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Effect of Diamond Paste Finishing on Surface Topography and Roughness of Dental Nanohybrid Composites – AFM Analysis

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Abstract

Dental restorative materials need to be carefully engineered and designed in order to meet many different clinical requirements. The oral biomaterials have to possess such properties which enable them to withstand the conditions present in the oral environment. The improvements in the dental materials science are the main initiators of the entire dental professional progress. In order to exploit all the improved characteristics of new commercial dental materials, dental clinicians need to be familiar with working mechanisms of dental processing methods, and to be able to choose the best therapeutic processing condition for the each material. The aim of this study was to investigate the influence of diamond paste finishing on surface topography and roughness of two dental resin-based nanohybrid composites. Results of this study showed that diamond paste polishing was useful processing method which significantly reduced surface roughness and created favorable topography of tested nanohybrid composite materials.

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Keywords: atomic force microscope; surface roughness; polishing protocols; dental resin-based composites; nanohybrid composites; diamond paste polishing

1. Introduction

The best and the most resistant material that withstands the conditions in the oral cavity environment is, surely, the natural tooth with its own naturally engineered tissues [1]. However, there are possible tooth-diseases or traumas that can harm the dental tissues, and leave the cavities and defects which need the reconstruction with oral

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biomaterials. Oral biomaterials need to be biocompatible materials, with optimal physical, mechanical, chemical and aesthetic properties [2]. Among them, very important properties of dental materials are their polish ability and polish retention, and the surface quality which do not cause undesirable biological interactions and the adhesion of the bacterial plaque on the reconstructive material [3,4]. Biofilm is the main cause of caries lesions and gingival and periodontal diseases, and its retention can be reduced by decreasing the surface roughness of the restorative biomaterial [5]. There were some experimental findings that dental material's surface roughness lower than 0,2 μm , significantly reduced the possibility of bacterial adhesion [6]. Smooth surface enables clinical durability, good aesthetic appearance, better optical compatibility with natural enamel tissue and surface gloss, as well as, preventing the discoloration and staining of the restoration [7,8]. There are many dental processing methods for obtaining good surface quality [9]. Dental usual final processing of restoratives includes contouring, finishing and polishing procedures in order to obtain the adequate anatomical morphology of the restoration and the satisfying surface quality [10]. Some dental polishing procedures recommend the so called "high gloss polishing" or "paste-polishing" with application of polishing aluminium-dioxide or diamond pastes for the intraoral use at the end of the restorative treatment [11,12,13]. For every dental clinical work, it is important for the operator to be familiar with procedures and to understand the mechanisms which certain material processing method produces [2]. This study was conducted on dental composite materials, which are the most commonly used materials in dental clinical practice [14]. The contemporary nanohybrid composites were chosen, because these new nanoparticles-containing materials are expected to provide better overall composites features, including the quality of polished surface [15,16]. Every effort in the synthesis of new materials with improved properties includes the evaluation and selection of the best processing conditions in order to utilize these materials improvements.

The aim of this study was to determine the influence of diamond paste finishing on surface topography and roughness of polished contemporary dental resin-based nanohybrid composites.

Nomenclature

LED	Light emitting diode
AFM	atomic force microscopy
Ra	average surface roughness [nm]
Rp-v	maximum peak-to-valley distance [nm]

2. Materials and methods

Two contemporary dental resin-based nanohybrid composites were tested in this study (Evetric and IPS Empress Direct, Ivoclar Vivadent). Detailed information about the materials used in the study is shown in the Tables 1 and 2.

Table 1. Details about Evetric tested in study.

Name	Evetric
Manufacturer	Ivoclar Vivadent, Schaan, Liechtenstein
Classification	Nanohybrid composite
Lot no	P50246
Shade	A3
Matrix	Dimethacrylates
Fillers	Barium glass, ytterbium trifluoride, mixed oxides, copolymers sized between 40 nm – 3000 nm
Filler loading	80-81 wt. %, 55-57 vol. %

Table 2. Details about IPS Empress Direct tested in study.

Name	IPS Empress Direct
Manufacturer	Ivoclar Vivadent, Schaan, Liechtenstein
Classification	Nanohybrid composite
Lot no	P74595
Shade	A2
Matrix	Dimethacrylates
Fillers	Barium glass, ytterbium trifluoride, mixed oxides, silicon dioxide and copolymers sized between 40 nm – 3000 nm, with a mean particle size of 550 nm
Filler loading	77.5-79 wt. %, 52-59 vol. %

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, they were polished by two dental polishing protocols: multi-step dental polishing protocol with SuperSnap sandpapers and the same multi-step polishing protocol followed by DirectDia diamond paste applied by SuperBuff polishers (Shofu, Inc. Kyoto, Japan). Detailed information about the polishing protocols used in the study is shown in Fig. 1 and Table 3.

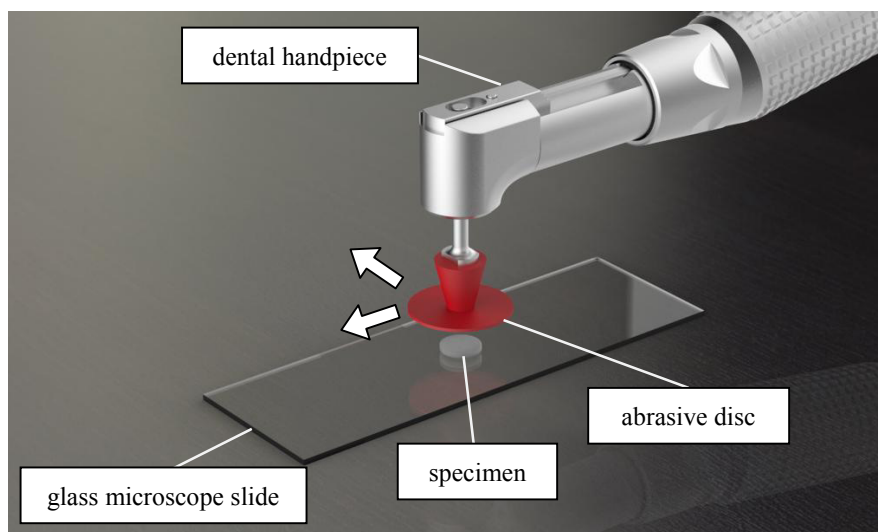


Fig. 1. Model of dental handpiece with polishing disk and the sample.

2.1. AFM scanning

Samples were examined by Veeco di CP-II Atomic Force Microscope, in contact mode with CONT20A-CP tips. 1 Hz scan rate and 256×256 resolution were used to obtain topography on a $90 \times 90 \mu\text{m}$ scanning area. Measured topography data were processed by Scanning Probe Microscopy (SPM) image processing software called Scanning

Probe Image Processor (SPIP 6.0.10). Following parameters were compared among specimens: average roughness (R_a) and maximum peak-to-valley distance (R_{p-v}).

Table 3. Details about polishing protocols used in this study.

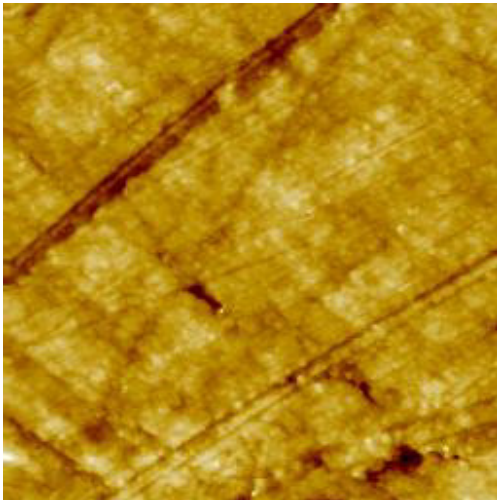
Polishing protocol	Polisher name	Manufacturer	Description	Usage	Conditions	Handpiece speed
No. 1	SuperSnap	Shofu, Japan	multi-step polishing protocol, four abrasive disks with successively reduced grits	one minute polishing for each abrasive disk	In dry conditions	10 000 rpm*
No. 2	SuperSnap followed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

* recommended from the manufacturer

3. Results

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. 4). 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. The values of measured AFM roughness parameters (R_a and R_{p-v}) were satisfying and showed relatively low surface roughness for the both materials polished by multi-step protocol (see Fig. 6 and Fig. 7).

(a)



(b)

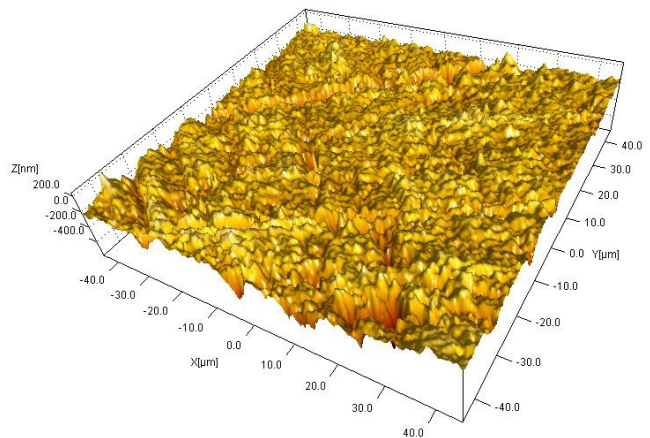


Fig. 2. (a) 2D AFM image of Evetric polished by multistep protocol; (b) 3D AFM image of Evetric polished by multistep protocol.

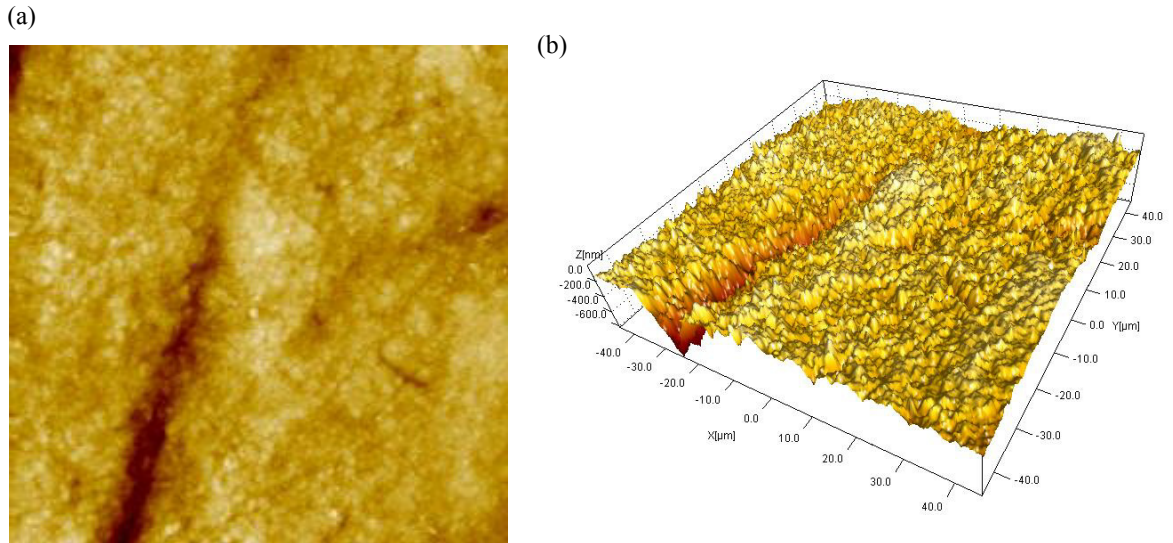


Fig. 3. (a) 2D AFM image of Evetric polished by multistep protocol followed by diamond paste polishing; (b) 3D AFM image of Evetric polished by multistep protocol followed by diamond paste polishing.

However, diamond paste polishing which followed the multi-step protocol, created even smoother surfaces of the samples, by sweeping the lines and grooves, leaving only a few new, hole-like defects of the surface (see Fig. 3 and Fig. 5). 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.

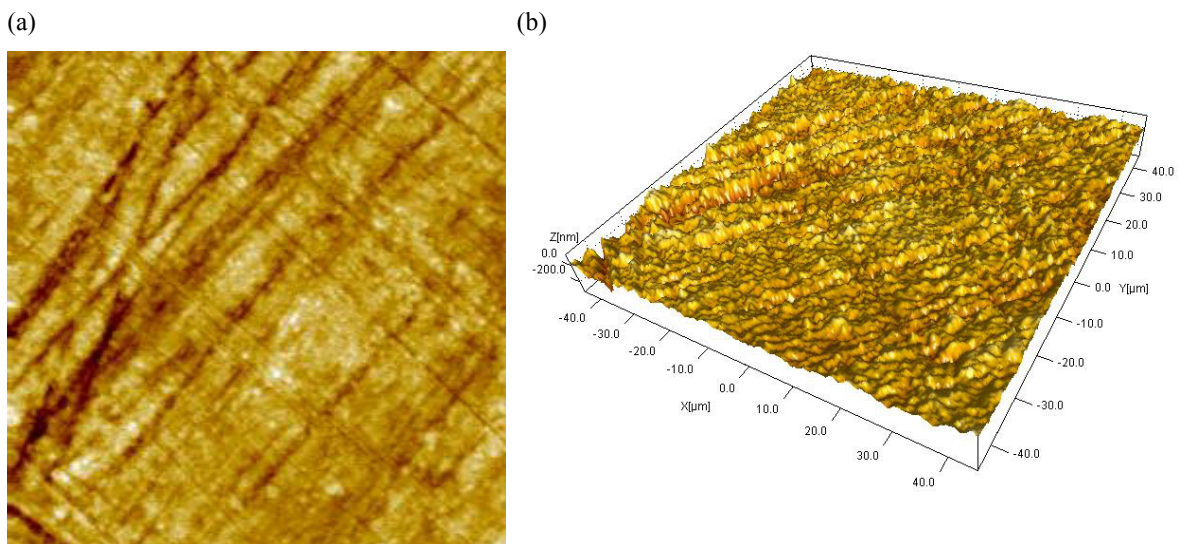


Fig. 4. (a) 2D AFM image of IPS Empress Direct polished by multistep protocol; (b) 3D AFM image of IPS Empress Direct polished by multistep protocol.

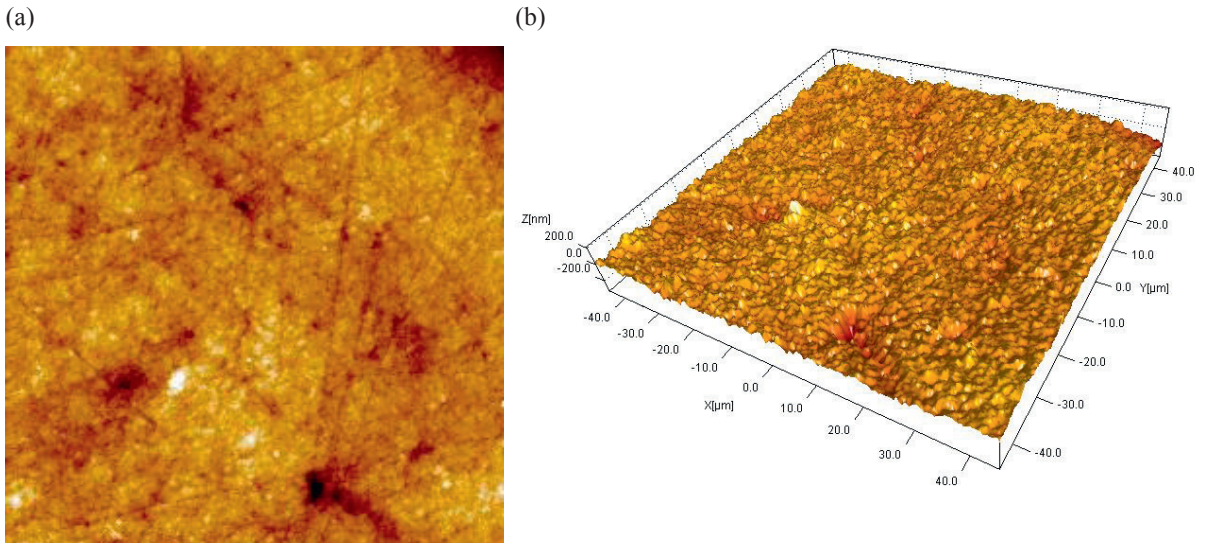


Fig. 5. (a) 2D AFM image of IPS Empress Direct polished by multistep protocol followed by diamond paste polishing; (b) 3D AFM image of IPS Empress Direct polished by multistep protocol followed by diamond paste polishing.

Quantitative analysis of calculated AFM roughness parameters (R_a and R_{p-v}) showed that both of the tested materials had significantly lower roughness values when samples were polished by diamond-paste polishing after the standard multi-step polishing protocol (see Fig. 6 and Fig. 7).

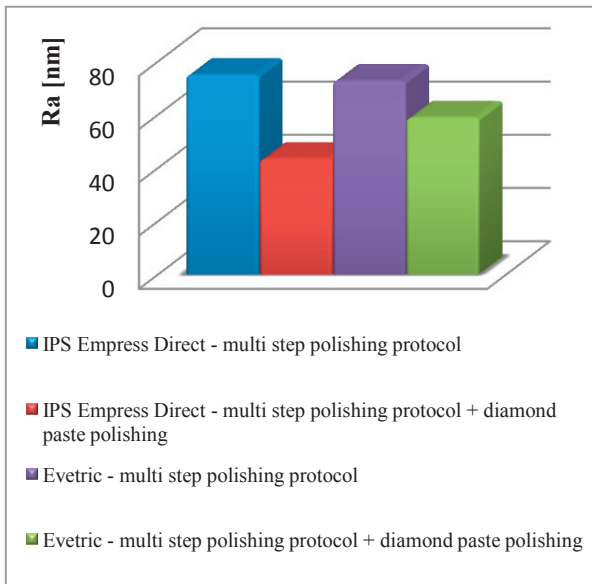


Fig. 6. Average surface roughness (R_a) of tested materials.

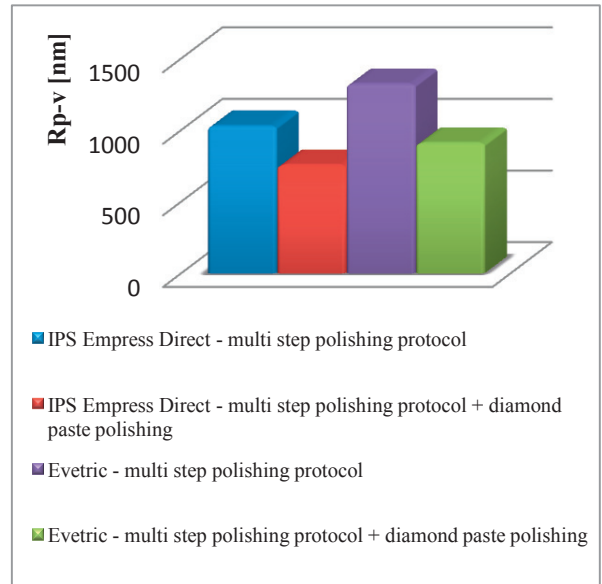


Fig. 7. Maximum peak-to-valley distance (R_{p-v}) of tested materials.

4. Conclusion

The great wear capacity of the diamond paste enabled this polishing system to create smoother surface of the both tested nanohybrid materials in this study. Diamond paste removed both of the composite's phases homogeneously, because the diamond components have been harder than the filler composite particles. It depends on the size of the fillers, whether their dislodgement will leave the smaller or bigger holes and damages. Analyzing these polishing mechanisms, 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. 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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