Research article

ISSN 2234-7658 (print) / ISSN 2234-7666 (online)
https://doi.org/10.5395/rde.2017.42.2.118

RDE
Restorative Dentistry & Endodontics

Color stability of bulk-fill and incremental-fill resin-based composites polished with aluminum-oxide impregnated disks

Uzay Koc-Vural[1], Ismail Baltacioglu[2], Pinar Altinci[3]*

[1]Department of Restorative Dentistry, Faculty of Dentistry, Hacettepe University, Ankara, Turkey
[2]Department of Restorative Dentistry, Faculty of Dentistry, Ankara University, Ankara, Turkey
[3]Department of Restorative Dentistry and Cariology, Institute of Dentistry, University of Turku, Finland

Objectives: This study aimed to evaluate the color stability of bulk-fill and nanohybrid resin-based composites polished with 3 different, multistep, aluminum-oxide impregnated finishing and polishing disks. ***Materials and Methods:*** Disk-shaped specimens (8 mm in diameter and 4 mm in thickness) were light-cured between two glass slabs using one nanohybid bulk-fill (Tetric EvoCeram, Ivoclar Vivadent), one micro-hybrid bulk-fill (Quixfil, Dentsply), and two nanohybrid incremental-fill (Filtek Ultimate, 3M ESPE; Herculite XRV Ultra, Kerr) resin-based composites, and aged by thermocycling (between 5 - 55°C, 3,000 cycles). Then, they were divided into subgroups according to the polishing procedure as SwissFlex (Coltène/Whaledent), Optidisc (Kerr), and Praxis TDV (TDV Dental) (n = 12 per subgroup). One surface of each specimen was left unpolished. All specimens were immersed in coffee solution at 37°C. The color differences (ΔE) were measured after 1 and 7 days of storage using a colorimeter based on CIE Lab system. The data were analyzed by univariate ANOVA, Mann-Whitney U test, and Friedmann tests (α = 0.05). ***Results:*** Univariate ANOVA detected significant interactions between polishing procedure and composite resin and polishing procedure and storage time ($p < 0.05$). Significant color changes were detected after 1 day storage in coffee solution ($p < 0.05$), except Quixfil/Optidisc which was color-stable after 7 days ($p > 0.05$). Polishing reduced the discoloration resistance of Tetric EvoCeram/SwissFlex, Tetric EvoCeram/Praxis TDV, Quixfil-SwissFlex, and all Herculite XRV Ultra groups after 7 days storage ($p < 0.05$). ***Conclusions:*** Discoloration resistance of bulk-fill resin-based composites can be significantly affected by the polishing procedures. (*Restor Dent Endod* 2017;42(2):118-124)

Key words: Bulk-fill resin-based composite; Color measurement; Discoloration; Polishing

Received November 8, 2016;
Accepted January 14, 2017

Koc-Vural U, Baltacioglu I, Altinci P

***Correspondence to**
Pinar Altinci, DDS.
Doctoral Candidate, Department of Restorative Dentistry and Cariology, Institute of Dentistry, University of Turku, Lemminkaisenkatu 2, 20520, Turku, Finland
TEL, +358-46-6391763; Fax, +358-2-3338390; E-mail, paltinci@hotmail.com

Introduction

Bulk-fill resin-based composites (BRBCs) with flowable and high-viscosity types have currently gained popularity due to the easiness in their application technique. Unlike to the conventional resin-based composites that are placed by layering with maximum 2 mm in thickness, BRBCs can be inserted with 4 mm single layer.[1-5] These composites contain similar monomers and particle/filler compositions with conventional nanohybrid resins, except the polymerization modulators and plasticizers that are incorporated to modulate polymerization kinetics.[6] In addition, the rate of filler content has been reduced in BRBCs to facilitate deeper light transmission while particle sizes have been increased to improve the mechanical strength. Recent studies have mostly focused on the polymerization-related properties of BRBCs including light transmission, depth of cure, degree of monomer conversion, shrinkage stress as well as microhardness and cytotoxicity of uncured monomers.[1-7] Except flowable ones that require an additional top layering with a conventional hybrid composite, the surface hardness and wear resistance of high-viscosity BRBCs was reported to be good enough to withstand occlusal forces.[1] However, the esthetic properties of BRBCs have not been well-documented yet.[5]

A successful direct composite resin restoration should not only demonstrate high strength and durability, but also should be esthetically pleasing. However, the color changes of direct composite resin restorations in time can still be a problem despite the advances in resin monomer and filler particle technology. Superficial discolorations due to the accumulation of colorants from food and drinks can be removed by refurbishing and polishing while, in severe cases, the repair or even the renewal of existing restoration can be inevitable.[8] The color stability of composite resins can be related with the material properties, *i.e.* composite matrix, filler composition, matrix-filler interface, and degree of polymerization, and with the restorative techniques including the finishing and polishing procedures.[8-11]

It is known that composite resins show a smooth and glossy surface when light-polymerized over a translucent mylar strip.[12,13] However, this resin-rich, superficial layer should be removed to enhance abrasion resistance, and most direct composite resin restorations also require marginal and occlusal adjustments.[8,14] The selected finishing and polishing technique may alter the restoration's resistance to staining, plaque accumulation, and wear, thereby can significantly affect the esthetic outcome and clinical longevity.[15-17] Current polishing methods includes the use of finishing burs and instruments followed by polishing disks, wheels, and cups coated with abrasives such as aluminum oxide, silicon carbide, diamonds, or a combination of these particles.[8] Aluminum-oxide particle-impregnated disks can be regarded as the standard tools in the polishing procedures of direct composite resin restorations, providing the maximum smooth surface by abrading the resin matrix and filler particles uniformly.[18,19] Hence, this study investigated the discoloration resistance of two different bulk-fill and two incremental-fill resin composites polished with different aluminum-oxide impregnated disks. The null hypothesis tested was that the discoloration resistance of bulk-fill nanohybrid composite resins would not be affected from the applied finishing and polishing procedures based on the use of aluminum-oxide particle-impregnated disks.

Materials and Methods

Resin-based composites used in the study are shown in Table 1. Disk-shaped specimens (8 mm in diameter and 4 mm in thickness) were prepared from two different bulk-fill (Tetric EvoCeram, Ivoclar Vivadent AG, Schaan, Liechtenstein; Quixfil, Dentsply DeTrey GmbH, Konstanz,

Table 1. The resin-based composites used in the study

Composite resin	Product	Manufacturer	Shade	Resin composition	Filler particle amount
Bulk-fill, Nanohybrid	Tetric EvoCeram	Ivoclar Vivadent, Schaan, Liechtenstein	IVA	Bis-EMA, UDMA, bis-EMA	81%, Barium glass, YbF3, mixed oxide, PPF, 0.04 - 3 µm in size
Bulk-fill, Micro-hybrid/hybrid	Quixfil	Dentsply DeTrey, Konstanz, Germany	Universal	Bis-EMA, UDMA, TEGDMA, di- and trimethacrylate resins, carboxylic acid modified dimethacrylate resin	86%, Strontium aluminum sodium fluoride phosphate silicate glass, 1 - 10 µm in size
Incremental-fill, Nanohybrid	Filtek Ultimate	3M ESPE, Seefeld, Germany	A2Dentin	Bis-GMA, UDMA, TEGDMA, bis-EMA and PEGDMA resins	72.5%, Silica, zirconia and aggregated zirconia/silica cluster fillers, 0.6 - 10 µm in size
Incremental-fill, Nanohybrid	Herculite XRV Ultra	Kerr, Orange, CA, USA	A2Dentin	Bis-GMA, TEGDMA and bis-EMA	71%, PPF, barium glass, silica nanofiller

Bis-EMA, Bisphenol-A polyethylene glycol diether dimethacrylate; Bis-GMA, Bisphenol-A diglycidyl ether dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate.

Germany) and two incremental-fill (Filtek Ultimate, 3M ESPE, Seefeld, Germany; Herculite XRV Ultra, Kerr, Orange, CA, USA) composite resins in teflon molds. The upper and bottom surfaces of the mold were covered by mylar strips and glass slabs during polymerization to produce a smooth surface, thereby preventing oxygen inhibition layer. The specimens were polymerized using a light-emitting diode curing unit (Cromalux LED 1200, Mega-Physik GmbH & Co., Rastatt, Germany, 1,200 mW/cm^2) from both directions for 20 seconds each. After stored in distilled water at 37°C for 24 hours, one surface of each specimen was firstly grinded with 600 grit SiC paper. Afterwards, the same surface was polished with one of the polishing procedures including Optidisc (Kerr), SwissFlex (Coltène/Whaledent AG, Altstätten, Switzerland) and Praxis TDV (TDV Dental Ltda., Pomerode, SC, Brazil) from coarse-grain size to fine-grain size according to the manufacturers' instructions (Table 2, $n = 12$ per group). Then, the specimens were undertaken to thermocycling for 3,000 cycles between 5 and 55°C with 60 seconds dwell time.

Coffee solution used as colorant was prepared by mixing 15 g of instant coffee powder without cream and sugar (Nescafé Classic, Nestlé, Vevey, Switzerland) and 200 mL hot distilled water in accordance with the recommendations of the coffee manufacturer. After being cooled to room temperature, the specimens were immersed in this solution while paying attention to avoid specimen-specimen contact in light-proof, stainless steel containers. For this purpose, each group was placed in a completely permeable holder keeping the specimens in vertical position. The solution was refreshed daily up to 7 days.

Color values (L*, a*, b*) were measured before thermocycling as baseline and after thermocycling, 1 day, and 7 days of storage using a colorimeter (Minolta CR-321, Konica Minolta, Tokyo, Japan). Before each measurement, the colorimeter was calibrated by using the supplied white calibration standard, and all specimens were removed from the storage solutions and rinsed in distilled water. Excess water on the surface was removed with air spraying. Three readings were done for each specimen, and the mean values of the L*, a*, and b* data were calculated. The color differences (ΔE) in the 3 dimensional L*, a*, b* color space were calculated after thermocycling, 1 day, and 7 days of storage compared to the baseline color with the formula of $\Delta E = ([\Delta L^*]^2 + [\Delta a^*]^2 + [\Delta b^*]^2)^{1/2}$, where $\Delta L^* = L^*_1 - L^*_0$, $\Delta a^* = a^*_1 - a^*_0$, $\Delta b^* = b^*_1 - b^*_0$. In the calculations, 0 represented the baseline reading while 1 is the value read after thermocycling, 1 day, or 7 days of discoloration.

Statistical analysis

The data were analyzed with Univariate ANOVA to detect the interactions between the variables of composite resin, polishing procedure, and storage time. Mann-Whitney U test was used to compare the color differences between the polished and unpolished surfaces at each time-point, and to compare the discoloration values of different polishing procedures after 7 days of storage since the data were not normally distributed. Friedmann tests were applied for the pairwise comparisons of the color differences within the same composite resin groups after thermocycling, 1 day, and 7 days of storage. All statistical tests were performed using SPSS 22.0 (SPSS for Windows, SPSS Inc., Chicago, IL, USA) at $\alpha = 0.05$.

Result

The mean (± standard deviation) color differences (ΔE) of the tested bulk-fill and incremental-fill resin-based composites are shown in Figures 1 and 2, respectively. Univariate ANOVA detected significant interactions between polishing procedure and resin composite and polishing procedure and storage time ($p < 0.05$) while no interaction was found between resin composite and storage time.

Thermocycling caused slight discoloration in all groups, which were not significantly different from the baseline. After 1 day storage, the discoloration significantly

Table 2. Tested polishing kits containing aluminum-oxide impregnated disks

Polishing kit	Manufacturer	Content
Optidisc	Kerr, Orange, CA, USA	Translucent polyester disks impregnated with aluminum-oxide particles with the grit sizes from extra coarse to extra fine.
SwissFlex	Coltène/Whaledent AG, Altstätten, Switzerland	Thin, transparent disks that are selectively coated with aluminum oxide particles. The coarse disc is completely coated on the upper side with black silicon particles.
Praxis TDV	TDV Dental Ltda., Pomerode, Brazil	Polishing disks made of aluminum-oxide, polyethylene terephthalate, synthetic rubber resin, metal eyelet, and water-based pigments.

https://doi.org/10.5395/rde.2017.42.2.118

increased ($p < 0.05$), except Quixfil-Optidisc group which was also color-stable after 7 days storage as well.

When compared with the respective unpolished surfaces, polishing significantly reduced the discoloration resistance of the Tetric EvoCeram-SwissFlex, Tetric EvoCeram-Praxis TDV, Quixfil-SwissFlex, and all Herculite XRV Ultra groups after 7 days ($p < 0.05$). On the other hand, there was no significant difference between the ΔE values of polished and unpolished surfaces of Quixfil-Optidisc and Quixfil-Praxis TDV groups. Regardless of the used polishing tool, Filtek subgroups showed similar discoloration levels compared to the respective unpolished surfaces.

Discussion

Discoloration of resin composites can be seen due to the influence of the external or internal factors. While surface irregularities can cause the retention of bacterial plaque or superficial stains, subsurface or internal color changes may occur because of the physiochemical characteristics of the resin structure including polymerization initiators, accelerators, the stability of resin-filler interface as well as the conversion rate and water sorption of polymerized resin matrix.[9] It has been previously demonstrated that finishing and polishing procedures can be a significant determinant

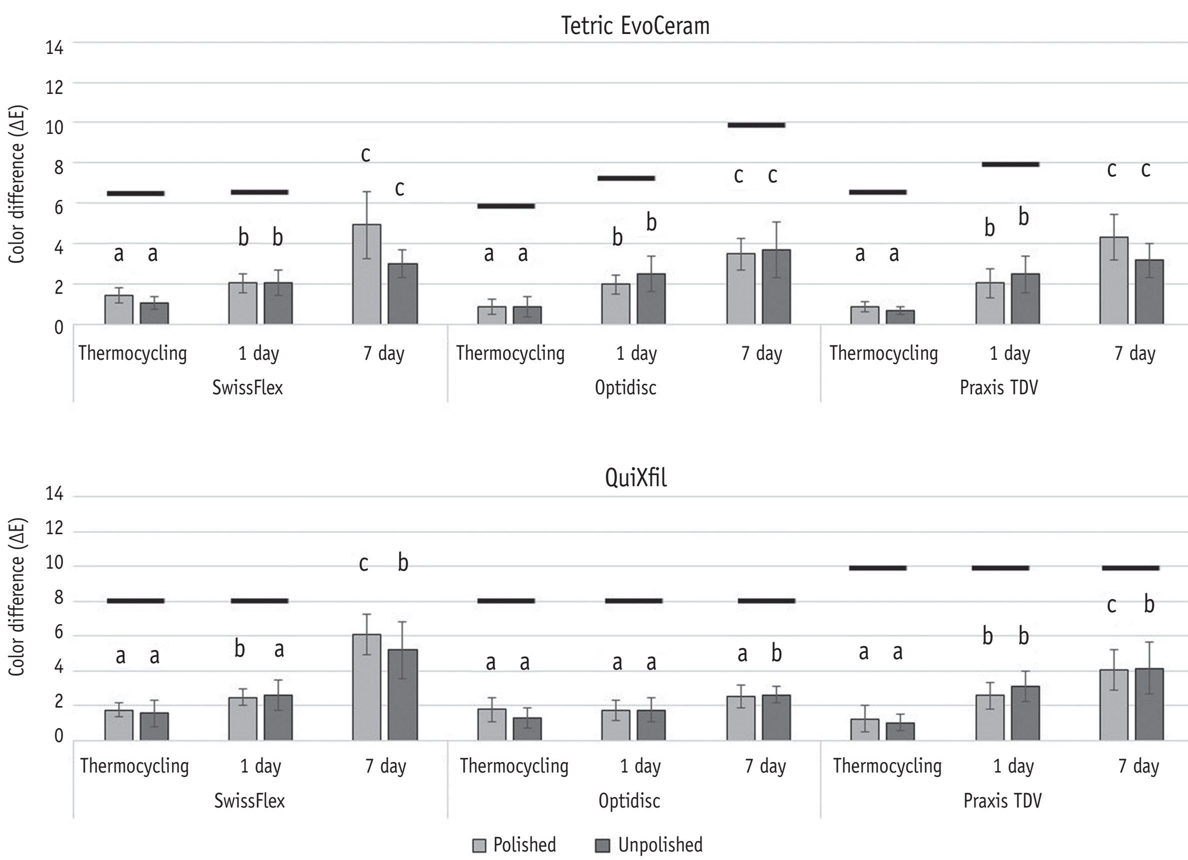

Figure 1. Bar charts comparing the mean color differences (ΔE) with standard deviations of Tetric EvoCeram (nanohybid bulk-fill resin composite) and Quixfil (micro-hybrid bulk-fill resin composite) after thermocycling and storage in coffee solution for 1 and 7 days. For the same polishing procedure and resin composite, the groups with the same lower case letters are not statistically different. The polished and unpolished groups connected by a solid bar are not statistically significant.

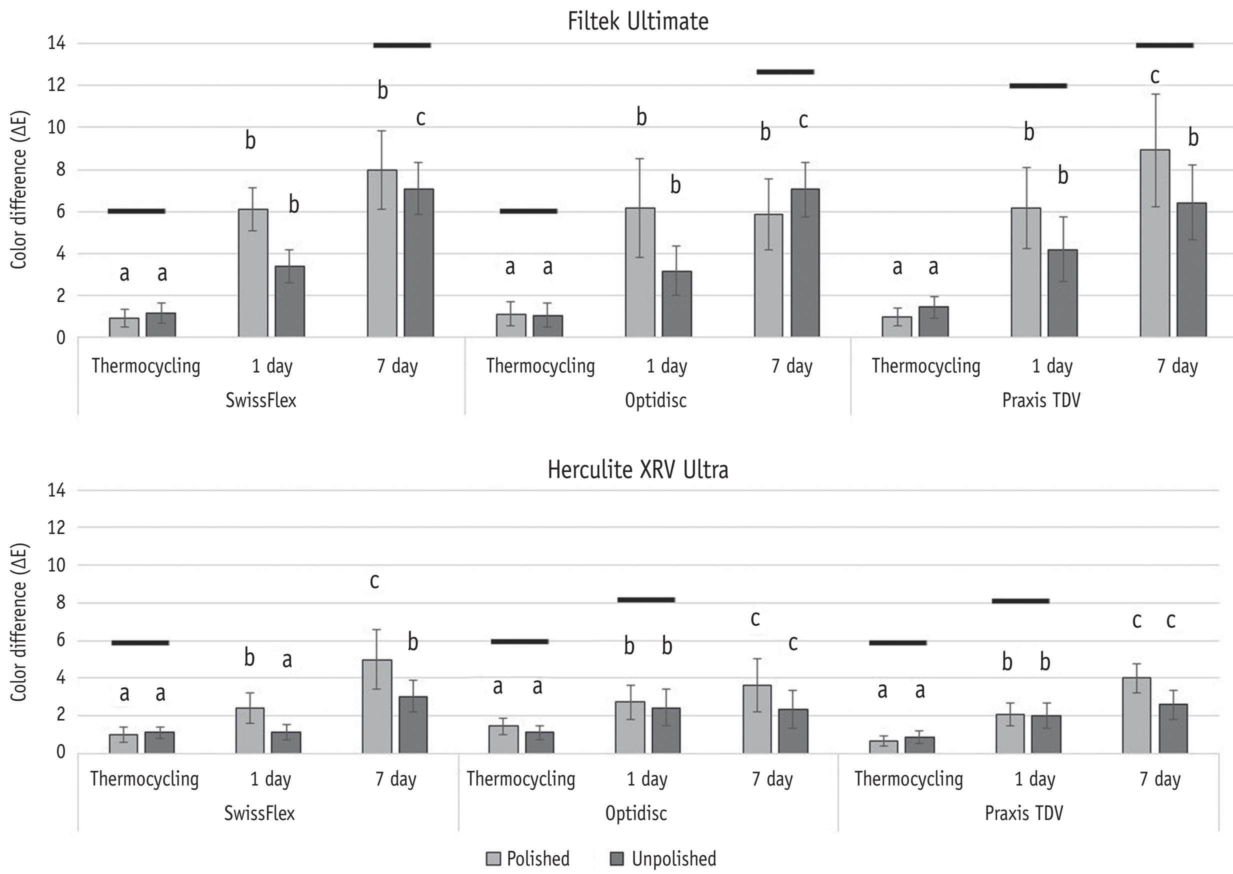

Figure 2. Bar charts comparing the mean color differences (ΔE) with standard deviations of Filtek Ultimate and Herculite XRV Ultra (nanohybrid incremental-fill resin composites) after thermocycling and storage in coffee solution for 1 and 7 days. For the same polishing procedure and resin composite, the groups with the same lower case letters are not statistically different. The polished and unpolished groups connected by a solid bar are not statistically significant.

of a discoloration resistance of a direct composite resin restoration.[8,10,11,20] In accordance, present study confirmed that different polishing procedures using aluminum-oxide impregnated disks can alter the color stability of BRBCs. Therefore, the tested null hypothesis was rejected. In addition, none of the polishing procedures consistently provided superior results for the all tested composite resins.

The surface roughness created by the polishing procedures was not investigated in this study. However, considering the composite resins polymerized under mylar strip demonstrates the minimum surface roughness, the unpolished, counterpart surfaces were taken as a reference to assess the influence of the polishing on the color change. In general, there was no significant difference between the discoloration rates of the different, unpolished subgroups of the same resin. Only among unpolished Quixfil subgroups, Swissflex gave significantly different ΔE value than Optidisc and Praxis TDV after 7 days storage. These variations in the ΔE values might be explained by a possible internal discoloration occurred in the resin since the discoloration levels were also correlated with the respective polished subgroups. Ibarra *et al.* detected a high rate of porosity in Quixfil specimens, which was attributed to the resin's manufacturing process.[21] In addition, its porous particle structure can also lead to an increase in water sorption.[22] Moreover, depending on the rotation speed, abrasive particle type, and size of polishing disks, applied load, and the duration of polishing, a superficial layer is removed from the resin surface during polishing.[23,24] Therefore, the extent of the removal of highly polymerized outer layer, together with the porous, micro-hybrid filler particles, and internal discoloration can be regarded as the main reasons of the different mean ΔE values obtained in the unpolished subgroups of Quixfil. Furthermore, the high color stability of Quixfil-Optidisc subgroup can be related with the low abrasiveness of the polishing disks, which can be investigated in a further study. In addition, compared to other polishing kits, the flush-mounted and coated mandrel system of Optidisc might also be effective in preventing scratch formation during polishing, thereby improving the discoloration resistance.

Discoloration resistance of composite resins has been reported to be more dependent on the monomer content and surface roughness, rather than the sizes of filler particles.[13] Barakah and Taner[11] reported that Filtek Ultimate specimens showed higher discoloration than Tetric EvoCeram polished with one step or multistep systems although the surface roughness of Tetric EvoCeram was greater than Filtek Ultimate. This result was ascribed to the hydrophilicity of the resin phase of Filtek Ultimate due to its TEGDMA content and the porosity caused by the filler particle-agglomerates. Similarly, in our study, Filtek Ultimate specimens showed the highest discoloration and no difference was detected between the color changes of polished and unpolished surfaces regardless of the used polishing procedure. In addition, the color changes mainly occurred during 1 day of storage, and significantly increased after 7 days storage as well. The discoloration profile of incremental-fill, nanohybrid Herculite XRV Ultra was quite similar with bulk-fill, nanohybrid Tetric EvoCeram. Taken into account that these composite resins have similar resin matrix and filler contents, this result can be interpreted as the discoloration has not been attributed to the additives admixed to modify polymerization process.

To assess the color stability of direct restorative materials, a ΔE value ≤ 3.3 is regarded as clinically acceptable.[25] The 1 day ΔE values of tested resins indicated that the color changes were lower than this critical value and visually imperceptible, except those in Filtek Ultimate subgroups. These results were clinically relevant, and in accordance with the previous studies.[11,20] Despite that the mean ΔE values higher than this threshold on the 7 days of storage cannot be regarded as these materials could be unsuitable for clinical use, the color differences increased after 7 days in the all subgroups with the exceptions of Quixfil-Optidisc, Filtek Ultimate-Swissflex, and Filtek Ultimate-Optidisc subgroups. The color maintenance observed in these subgroups might be due to the effect of the polishing tools, but such a claim should be confirmed with a detailed analysis of polished surfaces.

In this study, even though no significant difference was detected on the Tetric EvoCeram specimens after either 1 or 7 days of storage, the discoloration variations in the Quixfil subgroups showed that the esthetic lifespan of a BRBC restoration could be improved with the selection of proper polishing tools. Therefore, more studies are needed to understand the relationship between color changes of BRBC restorations exposed to various colorant beverages and foods, and different polishing techniques.

Conclusions

Considering the limitations imposed by this *in vitro* study, it was concluded that the discoloration attributes of Tetric EvoCeram groups were quite similar regardless of the used polishing procedure whereas Quixfil groups demonstrated significant alterations. Polishing procedures can significantly influence the discoloration resistance of BRBCs, probably depending on the variations in the resin matrix and filler compositions.

Acknowledgement

All authors contributed to the research design. U. Koc-Vural and I. Baltacioglu performed the laboratory analyses. U. Koc-Vural and P. Altinci drafted the manuscript. All authors participated in the data analysis, editing and final preparation of the manuscript.

Conflict of Interest: No potential conflict of interest relevant to this article was reported.

References

1. Ilie N, Bucuta S, Draenert M. Bulk-fill resin-based composites: an *in vitro* assessment of their mechanical performance. *Oper Dent* 2013;38:618-625.
2. Alshali RZ, Salim NA, Satterthwaite JD, Silikas N. Long-term sorption and solubility of bulk-fill and conventional resin-composites in water and artificial saliva. *J Dent* 2015;43:1511-1518.
3. Fronza BM, Rueggeberg FA, Braga RR, Mogilevych B, Soares LE, Martin AA, Ambrosano G, Giannini M. Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk-fill resin composites. *Dent Mater* 2015;31:1542-1551.
4. Rosatto CM, Bicalho AA, Veríssimo C, Bragança GF, Rodrigues MP, Tantbirojn D, Versluis A, Soares CJ. Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique. *J Dent* 2015;43:1519-1528.
5. Kim EH, Jung KH, Son SA, Hur B, Kwon YH, Park JK. Effect of resin thickness on the microhardness and optical properties of bulk-fill resin composites. *Restor Dent Endod* 2015;40:128-135.
6. Ilie N, Rencz A, Hickel R. Investigations towards nano-hybrid resin-based composites. *Clin Oral Investig* 2013;17:185-193.

7. Marigo L, Spagnuolo G, Malara F, Martorana GE, Cordaro M, Lupi A, Nocca G. Relation between conversion degree and cytotoxicity of a flowable bulk-fill and three conventional flowable resin-composites. *Eur Rev Med Pharmacol Sci* 2015;19:4469-4480.
8. Jefferies SR. Abrasive finishing and polishing in restorative dentistry: a state-of-the-art review. *Dent Clin North Am* 2007;51:379-397.
9. Dietschi D, Campanile G, Holz J, Meyer JM. Comparison of the color stability of ten new-generation composites: an *in vitro* study. *Dent Mater* 1994;10:353-362.
10. Sirin Karaarslan E, Bulbul M, Yildiz E, Secilmis A, Sari F, Usumez A. Effects of different polishing methods on color stability of resin composites after accelerated aging. *Dent Mater J* 2013;32:58-67.
11. Barakah HM, Taher NM. Effect of polishing systems on stain susceptibility and surface roughness of nanocomposite resin material. *J Prosthet Dent* 2014;112:625-631.
12. Ozgünaltay G, Yazici AR, Görücü J. Effect of finishing and polishing procedures on the surface roughness of new tooth-colored restoratives. *J Oral Rehabil* 2003;30:218-224.
13. Gönülol N, Yilmaz F. The effects of finishing and polishing techniques on surface roughness and color stability of nanocomposites. *J Dent* 2012;40 (Supplement 2):e64-e70.
14. Borges AB, Marsilio AL, Pagani C, Rodrigues JR. Surface roughness of packable composite resins polished with various systems. *J Esthet Restor Dent* 2004;16:42-47.
15. Lu H, Roeder LB, Lei L, Powers JM. Effect of surface roughness on stain resistance of dental resin composites. *J Esthet Restor Dent* 2005;17:102-108.
16. Da Costa J, Ferracane J, Paravina RD, Mazur RF, Roeder L. The effect of different polishing systems on surface roughness and gloss of various resin composites. *J Esthet Restor Dent* 2007;19:214-226.
17. Yazici AR, Tuncer D, Antonson S, Onen A, Kilinc E. Effects of delayed finishing/polishing on surface roughness, hardness and gloss of tooth-coloured restorative materials. *Eur J Dent* 2010;4:50-56.
18. Jung M, Sehr K, Klimek J. Surface texture of four nanofilled and one hybrid composite after finishing. *Oper Dent* 2007;32:45-52.
19. Hergott AM, Ziemiecki TL, Denisson JB. An evaluation of different composite resin systems finished with various abrasives. *J Am Dent Assoc* 1989;119:729-732.
20. Ergücü Z, Türkün LS, Aladag A. Color stability of nanocomposites polished with one-step systems. *Oper Dent* 2008;33:413-420.
21. Ibarra ET, Lien W, Casey J, Dixon SA, Vandewalle KS. Physical properties of a new sonically placed composite resin restorative material. *Gen Dent* 2015;63:51-56.
22. Iazzetti G, Burgess JO, Gardiner D, Ripps A. Color stability of fluoride-containing restorative materials. *Oper Dent* 2000;25:520-525.
23. Rémond G, Nockolds C, Philips M, Roques-Carmes C. Implications of polishing techniques in quantitative X-ray microanalysis. *J Res Natl Inst Stand Technol* 2002;107:639-662.
24. da Silva JM, da Rocha DM, Travassos AC, Fernandes VV Jr., Rodrigues JR. Effect of different finishing times on surface roughness and maintenance of polish in nanoparticle and microhybrid composite resins. *Eur J Esthet Dent* 2010;5:288-298.
25. Sepúlveda-Navarro WF, Arana-Correa BE, Borges CP, Jorge JH, Urban VM, Campanha NH. Color stability of resins and nylon as denture base material in beverages. *J Prosthodont* 2011;20:632-638.