Advances in Science and Technology Research Journal

Advances in Science and Technology Research Journal 2024, 18(1), 268–279
https://doi.org/10.12913/22998624/178515
ISSN 2299-8624, License CC-BY 4.0

Received: 2023.11.20
Accepted: 2024.01.05
Published: 2024.01.16

Influence of Different Polishing Methods on Surface Roughness and Microhardness of Dental Composites

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ABSTRACT

Six different composites were used in the study. From each material, 40 cylinder-shaped samples were made. All samples were polymerized and polished using three different methods. To evaluate surface roughness a confocal laser microscope was used, and microhardness was determined using a universal Vickers hardness tester. The data were analysed using the one-way ANOVA test at a significance level of 0.05 for both tests. The smoothest surfaces in all groups of composites were obtained for control samples. Also in all groups of composite samples no statistically significant differences were found between the Sof-Lex and Enhance+PoGo. The measurement of surface roughness obtained for the Kenda system showed significantly lower values than for the other two methods. The surfaces of the control samples showed statistically significantly lower microhardness values compared to all polishing systems for all six tested resin composites, additionally no statistically significant differences were found between all finishing and polishing methods. Regardless of the finishing and polishing method used, the lowest microhardness values among microhybrid materials were found for Charisma Flow, while among nanohybrid materials the lowest values were obtained for Herculite HRV Ultra. Finishing and polishing increases the microhardness of microhybrid and nanohybrid composite resin. The use of Kenda three step polishing system resulted in smoother surface for all tested composite materials compared to the Sof-Lex and Enhance+PoGo systems, while the finishing and polishing method had little effect on the microhardness of the surface.

Keywords: resin composites, dental fillings, polishing procedures, roughness, microhardness.

INTRODUCTION

Composite materials have been used in dentistry for many years. These are mixtures of polymers and fine-grained fillers that are used to fill cavities in teeth, which results in the reconstruction of their structure [1]. Composite fillings are available in various shades. This allows the color to be precisely matched to the natural color of the teeth [2]. Therefore, they are much less visible than traditional amalgam fillings. Composites can also be formed and shaped, which allows for the reconstruction of cavities in a manner consistent with the natural anatomy of the tooth [3].

Composite fillings are attached to the tooth using adhesive bonds. It means that they not only minimize the need to remove healthy tissue, but also strengthen the tooth structure, increasing its durability [4]. Moreover, the good adhesive properties of composites make these fillings adhere better to the tooth, minimizing the risk of bacterial penetration and the development of infection [5]. Because composites are flexible and more plastic than traditional metal fillings, the risk of tooth fracture, especially in the case of fillings of larger cavities, is significantly reduced [6]. Unlike amalgams, composites are less prone to cause allergic reactions in patients' bodies, and they do not corrode, which is a problem in the case of metal fillings [7]. Not without significance when working with composite materials is the fact that they are hardened using UV light or lasers, which allows the treatment to be shorter and more effective. Additionally, composites provide high translucency as well as mechanical properties appropriate to the conditions in which the enamel works [8, 9].

Unfortunately, the heterogeneous nature of composite resin fillings complicates the procedure of developing composite fillings, which are rough after hardening [10]. This roughness of the composite surface depends on several factors, including: filler content, particle size and shape, monomer type, degree of hardening and binding efficiency. This is a very important aspect because the proper finishing of composite fillings is particularly important for the quality of the filling surface, its aesthetics and durability, as well as patient comfort [11]. Therefore, it is necessary to focus efforts on improving the smoothness of the surface to obtain satisfactory results – proper filling, preventing the penetration of bacteria and maintaining the appropriate tooth geometry.

Finishing composite fillings involves removing any excess filling material and adapting the shape and contour of the filling to the natural shape of the tooth. Polishing fillings is therefore aimed at reducing roughness and, therefore, obtaining a smooth and uniform filling surface [12]. This is important not only for aesthetic reasons, but also for health reasons. The smooth surface of the filling makes it difficult for bacterial plaque and food debris to settle, which reduces the risk of caries around the filling and minimizes the risk of irritation or injury in the oral cavity. Moreover, fillings with smooth surfaces are less susceptible to discoloration and plaque retention [13]. A properly selected finishing and polishing (F/P) process should significantly affect the microhardness of the filling surface, which determines the composite's resistance to wear, cracking and deformation but also prevents occlusal disorders [14]. Choosing appropriate finishing and polishing methods is crucial to obtain the best possible quality and durability of fillings, while maintaining the appropriate tooth anatomy. There are several finishing and polishing methods for dental fillings that are used in dental practice. These include, among others: polyester strips, polishing discs and pastes, rotary tools. All these methods have their advantages and limitations. The choice of the appropriate method depends on the type of filling, tooth topography and unique aspects of the case [15].

However, despite many years of use of composite materials, there is no consensus among practitioners and in the literature on the recommended methods of finishing and polishing dental fillings. Therefore, the aim of this study was to investigate the effects of three different multistage finishing and polishing systems on the microhardness and roughness of various commercially available microhybrid and nanohybrid composites.

MATERIALS AND METHODS

Materials

Six different composites were used in the study (Table 1):

- micro-hybrid (Herculite XRV, Filtek Z250 and Charisma Flow) and
- nanohybrid (Herculite XRV Ultra, Filtek Z550 and Charisma Bulk Flow).

Specimen preparation

In accordance with the ISO 20795-1:2008 standard, a duralumin matrix was used to produce the samples – this allowed obtaining the desired shapes and dimensions. From each material, 40 cylindrical samples were made, measuring 6 mm in diameter and 2.5 mm in height. The composites were placed in the matrix using a ball feeder, and then the prepared form was placed between two glass plates covered with a transparent smooth polyester strips (TOR VM, Germany). The material was then compressed with a glass plate. The samples were subjected to a load of 500g for approximately 30 seconds to squeeze out excess composite and obtain flat surfaces.

Table 1. Characteristics of the tested materials (information provided by the manufacturer)

Resin composite	Matrix	Filler	Inorganic filler level	Average particle size	Manufacturer
Herculite HRV	Bis-EMA TEGDMA hexamethylene diacrylate 3-trimethoxysilylpropyl methacrylate	SiO_2 barium-silicate glass prepolymerized filler	69 wt% (59 vol%)	0.6 μm	Kerr USA
Filtek Z250	Bis-GMA UDMA Bis-EMA	zirconia/silica	66 wt% (60 vol%)	0.6 μm	3M ESPE USA
Charisma Flow	Bis-GMA	aluminum-barium-borosilicate glass barium-aluminum-borosilicate-fluorine glass fumed silica	68 wt% (59 vol%)	0.6 μm	Kulzer Germany
Herculite XRV Ultra	Ethoxylated Bis-GMA TEGDMA Bis-EMA	barium-aluminum-borosilicate glass fumed silica nanofiller prepolymerized filler	78 wt% (64 vol%)	0.03 – 0.05 μm	Kerr USA
Filtek Z550	Bis-GMA TEGDMA UDMA Bis-EMA PEGDMA	silica-zirconia fillers non-agglomerated / non-aggregated silica particles	82 wt% (64 vol%)	0.05 μm	3M ESPE USA
Charisma Bulk Flow	Bis-EMA HEDMA TEGDMA	barium-aluminum-fluoride glass	78 wt% (65 vol%)	0.02 – 0.07 μm	Kulzer Germany

Note: Bis-EMA – Bisphenol A ethoxylate dimethacrylate; TEGDMA – Di(ethylene glycol) methyl ether methacrylate; Bis-GMA – *2,2-bis*-[*4*-(*2-hydroxy-3-methacryloyloxy propoxy*) *phenyl*] *propane;* UDMA – 1,6-Bis(2'-methacryloyloxyethoxy-carbonylamino)-2,4,4-trimethylhexane; PEGDMA – Polyethylene glycol dimethacrylate; HEDMA – 2-hydroxyethyl methacrylate.

Each sample was polymerized according to the manufacturer's recommendations, using a C01-C LED polymerization lamp (Premium Plus, United Kingdom) at a radiation intensity of 900 mW/cm^2. The material was polymerized for 20 seconds, illuminating both sides of the sample. Immediately after hardening, the samples were removed from the matrix and stored in distilled water at 37 °C for 24 hours.

Finishing and polishing procedures

All samples were divided into four groups. Group 1 consisted of samples that were covered with a polyester strip (PS) and were not finished or polished (control group). In the remaining three experimental groups, the samples were pre-finished using a high-speed water-cooled head and two diamond drills, each used for 10 seconds,

Table 2. Technical details of finishing and polishing systems evaluated in the study

Polishing systems	Composition	Process	Manufacturer
Sof-lex disc (three-step)	aluminum oxide	medium grit disk 8690M – 20 s fine grit disc 8690F – 20 s superfine grit disc 8690SF – 20 s	3M ESPE USA
Enhance finishing point + PoGo (two-step)	aluminum oxide + diamond coated micro-polisher	finishing with light pressure – 20 s finishing with very light pressure – 20 s PoGo – 20 s	Dentsply Sirona USA
Kenda (three-step)	silicon carbide aluminum oxide	White rotation speed 7500-10000 RPM embankment size 63-150u – 20 s Green rotation speed embankment size nasypu 22-75u – 20 s Pink rotation speed 3000-7500 RPM embankment size 8-32u – 20 s	Industriezone Neugut Liechtenstein

in the same direction and parallel to the surface. Then, the samples were polished with three different systems (Table 2). Between each step, the samples were washed with water and dried with compressed air for 15 s.

All procedures were performed by a single trained employee to avoid operator variability. The test samples were polished once, and polishing was carried out in accordance with the manufacturer's instructions. A new polishing disc was used for each sample. After polishing, all samples were washed and then immersed in distilled water for 24 hours at 37 °C.

Microhardness measurement

A universal hardness tester (INNOVATEST VERZUS 750, Germany) was used, equipped with a strain gauge sensor and a precision actuator, guaranteeing repeatability of the set parameters and obtained results. The hardness of all materials was tested using a pyramid-shaped Vickers diamond indenter with an angle of inclination between opposite walls of 136°. The measurement methodology was developed based on the PN-EN ISO 6507-1 standard. Five measurements were made for each sample. To avoid irregularities resulting from the mutual influence of recesses, the distances between the centers of two impressions and between the impression and the edge of the sample were not less than twice the diagonal length of the impression. The test was carried out with a load of 200 g (1.96N; HV0.2) and lasting 15 s.

Roughness measurement

To measure the surface roughness, a confocal 3D laser measuring microscope (OLYMPUS OLS 4000 3D, Japan) was used. The measurement methodology was developed in accordance with the PN-EN ISO 4288:2011 standard. On its basis, 5 elementary sections with a length of Le = 0.25 mm were determined for each sample. The stereometry of the surface layer was defined using the amplitude parameter Ra – the average value of all deviations from a straight line within the length of the elementary section.

Microscopic analysis of surfaces and microstructure

To assess the surface of control samples and polished samples, two randomly selected discs were rinsed with distilled water and then dried with compressed air for 15 s. Then, to reveal the microstructure, the same samples were dehydrated using ethanol solutions (60%, 80% and 100%) immersed in an ultrasonic bath for 2 minutes each time. The samples were sputtered with gold and palladium and examined under scanning electron microscopy (Hitachi S-3000N, Hitachi High Technology Corp., Tokyo, Japan) at an accelerating voltage of 15 kV. The photos were obtained at x500 and x3500 magnification.

Statistical preparation

Data were statistically analyzed using SPSS Statistics 21 software (IBM Corpn., Armonk, NY, USA). One-way analysis of variance (ANOVA) and Tukey's multi-comparison were used to assess microhardness, while one-way analysis of variance was used to analyze roughness.

RESULTS

The average surface roughness values for six composites and selected sample finishing and polishing methods are presented in Table 3 and Figure 1.

According to one-way ANOVA, the effect of the type of composite and the indicated surface finishing methods on the roughness values was significant ($p < 0.001$). The lowest Ra values for samples not subjected to finishing and polishing among microhybrid composites were found in the Herculite HRV group (0.062 ± 0.015), while the highest - in the Filtek Z250 group (0.068 ± 0.012). Among the nanohybrid composites, the lowest values were recorded in the Herculite HRV Ultra group (0.031 ± 0.014), and the highest in the Filtek Z550 group (0.036 ± 0.052). The roughness results obtained for the control samples were characterized by significantly lower roughness values than the roughness values obtained after finishing and polishing the samples using all three polishing systems, both in the group of microhybrid and nanohybrid composites ($p < 0.05$).

For all groups of composite samples, no statistically significant differences were found between the Sof-Lex and Enhance+PoGo finishing and polishing methods ($p > 0.05$). At the same time, however, the measurement of surface roughness obtained after using the Kenda system for all materials showed significantly lower values than for

Table 3. Average values and standard deviations of surface roughness (Ra)

Material	Finishing/ polishing system	Mean values and standard deviations
Herculite HRV	PS Sof-Lex Enhance+PoGo Kenda	0.062 (±0.015) 0.210 (±0.012) 0.279 (±0.016) 0.161 (±0.010)
Filtek Z250	PS Sof-Lex Enhance+PoGo Kenda	0.068 (±0.012) 0.153 (±0.015) 0.175 (±0.011) 0.131 (±0.003)
Charisma Flow	PS Sof-Lex Enhance+PoGo Kenda	0.066 (±0.012) 0.236 (±0.018) 0.244 (±0.008) 0.193 (±0.005)
Herculite Hrv Ultra	PS Sof-Lex Enhance+PoGo Kenda	0.031 (±0.014) 0.158 (±0.011) 0.175 (±0.013) 0.126 (±0.012)
Filtek Z550	PS Sof-Lex Enhance+PoGo Kenda	0.036 (±0.015) 0.121 (±0.006) 0.135 (±0.014) 0.108 (±0.011)
Charisma Bulk Flow	PP Sof-Lex Enhance+PoGo Kenda	0.033 (±0.006) 0.142 (±0.010) 0.189 (±0.011) 0.125 (±0.009)

Note: PS – poliester strip (control group)

the other two methods ($p < 0.05$). Both samples made of the Filtek Z250 microcomposite material and samples made of the Filtek Z550 nanocomposite material were characterized by a lower Ra value than samples made of the other two materials ($p < 0.05$), finished with the Sof-Lex, Enhance + PoGo and Kenda methods.

The average surface microhardness and standard deviation obtained using the polyester strip, Kenda discs, Sof-Lex discs and the Enhance + PoGO system for six different composites are presented in Table 4 and Figure 2.

In the case of microhardness, the influence of the type of composite and the indicated surface finishing methods on the obtained values was also significant ($p < 0.001$). The surfaces of samples covered with a polyester strip and not subjected to finishing showed statistically significantly lower microhardness values compared to all polishing systems for all six tested resin composites ($p < 0.05$). The lowest microhardness values for samples not subjected to finishing and polishing among microhybrid composites were found in the Charisma Flow group (61.07 ± 1.71), while the highest – in

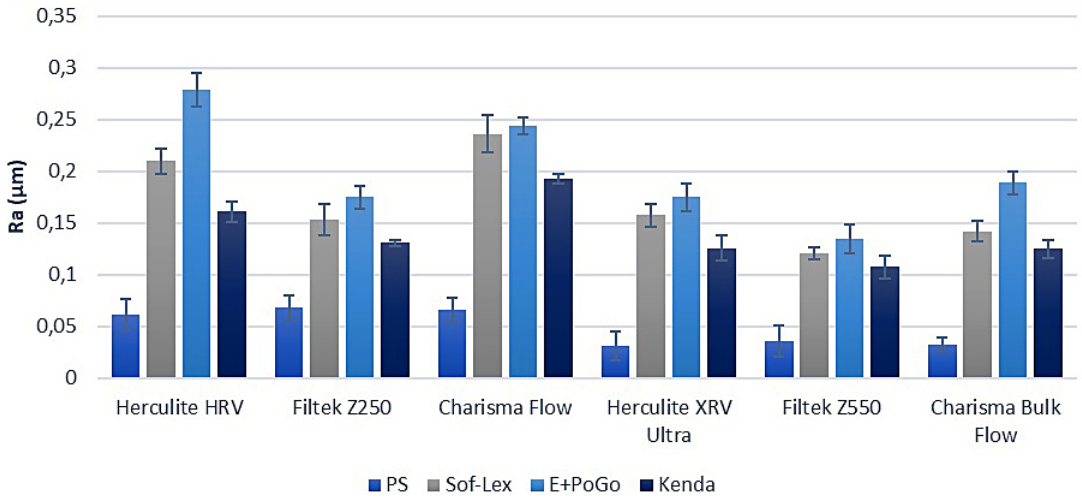

Fig. 1. Average values and standard deviations of surface roughness (Ra)

Table 4. Average values and standard deviations of surface microhardness

Material	Finishing/polishing system	Mean values and standard deviations
Herculite HRV	PS Sof-Lex Enhance+PoGo Kenda	67.52 (±1.12) 77.02 (±1.36) 76.12 (±1.19) 77.31 (±1.63)
Filtek Z250	PS Sof-Lex Enhance+PoGo Kenda	61.76 (±2.05) 67.24 (±1.35) 66.01 (±1.94) 68.73 (±1.74)
Charisma Flow	PS Sof-Lex Enhance+PoGo Kenda	61.07(±1.71) 67.76 (±1.04) 65.90 (±0.68) 67.71 (±1.23)
Herculite Hrv Ultra	PS Sof-Lex Enhance+PoGo Kenda	55.86 (±1.56) 67.31 (±1.01) 66.20 (±1.13) 67.54 (±1.51)
Filtek Z550	PS Sof-Lex Enhance+PoGo Kenda	53.44 (±1.42) 56.17 (±1.02) 57.12 (±0.81) 57.31 (±1.63)
Charisma Bulk Flow	PS Sof-Lex Enhance+PoGo Kenda	56.86 (±0.77) 68.12 (±1.19) 68.83 (±0.57) 69.63 (±0.70)

the Herculite HRV group (67.52 ± 1.12). Among the nanohybrid composites, the lowest values were recorded in the Filtek Z550 group (53.44 ± 1.42), and the highest in the Charisma Bulk Flow group (56.86 ± 0.77). Finishing and polishing of the samples resulted in a significant increase in microhardness in each group of samples, and no statistically significant differences were found between the microhardness obtained on the surface of the samples by the three finishing and polishing methods in all composite groups ($p > 0.05$).

It was noted that the microhardness value of Herculite HRV samples was statistically significantly higher than that of Filtek Z250 and Charisma Flow ($p < 0.05$), while for these two materials there were no statistically significant differences in microhardness values ($p > 0.05$). The lowest microhardness values were obtained for samples finished with the Enhance+PoGo method, however, in the case of the other two methods, the differences in microhardness were small and statistically insignificant ($p > 0.05$). The lowest

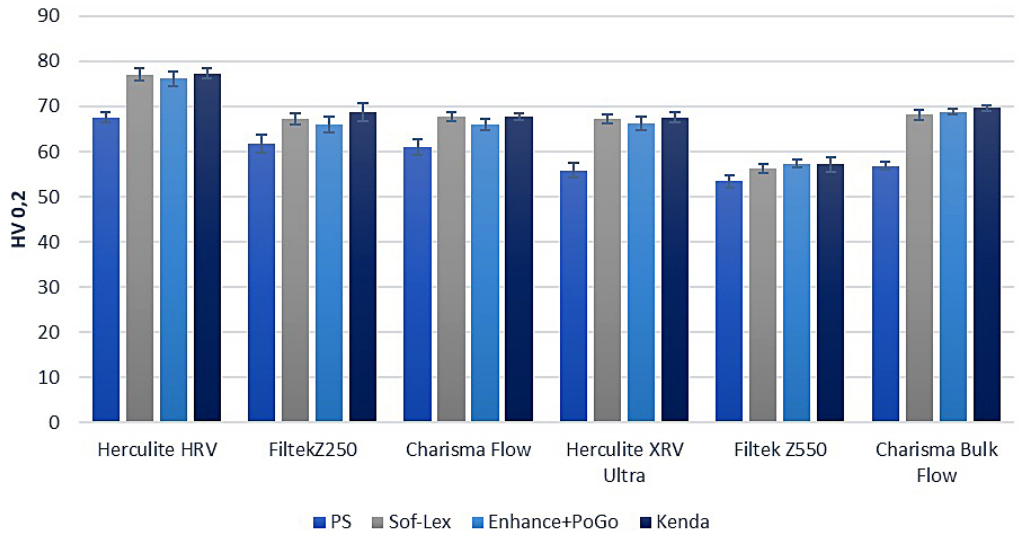

Fig. 2. Average values and standard deviations of surface microhardness (HV)

microhardness values among microhybrid materials were demonstrated for Charisma Flow ($p < 0.05$), while among nanohybrid materials the lowest values were obtained for Flitek Z550 ($p < 0.05$). In the case of Herculite HRV Ultra and Charisma Bulk Flow nanocomposites, very similar microhardness results were obtained both with respect to the material and the selected finishing and polishing methods.

The analysis of the sample surfaces was carried out using a Scanning Electron Microscope at a magnification of 500. Using the example of

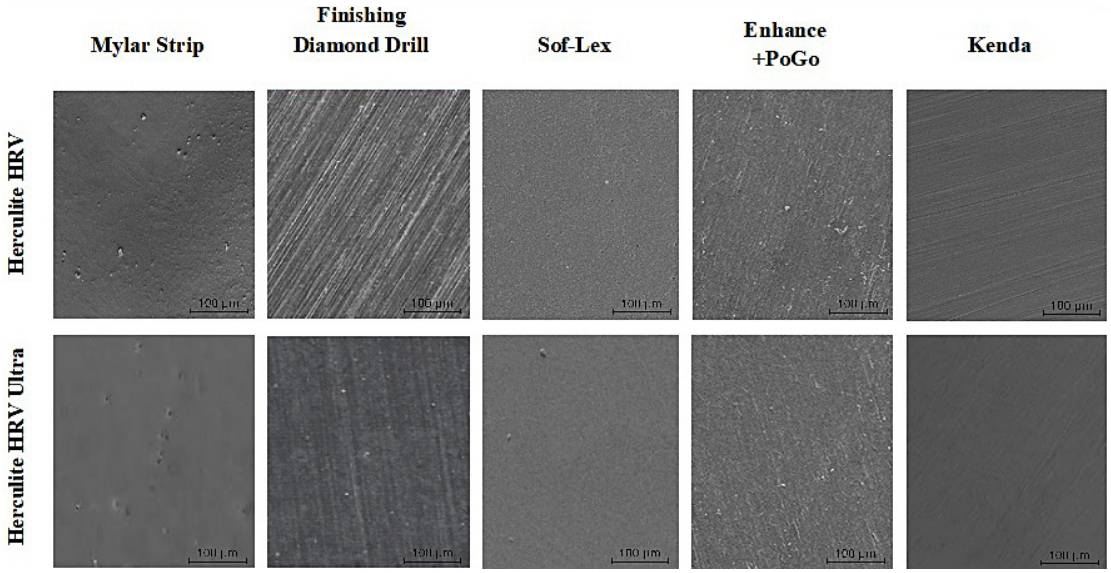

Fig. 3. SEM micrographs of the surface of control samples, finished with a diamond drill and polished using three methods on the example of Herculite HRV and HRV Ultra, ×500

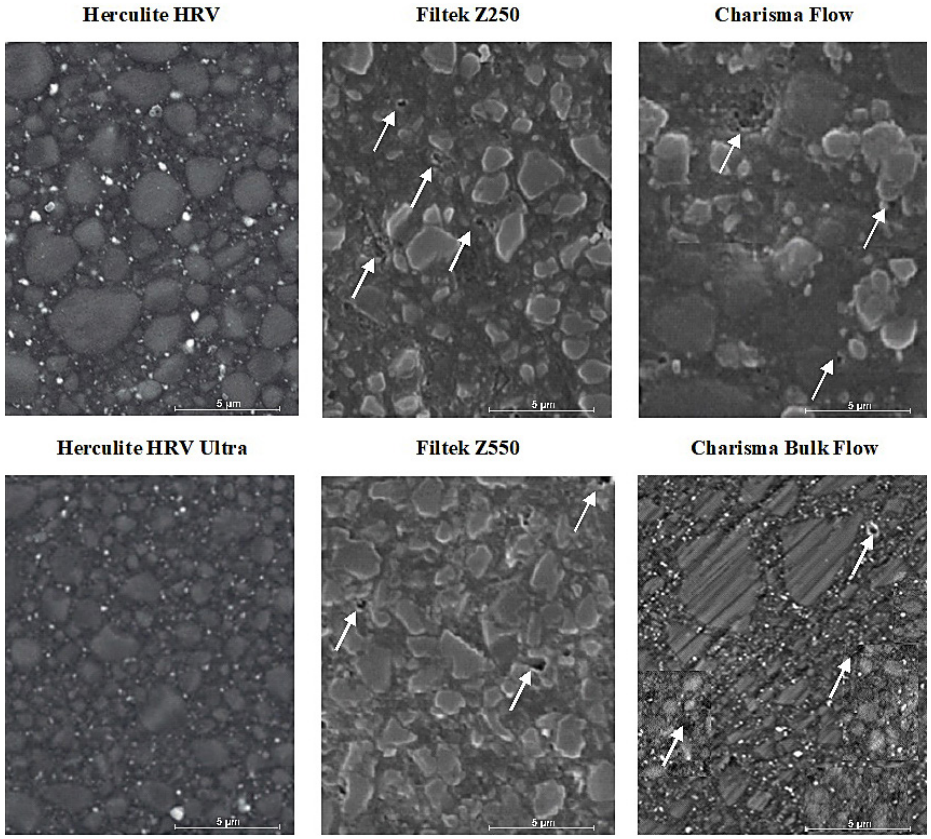

Fig. 4. Microstructure of representative composite samples, ×3500.
The arrows mark the pores revealed in the material

Herculite HRV and Herculite HRV Ultra materials, it was revealed that although the smoothest surface was obtained for control samples, microscopic observations revealed the presence of air bubbles and other flaws. The finished samples clearly show traces of the diamond drill used to remove excess material and pre-process. Microphotographs taken after polishing with the Sof-Lex and Kenda systems show the surface of the samples is smoother than in the case of Enhance+PoGo, where not only traces of the tool are visible, but also voids in the material (Fig. 3). Microscopic observations correlate with the results presented in Table 3 – samples finished with the Enhance+PoGo method were characterized by slightly higher roughness than the others.

The size, shape, number and type of filler particles mixed with the matrix are one of the factors affecting the properties of composites, therefore selected samples were subjected to microstructural assessment. Examination and analysis of the microstructure of representative samples revealed the presence of filler particles varying in size and shape. It is clearly visible that in the case of nanocomposites, the grain size is smaller and their number is larger. The filler particles in nanocomposites are finer and tightly arranged, which protects the resin matrix against excessive abrasion (Fig. 4).

DISCUSSION

In aesthetic dentistry, it is important to strive to obtain fillings that are as close as possible to the natural appearance of the tooth [16]. To achieve this, dentists take into consideration many key aspects when selecting materials – including finishing techniques, because when properly selected they improve the aesthetics and long-term quality of resin composite restorations [17].

Dental composites consist of a resin matrix and a filler in the form of microscopic particles. The flexible resin matrix affects the ability of the composite to deform under the influence of masticatory forces [18]. Too much flexibility may lead to an increase in surface roughness as a result of micro-deformations occurring in contact of the filling with the enamel of the opposing tooth [19]. The size, hardness and number of filler particles also have a significant impact on the mechanical properties, texture and roughness. The larger and harder the filler, the higher the load resistance, hardness and wear resistance (which is extremely important due to the contact of the filling with the enamel of the opposing teeth and the forces generated during chewing), but at the same time, the more uneven the filling surface [20-23].

Careful and precise finishing can reduce unevenness and improve the aesthetics of the filling. A rough composite surface results in a significant decrease in the quality of fillings. It also causes discoloration, which worsens their appearance [24, 25]. Greater retention of dental biofilm, especially in the gingival region, leads to gingivitis, but also to the dissolution of the organic matrix. All these factors may lead to the occurrence of secondary caries [26-28].

Dental composites – according to art – are applied in layers. The top layer of the composite is always removed during initial finishing. At this stage, it is necessary to adjust the filling surface to the patient's bite, so excess material is removed and shaped to reflect the geometry of the tooth. Finishing with a diamond drill not only removes material, but also increases the roughness. Therefore, the second stage of finishing is polishing, the aim of which is to make the surface of the composite filling the tooth as smooth as possible. There are several F/P systems available on the market, differing in the number of passes or stages, type of abrasive materials and chemical composition. However, to achieve the desired effectiveness, it is necessary that the abrasive particles have a higher hardness compared to the filler particles present in the resin – the hardness of the abrasive and the grain size affect how effectively the finishing material removes the irregularities of the composite surface. Otherwise, the inability to remove particles may result in tearing out fragments of the matrix, which results in an even higher final roughness than expected [29-31]. Another problem that cannot be ignored is the selection of a tool that, instead of smoothing the particles, selectively tears them out, which generates additional surface irregularities [32]. A higher Ra coefficient may also be caused by other factors related to the polishing tool, including: the geometry of the instrument and how it is used [33].The use of appropriate tools, techniques and degrees of polishing is therefore crucial to obtain a smooth surface.

Assessment of the effectiveness of finishing/polishing techniques requires determining not only the surface roughness, but also the surface microhardness value – these two features are one

of the most important factors determining the use of a specific material and the clinical success of the cavity filling procedure [34]. Three pairs of composite materials containing micro- and nanoparticles of fillers were selected to carry out this research. Although the average size of particles, their volume and mass fraction in these two groups of materials are similar, they differ in both the type of fillers and the matrix, which affects the results.

The research shows that the smoothest surfaces were obtained by hardening resin composite materials on a polyester strip. The unpolished surfaces of all tested composites were significantly smoother compared to the polished samples. This observation is also consistent with a published study by [35-37]. Moreover, the group of nanocomposites was also characterized by a significantly lower roughness value compared to the group of microcomposites. However, the surface layer of the control composites showed significantly lower surface microhardness, which results in lower physical, mechanical and biological properties [12, 38].

The clinical significance of surface roughness is strongly related to the bacterial colonization of surfaces in the oral environment. Many literature reports show that a surface roughness value Ra above 0.2 μm causes not only patient discomfort, but above all a significant increase in the colonization and adhesion of bacteria on composite surfaces [10, 39]. Roughness not exceeding the set value was achieved by all finishing and polishing methods in the nanocomposites group, while in the microcomposites group such results were achieved for Filtek Z250, Herculite HRV + Kenda system and Charisma Flow + Kenda. The nanoparticle material was characterized, as expected, by significantly better smoothness after polishing compared to the microhybrid material. A trend which indicates the best polishing effect with all three methods for the Filtek Z250 microcomposite material and the Filtek Z550 nanocomposite material, compared to the other materials was also noticed. Similar observations regarding the polishability of this group of materials were described by [35, 40, 41]. The roughnesses of materials from the Herculite and Charisma groups, both among microcomposites and nanocomposites, were similar to each other and significantly higher than the roughnesses of materials from the Filtek group. Although the average particle size of the fillers in both groups is very similar, differences in roughness are noticeable. This may be due to the fact that the smallest filler particles tend to form agglomerates, the final diameter of which may exceed the average values. Therefore, the smoothness of the filling surface will also depend on the quantitative ratio of free particles to the agglomerates formed and on their spatial distribution in the polymerized material [42, 43].

In this study, PoGo was used according to the manufacturer's recommendations, along with the Enhance drill. However, most researchers performed finishing with this method without preprocessin. Thus, Erdemir et al. used PoGo and Sof-Lex to polish nanohybrid dental fillings, obtaining lower surface roughnesses of samples after polishing with the first of these methods [36, 44]. Similar results – both for micro- and nanohybrid materials – were obtained by Korkmaz et al.[45] and Aljamhan et al. [46]. However, this research showed that the roughness of surfaces polished using the Sof-Lex system was lower, and this can be explained by the chemical composition of the abrasive – Sof-Lex discs are covered with aluminum oxide, while PoGo uses fine diamond powder – harder than aluminum oxide, therefore, it can cause deeper scratches on the surface of composites and, ultimately, higher roughness [47, 48]. This thesis seems to be confirmed by the results of Baseren's research, which showed that the use of abrasive discs impregnated with aluminum oxide allowed for obtaining the smoothest surfaces. The researcher assumed that these discs remove surface scratches resulting from the impact of diamond drills and tungsten carbide on the sample [49]. Also, Üçtasli et al. [50] and Koh et al. [51] assessed the impact of Sof-Lex and PoGo polishing systems on the surface roughness of composite resin. The results of their tests showed that for all materials tested, Sof-Lex discs produced a smoother surface than PoGo. However, these differences were not statistically significant, so such results can be explained by methodological differences adopted in the studies and the accuracy of the profilometer.

Alfawaz [47], Erdemir et al. [36] and da Silva et al. [52] indicated that there is a direct correlation between surface roughness and microhardness – high surface roughness values were associated with high microhardness values in restorative materials. Korkmaz et al. related the hardness of composites to the content of inorganic fillers. In their tests, the composite with the highest filler content showed significantly higher

microhardness compared to other materials [45]. However, this thesis was not confirmed in this study, and the nanocomposite with the highest filler content (82% by weight) – Filtek Z550, was characterized by significantly lower microhardness compared to other materials ($p < 0.001$). Moreover, as in the case of all biomaterials, it is important that dental composites have parameters similar to natural tissue; in the case of tooth structures, the hardness of enamel and dentin is 320 VH and 60 VH, respectively (measured on the Vickers scale). It was also stated that the minimum hardness of the dental composite should be 50 VHN [53]. Although all tested samples - including the control ones - were characterized by a hardness value higher than the minimum, the lowest results for this feature were demonstrated for the Filtek Z550 material.

CONCLUSIONS

The research was carried out on flat samples, while a dental filling must reproduce the geometry of the tooth. Nonethless, in the light of the above studies, it was shown that the polishing system and the size of the filler particles in the composite affect the microhardness and roughness of the filling surface. Surface polymerization of composites on a polyester strip provides the smoothest surface finish, but also the lowest microhardness. Composite surfaces after polishing with the Sof-Lex polishing system show a smoother surface than in the case of the Enhance + PoGo polishing system. The roughness of the composite surface affects the durability of the filling, the ability to maintain oral hygiene and aesthetics, so paying attention to this aspect is crucial to obtaining satisfactory results. Moreover, the nanohybrid composite obtained better results in terms of microhardness and surface roughness than the microhybrid composite.

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