus Real 3D, Belgium). Ra measurements were made at 20X magnification on five randomly selected polished surface sites. Three readings were taken from each site. The mean Ra for each specimen were tabulated for statistical analysis. After the first Ra measurement, specimens were stored dry at room temperature (20°C - 25°C).

Polishing Procedure

Specimens were polished within 24 hours after the first measurement. Fifteen FZ, 15 BB and 15 CN specimens were polished using Sof-Lex disc (3M ESPE) starting from course, medium, fine and superfine. Polishing was performed for 20s, using circular movement in a clockwise direction for each disc in dry condition. Specimens were rinsed and dried after each disc sequence. Fifteen BM specimens were polished with One Gloss (Shofu). Polishing was performed for 40 seconds using repetitive strokes in an outward direction on each specimen with intermittent water spray. Fifteen CM specimens were polished using Optrapol (Ivoclar Vivadent). Polishing was performed for 40 seconds using the same strokes as in BM specimens. All polished specimens were stored dry in an incubator (Mettler Incubator IN750, Germany) at 80% relative humidity at 37°C overnight. Mean surface roughness (Ra) for each specimen was remeasured and the mean Ra for each specimen were tabulated for statistical analysis. Measured specimens were stored dry in the incubator overnight and thermocycled the next day.

Thermocycling

Thermocycling was performed within two days between 50C and 550C for 500 cycles in one day

using an automated thermocyclic dipping machine (Zectron, Kuala Lumpur, Malaysia). The dwell time and transfer time were 20 seconds and two seconds, respectively. All specimens were stored dry in the incubator before continuing with the next 500 cycles of thermocycling the next day for a total of 1000 cycles. Mean Ra of each thermocycled specimen was remeasured within two days after completing the thermocycling.

Data Management or Statistical Analysis

Data were analysed using SPSS software (IBM SPSS Statistics for Windows, Version 25.0) The data was tabulated and evaluated to check if data was normally distributed by plotting histograms. Data was found to be normally distributed. Mean Ra values of different materials at each stage was analysed using one-way analysis of variance (ANOVA) followed by post-hoc Tukey's Honest Significant Difference (Tukey's HSD) test. Mean Ra values for each material at different stages were analysed using Repeated Measure ANOVA. All statistical testing was performed at $\alpha = 0.05$. The methodology flowchart is presented in Figure 1.

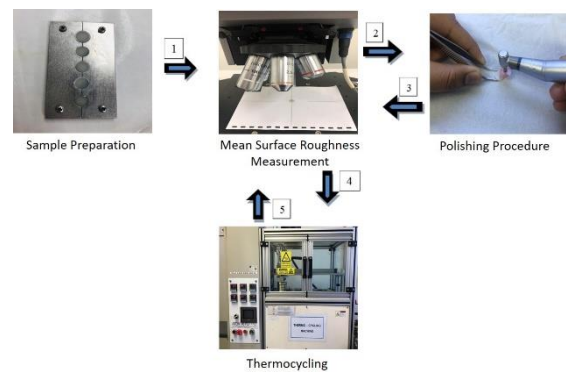


Figure 1: Flowchart of methodology for surface roughness measurement at various stages

RESULTS

The mean Ra value and standard deviation (SD) for each material at the Mylar, polished and thermocycled stages are presented in Table 3. Figure 2 displays the surface roughness of tooth coloured restorative materials polished according to manufacturers' instruction. Figure 3 portrays surface roughness of tooth-coloured restorative materials polished with Sof-Lex disc.

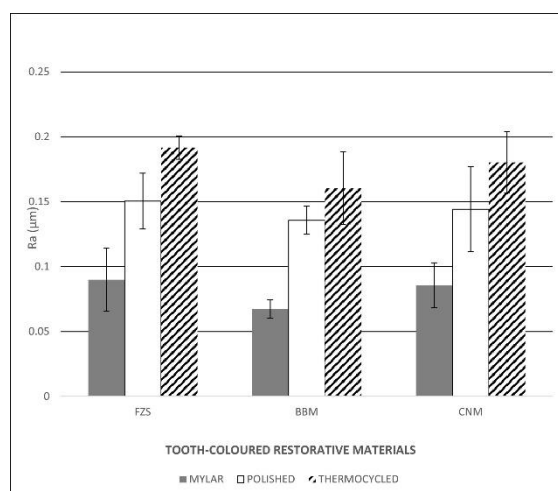


Figure 2: Surface roughness of Filtek Z350XT, Beautifil-Bulk Restorative and Cention N polished according to manufacturers' recommendation.

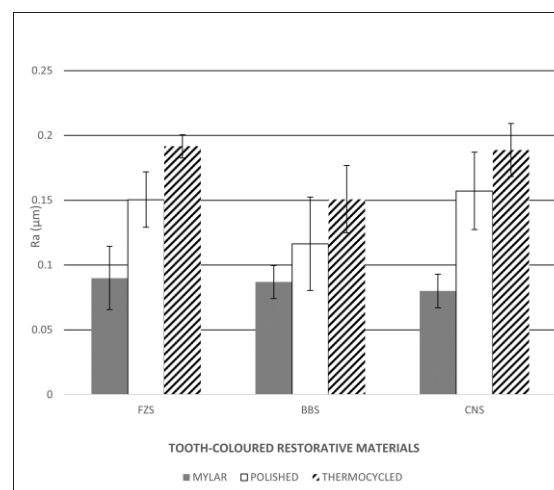


Figure 3: Surface roughness of FZ, BB and CN polished with Sof-Lex disc

Table 3: Mean Ra value (μm) and standard deviation for each material at different stages.

Materials	Mylar Strip		After Polished		After Thermocycling	
	Mean(μm)	SD	Mean(μm)	SD	Mean(μm)	SD
FZS	0.0900 ^a	0.0243	0.1505 ^a	0.0214	0.1916 ^{a,b}	0.0090
BBM	0.0673 ^{a,b}	0.0072	0.1357	0.0106	0.1603	0.0279
BBS	0.0869	0.0128	0.1164 ^{a,b}	0.0360	0.1508 ^{a,c}	0.0259
CNM	0.0857 ^b	0.0173	0.1441	0.0326	0.1803	0.0235
CNS	0.0800	0.0130	0.1572 ^b	0.0298	0.1887 ^{b,c}	0.0205

* The superscripts indicates statistical significance (p<0.05)

BBM exhibited the lowest surface roughness value of 0.0673 ± 0.0072μm at Mylar stage (Figure 2). There was a significant difference (p<0.05) between BBM and FZS as well as between BBM and CNM. After polishing, the lowest Ra could be seen in BBM at 0.1357 ± 0.0106μm. There was no significant difference in surface roughness between the three polished materials. After thermocycling, FZS had the highest Ra followed by CNM and BBM with a significant difference (p<0.05) detected between FZS and the other two materials. When all three materials are analyzed individually using repeated measures ANOVA, they

all showed an increase in surface roughness with significant differences (p<0.05) at every stage from placement with Mylar strip to after thermocycling.

At Mylar stage, CNS exhibited the lowest surface roughness value of 0.0800 ± 0.0130μm (Figure 3). However, there was no significant difference (p<0.05) between the three materials at this stage. After polishing, BBS had the lowest Ra value, followed by FZS and then CNS with a significant difference noted between BBS and the other two materials. After thermocycling, BBS still had the smoothest surface among the three materials with

Ra value of $0.1508 \pm 0.0259\mu\text{m}$. At this stage, there was a significant difference ($p < 0.05$) between FZS and BBS, FZS and CNS, as well as BBS and CNS. There was a difference in surface roughness between BBM and BBS as well as between CNM and CNS. However, the differences were not statistically significant. All Ra values were below $0.2\mu\text{m}$.

DISCUSSION

Tooth-coloured restorative materials were used in this study because of increase in demand for aesthetic direct posterior restorations in dental practice. Each of the materials used were of different composition. These were nano-hybrid composite, giomer and alkasite. Nano-hybrid composite such as Filtek Z350 XT are known for their good polishability characteristic in relation to their filler size. Giomer Beautifil-Bulk Restorative was introduced by Shofu and has S-PRG filler particles. Alkasite was introduced by Ivoclar as an amalgam replacement and has the capability of releasing acid-neutralizing ions. However, limited studies have been performed to compare the surface roughness of these three types of materials.

Proper finishing and polishing of the restoration is of utmost importance not only for patient comfort, satisfaction but also to ensure a longer-lasting restoration. This is because the surface texture or roughness plays an essential role in preventing plaque deposition, secondary caries, discolouration, wear as well as maintaining aesthetic value of a restoration [11]. Surface roughness is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. The larger the deviations, the rougher the surface. In this study, the more common parameter, arithmetical mean roughness (Ra) is used. Previous studies have shown that placing a clear cellulose matrix (Mylar strip) on the top most increment restorations can produce the smoothest surface at the same time preventing oxygen inhibited layer. Nevertheless, to reduce clinical wear and achieve a more resistant and stable surface, finishing and polishing has to be carried out in order to remove the resin rich layer and also restore appropriate anatomical morphology or contour that is rarely achieved using only Mylar strip [12,13]. This is because the organic matrix rich layer is relatively unstable. In our study, the quantitative evaluation of the surface roughness was performed using optical (non contact) profilometry and the results revealed that the Ra value of the restorative

materials cured against Mylar strip gave the lowest value of Ra irrespective of the type of material.

Bacterial plaque retention is closely related to surface roughness. One of the studies shows that a rougher composite surface exerted stronger bacterial adhesion forces, regardless of composite type or bacterial strain [14]. The threshold value of surface roughness suggested by a study on bacterial adhesion is at $0.2\mu\text{m}$. It is stated that plaque accumulation will increase simultaneously with the increase of surface roughness beyond the threshold [15]. From our study, all three tooth coloured restorative materials exhibited acceptable surface roughness at different stages at the Ra threshold value of $0.2\mu\text{m}$, below which no further reduction in bacterial accumulation could be expected.

The factors which contribute to the surface roughness of a surface could vary from intrinsic factors or a combination of both [8]. It can be dependent on resin composition, particularly the filler particle type, geometry, hardness, shape as well as size and type of polishing system used [14,16]. Besides, the examples of extrinsic factors could be the type of polishing system used, such as the hardness of the polishers as well as operator related factor. In the present study, Ra values for BB is the lowest at Mylar and polished based on manufacturer's instructions stages compared to FZ and CN at the stages but there is no statistically significant difference. Smaller size filler particles can be adhered to resin matrix, thus providing a smoother surface finish [17]. In comparison, BB has a smaller filler particle size than FZ and CN which may contribute to its relatively smooth surface. At the polished stage, even though there are statistically significant differences in Ra among the three groups, all values were below the $0.2\mu\text{m}$ threshold value. This was also true for the three groups of materials polished with Sof-Lex, where there are significant differences between BBS with FZS and CNS but values are below the bacterial adhesion threshold.

There are a number of studies where Sof-Lex polishing disc gave the best surface polish compared to other polishing systems. For instance, Rashmi et al claimed that Sof-Lex group produced smoother surface compared to Astrobrush, and diamond polishers. The ability of Sof-Lex to give better surface finish may be attributed to the presence of aluminum oxide that has higher hardness than most filler particles in composite resin that promotes homogenous abrasion [18]. In

the present study, there is a difference in the Ra when using Sof-Lex on BBS and CNS. For BBS, the results show lower value of roughness as compared to those polished following the recommended polisher, One Gloss. This finding is in accordance to previous studies that claimed multistep polishing system performed better than single step [19]. However, in polishing CN, the manufacturer recommended polishing system, Optrapol achieved lower Ra than Sof-Lex. The high diamond particle content of over 70% by wt present in Optrapol may be the reason for this. This is in agreement with statement of Kumari et al that the hardness of the diamond particles enables it to remove the resin matrix and filler particles homogeneously [20].

The most commonly used artificial ageing technique is long-term water storage. Another widely used ageing technique is thermocycling. The combination of coffee and ice cream sets the parameters for one of the most used test protocols for dental materials. Thermocycling is performed aiming to simulate thermal changes in the oral cavity where test specimens are held repeatedly first in 5 °C cold water and then in 55 °C hot water for a large number of cycles.

A thermocycling regimen comprising 500 cycles in water between 5 and 55°C is prescribed by The International Organization for Standardization (ISO) TR 11450 standard (1994) as an appropriate artificial ageing test, and many studies have been carried out following the ISO standard [21]. Therefore, in this study, all of the specimens were subjected to thermal ageing for 1000 cycles to simulate the thermal changes in the oral cavity. Gale and Darvell proposed that 10,000 cycles might represent approximately one year of in vivo functioning, with 20 to 50 cycles considered equivalent to a single day. However, the temperature sequence in their study was 35°C, 15°C, 35°C and then 45°C. If we were to follow their guideline, 1000 cycles would be equivalent to approximately one month [22].

After 1000 cycles of thermocycling, all of the materials in this study showed a significant change in surface roughness. The reason behind this is that thermal cycling is known to produce internal tensions in the resin structure due to differences in the linear thermal expansion coefficient of the organic matrix and filler components which eventually cause degradation and possible surface microcracks [23]. This means that within a month, the tested materials may already exhibit surface roughness changes. The larger Ra values, however,

were still below the threshold value (0.2µm) for bacterial retention.

Having said that, materials may be thermocycled using increasing number of cycles to determine the number of cycles needed to increase the Ra values above 0.2µm. From there we can estimate the approximate age of the restoration when repolishing is needed. This is very important as surface roughness of restorative materials has been recognized as a parameter of high clinical relevance for not only plaque accumulation, but also staining susceptibility, and wear [24].

Limitations and Recommendations

Filtek Z350XT, a nanohybrid used as the positive control, is not a bulk-fill material but is acknowledged to produce highly polished surface. It is recommended that other bulk-fill material should be used to compare surface polish and identify the bulk-fill materials that produce high polish.

The specimens were stored dry as it was the material polishability that was being studied independent of the external conditions. Future studies may include storage in different media to determine the effect of these on the bulk-fill composite resin tested. Thermocycling simulates aging by subjecting materials to extreme temperatures, restorations in the clinical condition are exposed to the detrimental effects of food, beverages, saliva components, and to the mechanical action of chewing and brushing. Therefore, these aspects should be considered in future investigations [25].

CONCLUSION

Within the limitation of this study, following conclusions can be made:

1. There was no significant difference in surface roughness between Filtek Z350XT, Beautifil-Bulk Restorative and Cention N polished according to manufacturers' instruction.
2. There was a significant difference in surface roughness between Beautifil-Bulk Restorative and the other two materials when polished with Sof-Lex.
3. There was a significant difference in the surface roughness of Filtek Z350XT, Beautifil-Bulk Restorative and Cention N pre and post thermocycling.

4. All polished and aged tooth-coloured restorative materials showed surface roughness below threshold value for bacterial adhesion.

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DECLARATION OF INTEREST

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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