

# **EFFECT OF DIAMOND PASTE FINISHING ON AFM SURFACE TEXTURE PARAMETERS AND TOPOGRAPHY OF DENTAL NANOCOMPOSITES POLISHED BY TWO DIFFERENT PROCEDURES**

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**Abstract:** Commercially available and the most widely used oral bionanomaterials in dental practice are resin-based composites containing oxide nanoparticles. The aim of this study was to determine the effect of diamond paste finishing on AFM surface texture parameters of dental nanocomposites polished by two different dental polishing protocols. Representative dental resin-based nanofilled and nanohybrid composite were tested in this study. The samples were polished by two dental polishing protocols using multi-step and one-step system. These protocols were then followed by diamond paste polishing. Samples were examined by Veeco di CP-II Atomic Force Microscope, in contact mode with CONT20A-CP tips. Average roughness ( $R_a$ ) and maximum peak-to-valley distance ( $R_{p-v}$ ) were analyzed and compared between samples. Multi-step polishing protocol produced significantly lower  $R_a$  and  $R_{p-v}$  values, for both tested materials, than one-step polishing protocol, even when it was followed by diamond paste polishing.

**Keywords:** Nanocomposites, Composite Dental Resin, Microscopy, Atomic Force, Surface Roughness, Dental Polishing

## **I. INTRODUCTION**

Nanotechnology, as a revolutionary technology, has taken a wide range of applications in various fields [1]. Improvements in materials science and engineering have led to the development of modern and advanced nanomaterials for dental practice [2]. The most widely used dental nanostructured materials are resin-based composites containing oxide nanoparticles [3]. These materials are divided in two groups: nanofilled and nanohybrid composites [4]. Nanofilled materials are resin-based materials containing only nanometer-sized fillers, while nanohybrid composites include micrometer particles (0.4–5 $\mu$ m) mixed with nano-sized inorganic particles [5]. Evolution to nanostructured materials made dental composites more mechanically resistant materials, with reduced polymerization shrinkage, thermal expansion and water solubility, with improved optical and aesthetic characteristics, more wear resistant, with better polish ability and polish retention [2,6,7]. It is known that not only the materials properties are important, but also a high quality of working tools and processing mechanisms, in order to benefit from the characteristics of the new synthesized materials in the best possible way.

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## II. RELATED WORK

The modern dental professional demands for quality of the restoration are increasing all the time, and for now, it is considered that the roughness below 0.2  $\mu\text{m}$  is satisfactory feature for direct dental restoration [8,9]. This is the approximate limit under which the bacterial biofilm is not retained. The other demands include smooth and glossy surface, low retention possibility for stains and discolorations, lower wear during time of function [10,11]. On the other hand, there is a professional need for a more and more rapid clinical interventions with the introduction of a number of simplified procedures in every-day clinical work [12-14]. For this reasons, a method of materials polishing in a single step has been introduced in dentistry, so-called “single-step” or “one-step” polishing protocol [9,15]. This method supposed to push the multi-step polishing procedure in a second plan, by reducing of clinical chair-time. For this purpose, and in order to have a high quality of finishing procedure, a diamond paste polishers has appeared on the market [16-18].

The aim of this study was to evaluate the effect of conventional multi-step polishing protocol on surface topography and roughness of resin-based nanocomposites comparing it with the effect of one-step polishing protocol. The diamond paste polishing effect on the surface features was also examined, following both of these previously conducted procedures.

## III. MATERIALS AND METHODS

Two contemporary dental resin-based nanocomposites were tested in this study: nanofilled (Filtek Ultimate Body, 3M ESPE), and nanohybrid composite (FZ550, 3M ESPE). Detailed information about the materials used in the study is shown in Table 1.

Table 1. Details about nanofilled and nanohybrid composites tested in the study\*.

Name	Filtek Ultimate Body	Filtek Z550
Manufacturer	3M ESPE, St. Paul, MN, USA	3M ESPE, St. Paul, MN, USA
Classification	Nanofilled composite	Nanohybrid composite
Lot no	N349776	N340139
Shade	A2	A2
Matrix	Bis-GMA, UDMA, Bis-EMA, TEGMA and PEGDMA	Bis-GMA, UDMA, Bis-EMA, TEGMA and PEGDMA
Fillers	non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4-11 nm zirconia filler, and aggregated zirconia/silica cluster filler (average cluster particle size – 0,6-10 $\mu\text{m}$ )	Surface-modified zirconia/silica fillers 3000 nm (3 $\mu\text{m}$ or less) , non-agglomerated/non-aggregated surface-modified silica particles 20 nm
Filler loading	78,5 wt%; 63,3 vol%	82 wt%; 68 vol%
Bis-GMA- bisfenol A diglicidil ether dimethacrylate; Bis-EMA- bisfenol A polyethylene glycol diether dimethacrylate; UDMA- urethane dimethacrylate; TEGMA- triethyleneglycol dimethacrylate; PEGDMA- polyethylene glycol dimethacrylate *Data obtained from the manufacturers		

### Procedure for preparing the specimens

Specimens were prepared in the cylindrical plastic molds (8 mm diameter x 2 mm depth) which were placed on the glass microscope slide, filled with material and covered with a polyester strip and a glass slide, taking care to obtain a flat surface without any defects and entrapped air. Material was then polymerized for 40 seconds with a SmartLite® IQTM 2 dental LED light curing unit (Dentsply Caulk). After removing glass plate and polyester strip from the top of the samples, After polymerization, the samples were polished by four dental polishing protocols: multi-step – MS (Super Snap, Shofu), multi-step followed by diamond paste polishing – MSD (DiamondDia, Shofu), one-step – OS (OneGloss, Shofu) and one-step followed by diamond paste polishing –OSD (See Fig 1. and Table 2. for details).

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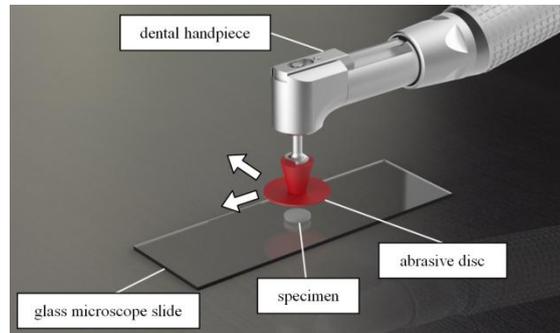


Fig. 1. Model of dental handpiece with polishing disk and the sample

During the polishing procedure, each abrasive disk was used only once for each material, in the dry condition, for 1 minute, using handpiece rotating 10 000, 8000 or 5000 revolutions per minute, depending on the polishing system and the manufacturer’s instructions. One single operator did all of the polishing treatments, simulating clinical finishing and polishing procedure. Two mutually perpendicular grinding directions were used during polishing procedure.

Table 2. Details about polishing protocols used in this study

Polishing protocol	Polisher name	Manufacturer	Description	Usage	Conditions	Handpiece speed
No. 1	SuperSnap	Shofu, Japan	multi-step polishing protocol, four abrasive disks with successively reduced grits	one minute polishing for each abrasive disk	In dry conditions	10 000 rpm*
No. 2	OneGloss	Shofu, Japan	one-step polishing protocol, one abrasive silicone discoid disk	one minute polishing	In dry conditions	5000 rpm*
No. 3	SuperSnap followed by Direct Dia with SuperBuff	Shofu, Japan	multi-step polishing protocol, four abrasive disks with successively reduced grits followed by diamond paste applied with polishing disk	one minute polishing for each abrasive disk followed by one minute diamond paste polishing	In dry conditions followed by slightly moistened SuperBuff disk with water before applying diamond paste on it	8 000 rpm*
No. 4	OneGloss followed by Direct Dia with SuperBuff	Shofu, Japan	one-step polishing protocol, followed by diamond paste applied with polishing disk	one minute polishing with one step abrasive disk followed by one minute diamond paste polishing	In dry conditions followed by slightly moistened SuperBuff disk with water before applying diamond paste on it	8000 rpm*

\* recommended from the manufacturer

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## AFM scanning

After the polymerization and polishing procedures, samples were examined by Veeco di CP-II Atomic Force Microscope, in contact mode with CONT20A-CP tips. 1 Hz scan rate and  $256 \times 256$  resolution were used to obtain topography on the  $80 \times 80 \mu\text{m}$  scanning area. Measured topography data were processed by Image Processing and Data Analysis v2.1.15 software. Following parameters were compared among specimens: average roughness ( $R_a$ ) and maximum peak-to-valley distance ( $R_{p-v}$ ).

## IV. RESULTS AND DISCUSSION

### Topography of the tested materials

Qualitative analysis of the 2D and 3D AFM images showed that multi-step polishing protocol produced lines and scratches on the tested materials' surfaces, which were results of the machining process with abrasive sandpapers (see Fig. 2 and Fig. 3). The abrasive wear mechanism of this polishing method created surface with furrowed and microploughed topography, with rare round local damages made as a consequence of the inorganic fillers dislodgement. One-step polishing procedure produced much higher elevations and depressions of the surface of both tested materials, but the damages were also linear and channel-type. Diamond paste polishing created smoother surfaces after both polishing procedures, by sweeping the lines and grooves, leaving only deep channels and a few new, hole-like defects of the surface. Nanofilled material had more regular surface with smaller holes, more shallow channels and less damages, than nanohybrid composite. Only one-step polishing system produced greater microploughing on nanofilled comparing to nanohybrid material.

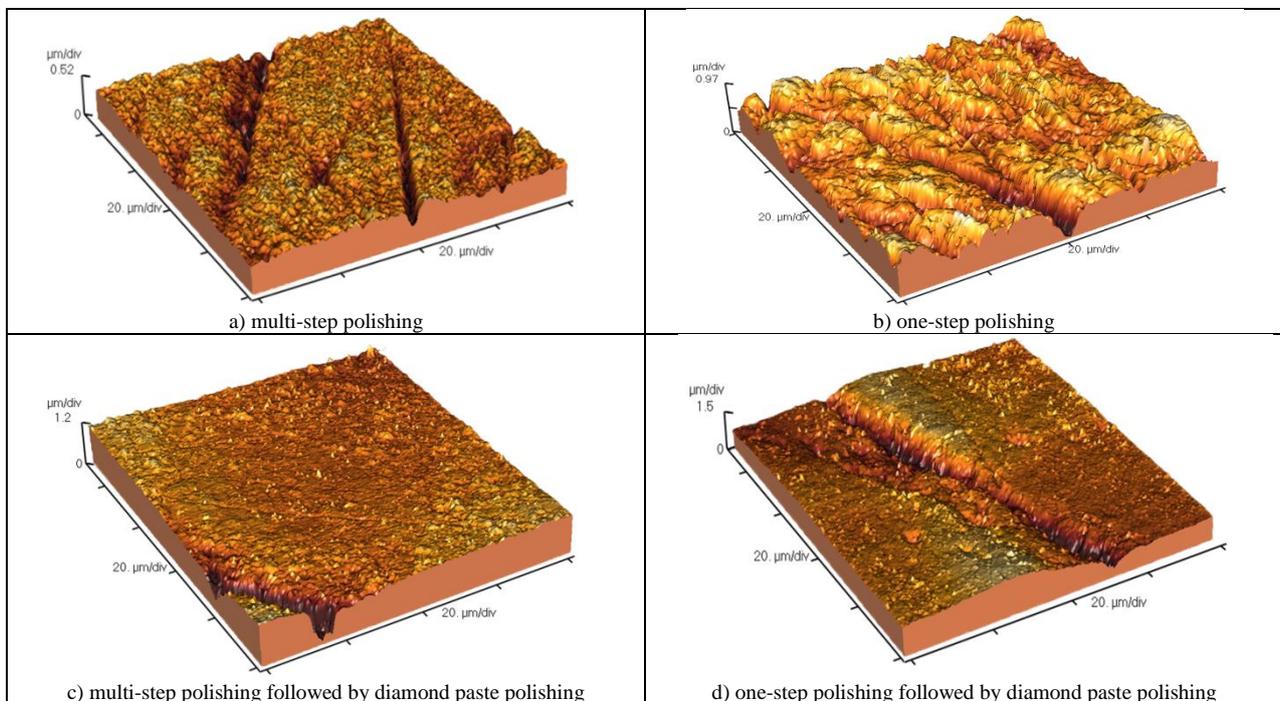


Fig. 2. 3D AFM images showing the topography of nanofilled composite FUB polished by different polishing protocols

### AFM surface texture parameters

Analysis of the quantitative results showed that multi-step polishing protocol produced significantly smoother surface and lower AFM surface texture parameters than one-step polishing protocol on the both tested nanomaterials. Calculated AFM roughness parameters ( $R_a$  and  $R_{p-v}$ ) showed that both of the tested materials had significantly lower

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roughness values when samples were polished by diamond-paste polishing after the standard polishing protocols (see Fig. 4 and Fig. 5). This improvement was especially significant for the one-step polished samples, where this reduction was sometimes up to 200 nm in average roughness. Nanofilled material had lower  $R_a$  and  $R_{p-v}$  values nearly for all of the tested polishing protocols, than nanohybrid composite.

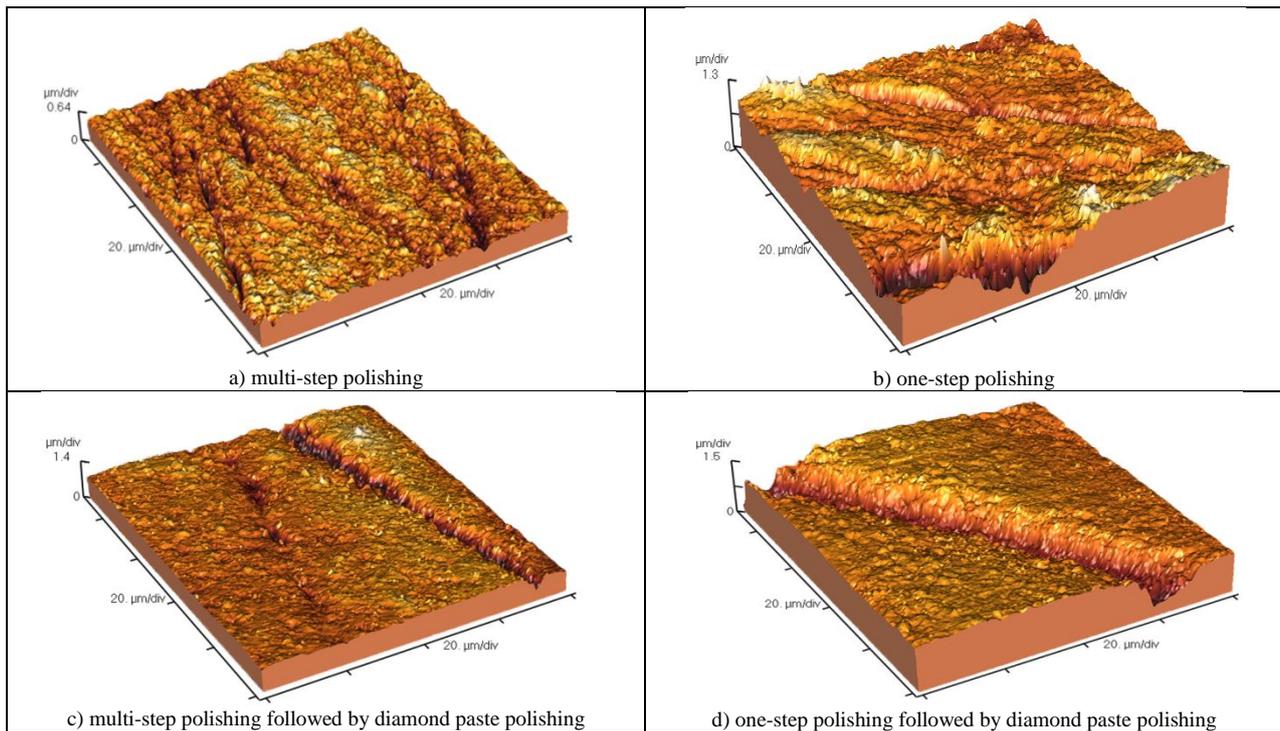


Fig. 3. 3D AFM images showing the topography of nanohybrid composite FZ550 polished by different polishing protocols

The reasons for these results lay in the polishing mechanisms of differently designed polishers. The multi-step finishers and polishers are elastic silicone sandpapers, with four successively reduced grits, consisting of silicone carbide (Black and Violet sandpaper) and aluminium-oxide particles (Green and Red sandpaper). This polishing system turn out to be optimally designed for dental composite materials polishing, and shown great polishing results in other studies, also [19]. OneGloss is a one-step, aluminium-oxide impregnated silicone polisher, which is designed with the idea to save operative time, and to serve either for finishing, or polishing only by altering the contact pressure. In this study, it is shown that such a method, with rigid silicone polisher, can not provide the optimal polishing results, which is also the confirmation of some previous experimental results [20]. Polishing with this tool causes greater microploughing of the material and dislodging of filler or resin particles. This single-step protocol may be successfully used for dental ceramics or enamel polishing, but it is not suitable method for composite polishing. Only when it's followed by diamond paste, it can reduce clinical chair time, and to create the acceptable surface topography and roughness parameters. The great wear capacity of the diamond paste reduced surface roughness of both tested materials, by erasing the scratched topography and leaving only sporadic deep grooves. Diamond paste removed both of the composite's phases homogeneously, because the diamond components have been harder than the filler composite particles. This polishing protocol can save dental operative time and provide acceptable topography and roughness results. It depends on the size of the fillers, whether their dislodgement will leave the smaller or bigger holes and damages. Analyzing these experimental results, it can be concluded that the nano-sized particles in the material composition and the adequate polishing protocols have the major role in the final surface quality.

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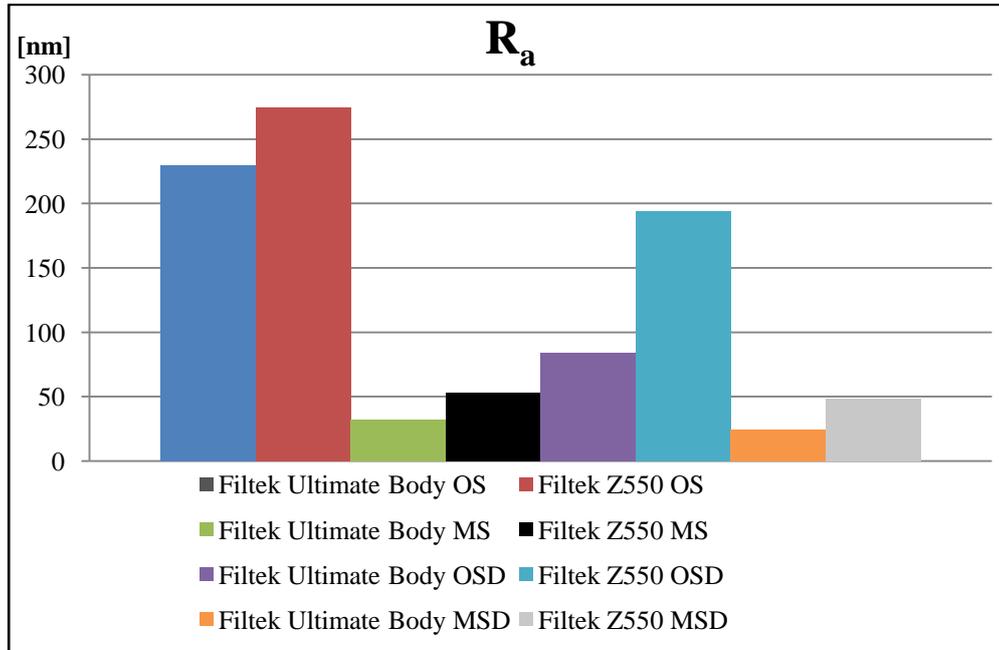


Fig. 4. Comparison of average roughness ( $R_a$ ) among specimens after polishing procedures

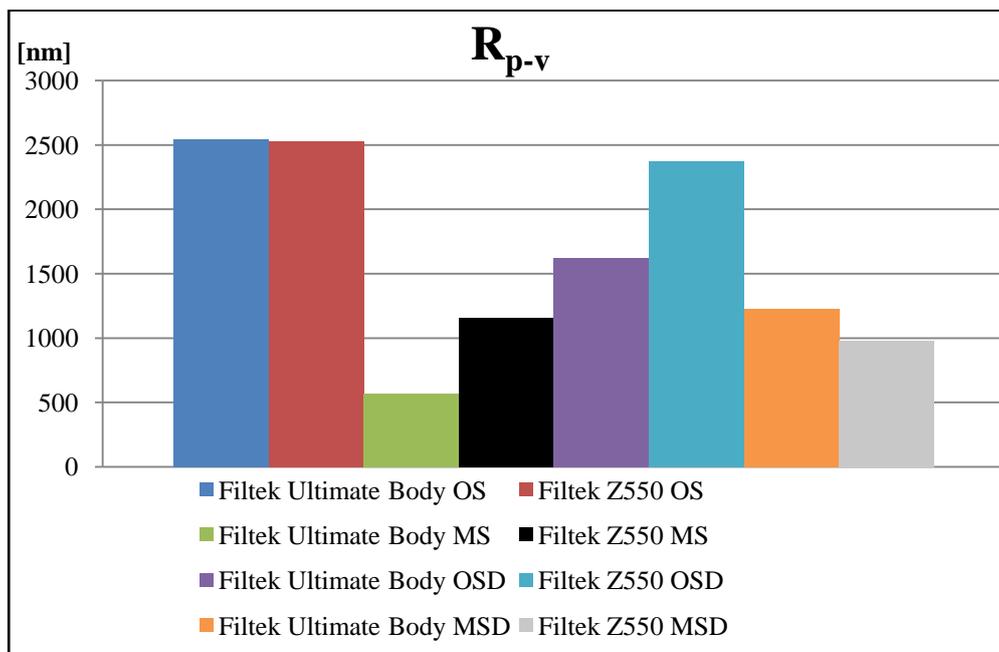


Fig. 5. Comparison of peak-to-valley ( $R_{p-v}$ ) distances among specimens after polishing procedures

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## V. CONCLUSION

Multi-step polishing protocol produced significantly lower  $R_a$  and  $R_{p-v}$  values, for both tested materials, than one-step polishing protocol, even when it was followed by diamond paste polishing. The great wear capacity of the diamond paste enabled this polishing system to create smoother surface of the both tested nanocomposites and after both tested previously conducted polishing protocols. Nanofilled composite had lower roughness values than nanohybrid composites, due to its composition. There are two major factors which determine the smoothness of final composite restoration: nano-sized particles in the material composition and the adequate polishing protocols. Only the right choice of dental polishing mechanism, can lead to satisfying and good long-term clinical results. Although it is intended for reduction of clinical chair-time, one-step polishing protocol did not meet the high quality restoration demands of modern dental practice. In order to reduce chair time, dentists can use diamond paste polishing, after any multi-step or one-step polishing procedure, because it can reduce roughness in nearly every case creating smooth surface and satisfactory topography. Further studies need to investigate the effect of the other commercially-available polishing systems on the surface topography and roughness of different new dental composite materials containing nanoparticles.

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## REFERENCES

- [1] Nano.gov, National Nanotechnology Initiative, "Benefits and Applications", available at <http://www.nano.gov/you/nanotechnology-benefits>
- [2] S.B. Mitra, D. Wu, B.N. Holmes, "An application of nanotechnology in advanced dental materials", JADA, vol. 134, pp. 1382-1390, 2003.
- [3] S.B. Mitra, "Nanoparticles for Dental Materials: Synthesis, Analysis and Applications", in K. Subrahmi, W. Ahmed, "Emerging Nanotechnologies in Dentistry – Materials, Processes and Applications", Waltham, MA: Elsevier Inc, pp. 15-34, 2012.
- [4] S.A. Saunders, "Current practicality of nanotechnology in dentistry. Part I: Focus on nanocomposite restoratives and biomimetics", Clinical, Cosmetic and Investigational Dentistry, vol. 1, pp. 47-61, 2009.
- [5] M.H. Chen, "Update of dental nanocomposites", Journal of Dental Research, vol. 89, no. 6, pp. 549-560, 2010.
- [6] A.R. Curtis, W.M. Palin, G.J.P. Fleming, A.C.C. Shortall, P.M. Marquis, "The mechanical properties of nanofilled resin-based composites: The impact of dry and wet cycling pre-loading on bi-axial flexure strength", Dental Materials, vol. 25, pp. 188-197, 2009.
- [7] B. Yu, H. Lim, Y. Lee, "Influence of nano- and micro-filler proportions on the optical property stability of experimental dental resin composites", Materials and Design, vol. 31, pp. 4719-4724, 2010.
- [8] S.A. Antonson, A.R. Yazici, E. Kilinc, D.E. Antonson, P.C. Hardigan, "Comparison of different finishing/polishing systems on surface roughness and gloss of resin composites", Journal of Dentistry, vol. 39, No. suppl.1, pp. e9-e17, 2011.
- [9] H. Bashetty, S. Joshi, "The effect of one-step and multi-step polishing systems on surface texture of two different resin composites", Journal of Conservative Dentistry, vol. 13, No.1, pp. 34-38, 2010.
- [10] J. Janus, G. Fauxpoint, Y. Arntz, H. Pelletier, O. Etienne, "Surface roughness and morphology of three nanocomposites after two different polishing treatments by a multitechnique approach", Dental Materials, vol. 26, pp. 416-425, 2010.
- [11] U. Erdemir, E. Yildiz, M.M. Eren, A. Ozsoy, F.T. Topcu, "Effects of polishing systems on the surface roughness of tooth-colored materials", Journal of Dental Sciences, vol. 7, pp. 160.169, 2013.
- [12] Dental technology reduces your time in the chair, available at <http://hewittdentist.com/dental-technology-reduces-your-time-in-the-chair/>
- [13] Today's Dental Technology Reduces Your Time in the Chair, available at <http://www.orangedentalblog.com/todays-dental-technology-reduces-your-time-in-the-chair/>
- [14] E. Berutti, G. Chiandussi, D.S. Paolino, N. Scotti, G. Cantatore, A. Castellucci, D. Pasqualini, "Canal Shaping with WaveOne Primary Reciprocating Files and ProTaper System: A Comparative Study", Journal of Endodontics, vol. 38, No. 4, pp. 505-509, 2012.
- [15] A.U. Yap, S.H. Yap, C.K. Teo, J.J. Ng, "Finishing/polishing of composite and compomer restoratives: Effectiveness of one- step systems", Operative Dentistry, vol. 29, pp. 275-9, 2004.
- [16] S.A. Whitehead, N.H.F. Wilson, "The nature and effects of composite polishing pastes", Journal of Dentistry, vol. 17, pp. 234-240, 1989.
- [17] D. Şen, G. Göller, H. İşsever, "The effect of two polishing pastes on the surface roughness of bis-acryl composite and methacrylate-based resin. J. Prosthet. Dent. 88 (2002) 527-532.
- [18] K.W. Mopper, "Finishing and polishing. Using the best tool to achieve natural-looking results", Inside Dentistry, vol. 9, pp. 90-92, 2013.
- [19] T. Watanabe, M. Miyazaki, B.K. Moore, "Influence of polishing instruments on the surface texture of resin composites", Quintessence International, vol. 37, No.1, pp. 61-67, 2006.
- [20] A.U. Yap, J.J. Ng, S.H. Yap, C.K. Teo, "Surface finish of resin-modified and highly viscous glass ionomer cements produced by new one-step systems", Operative Dentistry, vol. 29, No.1, pp. 87-91, 2004.