Comparison of the Mechanical Properties of Various Microhybrid Dental Composites

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Abstract

Aim The objective of this study was to investigate the surface microhardness and roughness of several michrohybrid dental composite restorative materials comparatively.

Material and method The study encompassed four distinct brands of microhybrid-type dental composites, including two newly introduced ones, Dentac Myra and Dentac Pergamon, alongside Gradia Direct Posterior and 3M Z250. Additionally, a newly manufactured Parion Flow flowable composite was also included. For surface microhardness testing, 45 composite discs were prepared with a diameter of 5 mm and a thickness of 2 mm for each group (n=9). For surface roughness, 45 composite discs with a diameter of 8 mm and a thickness of 2 mm were prepared (n=9). Surface microhardness was measured using the Vickers Hardness Test device, and surface roughness was measured using a contact profilometer. One-Way ANOVA with Tukey's HSD analysis and the Kruskal-Wallis H test with Dunnett's correction were used for intergroup comparisons.

Results Strongly significant differences were observed among groups in terms of microhardness ($p < 0.0001$; $F = 94.75$). The highest Vickers hardness number (VHN) was obtained for 3M Z250, while Gradia Direct Posterior exhibited inferior values compared to Myra ($p > 0.05$) and Pergamon ($p = 0.0378$). Significant differences were found among groups in terms of surface roughness ($p < 0.0001$; $H = 34.36$), with Gradia Direct Posterior having the highest roughness value.

Conclusion Myra and Pergamon demonstrated better performance in terms of surface roughness and microhardness values compared to Gradia Direct Posterior. The similar performance was not observed compared to 3M Z250

Keywords Dental composite, Inorganic fillers, Microhybrid mechanical properties, Surface microhardness, Surface roughness

Introduction

Resin-based composites, widely employed among dental restorative materials, are extensively utilized by clinicians in both anterior and posterior regions due to their enduring lifespan and remarkable aesthetic performance (1). For dental composites chosen for treatment purposes, it is necessary that certain mechanical, physical, and aesthetic attributes to be at an elevated level, and the components constituting the composite structure be formulated in specific proportions (2).

Fundamentally, the content of the inorganic phase in dental composites, which is primarily composed of organic (3), inorganic (4), and intermediary phases binding these two (5), significantly influences the physical properties, characteristics, and thus, the longevity of the restorative material within the oral environment (1). The presence of various fillers constituting the inorganic phase in different weights and volumes contributes to the production of composites with enhanced mechanical properties and durability (6). Depending on the particle sizes of these fillers, they can be classified as macrofills, microfills, or hybrids (7). The particle size and quantity of the fillers composing the structure of dental composites are associated with characteristics such as polymerization shrinkage, mechanical adequacy in areas of high occlusal load, fracture and wear resistance, and surface roughness, directly impacting the performance of the composite.

The physical, mechanical, optical, and efficacy against microorganisms of dental composites can be tested using various methods in a laboratory environment. In the literature, test methods such as microhardness (8), color stability (9), surface roughness measurement (10), water absorption (11), monomer conversion (12,13), dental biofilm and microorganism adhesion (14) are observed to be used to assess the properties of resin-based materials.

In light of this information, the aim of this study is to investigate the mechanical properties of produced microhybrid-type dental composite materials using Vickers microhardness and contact surface roughness test methods. Given the limited number of studies in the literature concerning newly produced dental composite materials (Dentac Myra & Dentac Pergamon), this study was conducted. The null hypothesis of the study is that there is no statistically significant difference among dental composites in terms of both microhardness and surface roughness values.

Material and Methods

Preparation of Samples and Determination of Sample Size

This study's experimental design was conducted in a laboratory setting. The determination of group sample sizes for both methods was realized using the statistical analysis program G. Power 3.1.7. Power analysis was performed, expressing the study's

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power as 1-ß (ß = Type II error probability). For the surface microhardness test, an effect size of f = 2.77 was determined, considering the values from Marović et al.'s study (15). To achieve an 80% power at α: 0.05, a minimum of 8 composite disk samples was calculated to be required in each group. For the surface roughness test, with an effect size (d) of 1.6641106 based on Junior et al.'s study (16), and with the study's power set at 80% at a: 0.05 level, a minimum of 6 composite disk samples per subgroup was determined.

Table 1: The origins, compositions, and characteristics of dental composites

Name	Manufacturer, Origin	Ingredients (Organic / Inorganic)	Filler load (wt%/ vol%	Type	The recommended polymerization type	Lot number
Parion Flow	Dentac T-Resto, Türkiye	BIS-GMA BIS-EMA UDMA TEGDMA / inorganic filler, silica, quartz	60/40	Flowable	LED A1-A2 : 10 sec A3,5-A4: 20 sec	DC741A2
Myra	Dentac T-Resto, Türkiye	BIS-GMA BIS-EMA UDMA TEGDMA / inorganic filler, silica, quartz	77-78/66	Microhybrid*	LED A1-A2 : 10 sec A3,5-A4: 20 sec	DC702A2
Pergamon	Dentac T-resto, Türkiye	BIS-GMA BIS-EMA UDMA TEGDMA / inorganic filler, silica, quartz	77-78/66	Microhybrid	LED A1-A2 : 10 sec A3,5-A4: 20 sec	DC731A2
Gradia Direct Posterior	GC Dental Products, Japan	UDMA, dimethacrylate, co-monomers / Fluoro-alumino-silicate glass, prepolymerised filler, silica	77/65	Microhybrid	High power LED (more than 1200 mW/cm2) : 10 sec Halogen / LED (700 mW/cm2) : 20 sec	2111021
Z250	3M ESPE, USA	BIS-GMA, UDMA, BIS-EMA / zirconia-silica, particul size range of 0.01 – 3.5 µm	77.5/ 60	Microhybrid	Halogen or LED minimum intensity 400 mW/cm2 : 20 sec	NC38554

Abbreviations: BIS-GMA: Bisphenol A diglycidyl methacrylate, UDMA: Urethane dimethacrylate, TEGDMA: Triethylene glycol dimethacrylate, BIS-EMA: Bisphenol A ethoxylate dimethacrylate, LED: Light Emitting Diode, n.i: not informed.
*According to the information obtained from the product manager, in the Myra composite, a small amount of certain nanopartides has been incorporated into the structure, distinguishing it from Pergamon. The product is marketed as a microhybrid.

For both testing methods, a total of 90 composite disk samples were prepared, with 9 samples in each subgroup (n=9). In the assessment of surface roughness, the sample discs of 2 mm thickness and 8 mm diameter were created. Conversely, the microhardness examination involved the utilization of specimens characterized by a thickness of 2 mm and a diameter of 5 mm. The names, brands, origins, and content information of the dental composites used in the study are presented in Table 1.

Evaluation of the Surface Microhardness

The composite samples to be used for the microhardness test were prepared with a thickness of 2 mm and a diameter of 5 mm. With the assistance of a specialized teflon mold, a total of 45 samples were prepared, with at least 9 samples in each group. Initially, a glass substrate was placed at the bottom. Transparent mylar strip was applied to both surfaces of the teflon mold placed on the glass. The polymerization process of each sample was carried out using a recommended light source and duration (Valo, Ultradent Inc., Utah, USA) in accordance with the manufacturer's instructions. A Vickers hardness-testing device (Shimadzu HMV-G31D, Shimadzu Corporation, Japan) was used for the microhardness test. Using a Vickers Hardness tester, notches were created on the composite discs by applying a ≈50 g (490.3 mN) force for 15 seconds. The led beam from the Vickers test arm of the device was used to attempt to create the notches at the center of the composite disc. The diagonal lengths of each created notch were calculated using an ocular lens magnified to 40x. The following equation was used to measure surface microhardness: $H= 1854.4 (Pd^{-2})$. Where H represents Vickers hardness (kg/mm^2), P denotes the applied force (g), and d signifies the average length of the diagonals (µm). The obtained results were expressed as Vickers hardness number (VHN).

Evaluation of the Surface Roughness

For the measurement of surface roughness of the included composites in the study, composite discs were prepared using a specialized teflon mold. The prepared discs had a thickness of 2 mm and a diameter of 8 mm, with a total of 45 samples, 9 in each composite group. Composite disc samples were prepared by applying transparent polyester tape to both surfaces of the Teflon mold on a glass substrate. The polymerization process of each sample was carried out using a recommended light source and duration (Valo, Ultradent Inc., Utah, USA) in accordance with the manufacturer's instructions. A contact profilometer device (Surtronic S128, Taylor Hobson, Leicester, United Kingdom) was used to measure surface roughness. Prior to measurement, the upper surface of the composite discs underwent a low-speed micromotor finishing-polishing process using a finishing-polishing kit (Sof-Lex Disc 3M ESPE, St. Paul, USA) to create a uniform area for measurement and ensure standardization. To establish a standardized measurement surface for all samples, the thickest-grit disc of the relevant kit was used to roughen the measurement surface of the composite discs without water. Then, the debris on the sample surfaces was washed and rinsed, and the samples were incubated in an oven at 37°C for 24 hours until the measurement time. The preparation and measurement of all samples were conducted by a single researcher (M.K.U.) to ensure standardization. Prior to measuring each composite group, the device was calibrated using its calibra-

tion mode. Measurements were taken from three different regions for each sample, and their averages were calculated. Using a portable contact profilometer, the roughness values of each sample were calculated in terms of Ra. The profilometer device was used with a stylus having a 0.2 mm cutoff length, a 2 mm evaluation length, within the range of up to 400 μm.

GraphPad Prism software (GraphPad Software, Inc., California, USA) was used for statistical analyses. While assessing the study data, in addition to the descriptive statistical methods (mean, standard deviation, minimum, maximum), the normality of quantitative data, where n<50, was examined using the Shapiro-Wilk test. Furthermore, confirmation of normal distribution was verified through Q-Q plots and computation of skewness-kurtosis values. If normal distributiona was established, the presence of statistically significant differences in multiple comparisons was explored utilizing the One-Way ANOVA with Tukey's honestly significant difference (HSD) analysis. If normal distribution was not observed, the presence of statistically significant differences in multiple comparisons was examined using the Kruskal-Wallis H test with Dunnett's correction. Significance was evaluated at the lowest level p<0.05.

Results

In present study, the results obtained for Vickers surface microhardness are presented in Table 2-3 (Figure 1), and the results for surface roughness are shown in Table 4 (Figure 2). Regarding microhardness, a statistically strong significant difference was detected among the composites (p < 0.0001; F = 94.75), and additional tests revealed from which groups the difference originated (Table 3). The microhardness values of the composites were ranked from highest to lowest as follows: Z250 (70.92 VHN) > Pergamon (58.82 VHN) > Myra (53.87 VHN) > Gradia Direct Posterior (52.74 VHN) > Parion Flow (30.67 VHN). Parion Flow had significantly lower microhardness values with a very strong statistical significance compared to all other composites (p<0.0001), conversely, this was observed for Z250 (p<0.0001). No statistically significant difference was observed between Myra and Pergamon or Gradia Direct Posterior in terms of VHN (p>0.05). On the other hand, a significant difference was found between Pergamon and Gradia Direct Posterior (p=0.0378). With respect to surface roughness among the composites, a statistically strong significant difference was found (p<0.0001; H = 34.36), and additional tests showed from which groups the difference originated (Table 4). The surface roughness values of the composites were ranked from highest to lowest as follows: Gradia Direct Posterior (3.056 Ra) > Pergamon (2.474 Ra) > Z250 (1.959 Ra) > Myra (1.844 Ra) > Parion Flow (1.296 Ra).

Table 2: ANOVA analysis result

ANOVA table	SS	DF	MS	F (DFn, DFd)	p
Treatment (between columns)	22923	4	5731	F (4, 130) = 94.75	<0.0001
Residual (within columns)	7863	130	60.49		
Total	30787	134			

Parion Flow did not exhibit a statistically significant difference with Myra (p>0.05), while Pergamon showed a strong (p<0.001) and Gradia Direct Posterior exhibited a very strong (p<0.0001) statistical significance.

Table 3: Comparison of the surface microhardness values

VHN	Mean ± sd (Min – Max)	p*	Differences
Parion Flow (A)	30.67 ± 6.72 (17.60 - 49.20)	$<0.0001^{B-C-D-E}$	B-C-D-E
Myra (B)	53.87 ± 7.97 (34.00 - 66.10)	$<0.0001^{A-E}$	A-E
Pergamon (C)	58.82 ± 5.63 (48.80-71.50)	$<0.0001^{A}$ 0.0378^{D} $<0.0001^{E}$	A;D;E
Gradia Direct Posterior (D)	52.74 ± 6.39 (36.10 - 62.60)	$<0.0001^{A-E}$ 0.0378^{C}	A-E;C
3M Z250 (E)	70.92 ± 11.00 (46.30 - 88.00)	$<0.0001^{A-B-C-D}$	A-B-C-D

**One-way ANOVA with Tukey's HSD (p<0.05)*

A significant difference was also detected between Z250 (p<0.05). No statistically significant difference was found between Gradia Direct Posterior and Z250 (p>0.05), and there was no statistical significance between Myra and Pergamon (p>0.05). The microscopic images of all dental composites included in the study at a magnification of x40 are presented in Figure 3.

Table 4: Comparison of the surface roughness values

Surface Roughness	Mean ± sd (Min – Max)	p*	Differences	H	p**
Parion Flow (A)	1.296 ± 0.762 (0.6 – 3.5)	$<0.001^{C}$ $<0.0001^{D}$ $<0.05^{E}$	C;D;E		
Myra (B)	1.844 ± 0.859 (0.9 – 3.9)	$<0.05^{D}$	D		
Pergamon (C)	2.474 ± 1.182 (0.7 – 4.8)	$<0.001^{A}$	A	34.36	<0.0001
Gradia Direct Posterior (D)	3.056 ± 1.337 (0.9 – 6.2)	$<0.0001^{A}$ $<0.05^{B}$	A;B		
3M Z250 (E)	1.959 ± 0.766 (1 – 3.6)	$<0.05^{A}$	A		

**Kruskal-Wallis H test with Dunnett's correction (p<0.05), **Kruskal-Wallis H test*

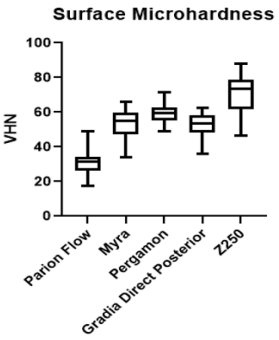

Figure 1: Graphical representation of the surface microhardness values

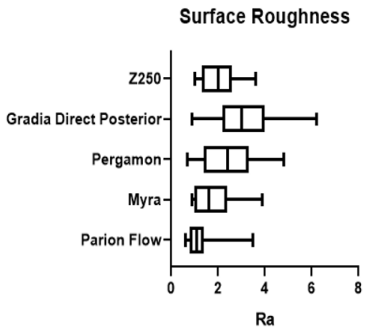

Figure 2: Graphical representation of the surface roughness values

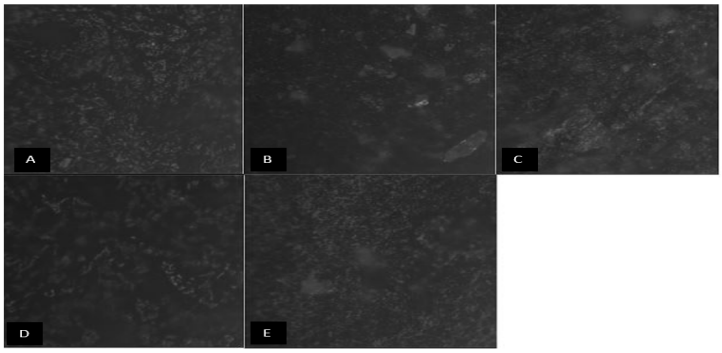

Figure 3: The images of dental composites at a magnification of x40. (A: Gradia Direct Posterior, B: Dentac Myra, C: Dentac Pergamon, D: Dentac Parion Flow, E: 3M Z250)

Discussion

The null hypothesis of the study was disproven based on the obtained data. According to both methods, statistically significant differences were found among dental composites. Through research in the field of composites, inferences about the success of restorations can be drawn, and restorative materials are constantly improved, striving towards achieving the most optimal restorative material (2). Clinicians need to have a comprehensive understanding of the components, advantages, and disadvantages of any biomaterial, as this holds crucial importance for the accurate selection of restorative materials (17). A study revealed that microhybrid composite materials are preferred to nanohybrids in higher proportions (55.9% and 44.10%, respectively) (17). Additionally, in the study by Kazier et al., out of 38 identified composites in the literature, 31 were determined to be of the microhybrid type (1). Microhybrid composites exhibit high wear resistance and can be endowed with improved mechanical properties, displaying abrasion capability similar to that of enamel (18). Consequently, they are suitable for dental restorations that require high occlusal stress-bearing capacities (19). As a result of the inadequate polishing efficacy exhibited by hybrid composites, manufacturers have opted to diminish the dimensions of larger filler particles. This alteration is aimed at improving the potential for achieving a smoother finish, all the while preserving a substantial filler content. Thus, microhybrid composites, which offer approximately 75-85% filler loading, have been introduced as materials with good durability, lacking particles larger than 1 μm, and are safe for use in both anterior and posterior restorations. Based on this information, our study comprehensively examined the performance of four microhybrid dental composite restorative materials, including two newly introduced ones (Dentac Myra and Dentac Pergamon), in terms of surface hardness and surface roughness.

Hardness is defined as the measure of resistance that emerges as a material undergoes plastic deformation at the point where force is applied, either through an indenter or as a result of an applied force. Today, non-destructive testing (NDT) methods have gained importance, allowing the measurement of material performance without any invasive intervention into the material being tested (20). Among hardness testing methods, it is noted that macro, micro, and nano-indentation tests are used. Additionally, methods such as Brinell, Knopp, Rockwell, and Vickers are applied, with load ranges in microhardness methods varying from 1 to 1000 grams (21). In the field of dentistry, Knopp and Vickers tests are the most commonly encountered in the literature; the Vickers test is a non-destructive method that can be applied across a wide range of materials. Moreover, the diagonal length of the square formed by the diamond indenter can be automatically measured using devices, and the aforementioned formulation can be computed automatically in a computer environment (21). Hence, in this study, the Vickers surface microhardness test was utilized. Although there is an ISO standard attributed to this method in the literature (22), it is observed that different forces and holding times are applied in studies. Examples include 300 g – 20 sec (23), 300 g – 15 sec (24), 200 g - 10 sec (25), 100 g - 10 sec (8), and 5 g or 10 g (15). Moreover, disks of different thicknesses and diameters have been used, such as 1x7mm (24), 2x8mm (26), 4x6mm (8), and 2x10mm (23). Although these variations might appear as a lack of standardization, each study is conducted uniquely with distinct purposes and various resources (financial and laboratory conditions). Therefore, researchers can consider different loading forces, application durations, and disk sizes based on their objectives. In our study, an approximate force of 50 g was applied to the sample surfaces for 15 seconds. Following measurements, the highest VHN value was observed in Z250, while the lowest value was in Parion Flow. The values of Gradia Direct Posterior were found to be lower than those of Myra and Pergamon. The nature and quantity of the inorganic structure can directly influence microhardness values (27). In Z250 samples (77.5 wt%, 60 vol%), higher values in Myra (77-78 wt%, 66 vol%), Pergamon (77-78 wt%, 66 vol%), and Gradia Direct Posterior (77 wt%, 65 vol%) could be attributed to the higher filler content compared to others (8). Additionally, the amount of residual monomers and different matrix polymers can lead to different results (28,29). Prior to testing, these materials were stored in distilled water at 37°C for 24 hours. Z250's structure includes zirconia-silica particles. It is known that zirconia-silica can be affected by water over time due to its spherical structure, potentially leading to water uptake and adversely affecting the connection with the resin matrix and mechanical properties (29). However, as this study only involved immersion in water for 24 hours, these negative effects were not realized, and hence, higher values were observed in Z250. Additionally, zirconia-silica can behave like nanoclusters, enhancing the mechanical properties of the structure

(30). According to information obtained from the product manager, Myra's structure contains some nanoparticles in addition to the normal content. Although not statistically significant, the difference in VHN values between Myra and Pergamon and Myra's higher value may be attributed to this aspect. Gradia Direct Posterior contains pre-polymerized fillers with C=C bonds. This structure can form covalent and hydrogen bonds with the methacrylate matrix. Moreover, it can be stated that Gradia Direct Posterior is a more hydrophobic composite due to the use of a more hydrophobic silane treatment compared to conventional silanol treatment (31). The hydrophobic or hydrophilic nature of the polymer structure and the degree of conversion are factors that can affect water absorption (32). Additionally, a low degree of conversion hampers polymer cross-linking in the composite, rendering it susceptible to water absorption, resulting in a decrease in hardness and mechanical properties (33). Regarding monomers, TEGDMA has a higher water-absorbing character compared to other methacrylates, and when used in conjunction with BIS-GMA, it increases the composite's hydrophilic character and invites deterioration in mechanical properties in water-based environments (34). In light of this information, despite Gradia Direct Posterior having a low viscosity due to containing only UDMA as a monomer (3) and having a more hydrophobic structure due to the aforementioned features, its lower microhardness values compared to composites with BIS-GMA and TEGDMA might also be related to the degree of conversion of the composite. This introduces a limitation in the study, requiring a future research agenda in this field.

In surface roughness studies, surfaces can be scanned using mechanical or optical probes, and they can also be visualized in either 2D or 3D. While non-contact optical profilometers that perform three-dimensional measurements are much more successful in distinguishing and detailing surface topography (35), in this study, a contact surface profilometer was used due to laboratory facilities and its frequent utilization in the literature for obtaining rapid results (1,36,37). The necessity of maintaining specific standards for surface roughness has been discussed for the long-term preservation of the esthetic characteristics of composites and the prevention of microbial colonization on the structure. In this context, the result of a systematic review indicated that for preventing bacterial accumulation in composites in most in vivo studies, the threshold value for surface roughness should be 0.2 μm (38). In our study, during the preparation of composite samples, the coarsest-grit disk from a finishing-polishing set was used without water. According to the literature, it is reasonable to consider that lower values might be observed in samples where all components of a similar set are used compared to our samples (10,39).

The objective of this study is to measure the surface roughness values of composites in their most natural state, and it is not one of the purposes to evaluate how effective any polishing set is. In this context, in order to make the most accurate assessment, all components of a polishing set were not applied. Different grit sandpapers were reported to be used in the preparation of composite samples (27). This situation emerges as a limitation of the study, and the investigation of surface roughness values that would be obtained after using various finishing and polishing systems with the materials used in the study is a topic for future research. In our study, the lowest surface roughness was observed in Parion Flow, while the highest value was obtained in Gradia Direct Posterior. Myra and Pergamon exhibited lower values compared to Gradia Direct Posterior, while Pergamon showed higher values than Myra, albeit not statistically significant. In a systematic review where various types of composites (submicron-nanofillers-microhybrids) were evaluated in terms of roughness and gloss, although there is no definitive evidence in the early stages of the study that the composite type affects the roughness performance (1), nanofilled or submicron composites may perform better in terms of roughness than microhybrids (1). Although Myra and Pergamon resemble each other in terms of content on paper, a difference was observed in surface roughness values, albeit not statistically significant, indicating that Myra is better than Pergamon in terms of roughness. According to information obtained from the product manager, it is believed that this difference arises due to the addition of a small amount of nanoparticles to the Myra structure. It is evident that as the particle size in the inorganic structure decreases, smoother surfaces will form, and it has been reported that contemporary microhybrids have particle sizes up to an average of 1 μm (1). According to the usage guidelines of the composites included in the study and information obtained from the product manager, the average particle size of Z250 is 0.6 μm (range: 0.01 - 3.5 μm), the average particle size of Gradia Direct Posterior is 0.85 μm (range not specified), and the particle size of Myra and Pergamon is reported as (>1 μm). In light of this information, although different surface roughness values were observed between Myra, Pergamon, and Z250, there is no statistically significant difference, and the average particle size may not parallel surface roughness. However, there is a statistically significant difference between Gradia Direct Posterior and Myra, and this difference is thought to be due to Myra containing a small amount of nanoparticle structure.

Surface roughness is influenced not only by particle size but also by factors such as particle shape, size distribution, resin matrix composition, and degree of conversion (40). Furthermore, an increase in surface roughness adversely affects color stability, and multi-step polishing techniques applied to reduce surface roughness create a smooth surface that ensures color stability (41). In a retrospective clinical study, the 10-year performance of four different microhybrid composites was examined. Among these composites, Gradia Direct Posterior showed acceptable clinical performance, but there was a statistically significant difference in terms of color stability, and its failure rate (8.57%) was higher compared to the others. The study also found that Z250 had the lowest failure rate (0.9%) among the composites (42). A similar prospective study also reported a failure rate of 8.5% for Gradia Direct Posterior (43). Lempel et al. suggested that significant color changes in the material might be attributed to the higher average particle size of Gradia Direct Posterior compared to other our study's results are in line with these findings (42). Z250 has a lower average particle size compared to Gradia Direct Posterior and exhibited lower surface roughness. The lower values of Myra and Pergamon compared to Gradia Direct Posterior could stem from various factors, such as other inorganic fillers in the composition (quartz, fluoro-aluminosilicate, etc.) or unreacted matrix monomer (degree of conversion). In future studies on dental composites, SEM imaging along with EDX elemental analysis will contribute to a better understanding of the obtained results. An in vivo study focusing on

surface roughness revealed that individuals can perceive roughness differences in the range of 0.25 to 0.50 μm, which covers the natural enamel roughness. Consequently, it has been emphasized that the maximum roughness should not exceed 0.50 μm during finishing and polishing procedures of restorative materials to ensure they go unnoticed by patients (44). The amount of roughness can affect not only patient awareness but also the formation of biofilms due to plaque and bacterial adhesion (14). Bacterial adhesion not only contributes to the development of decay and other oral diseases but also compromises the mechanical properties of the material. For instance, in resin-based materials, a one-month S. mutans adhesion increases surface roughness and promotes bacterial attachment, creating a potentially incessant loop (45).

One limitation of the study is the comparison of only microhybrid-type dental composites. In subsequent studies, a comprehensive investigation can be conducted by comparatively testing dental composites of different types. Another limitation is that certain materials that are not explicitly stated in the ingredients list mentioned in the usage guidelines of dental composites might be considered trade secrets, and these materials could directly affect the test results. Looking towards future research, similar to Myra and Pergamon, the recently produced and developed flowable composite, Parion Flow, can be evaluated against other existing flowable composites on the market. Other mechanical tests, biocompatibility assessments, and methods for color stability that were not covered in this study should be taken into consideration. Tests related to monomer conversion and monomer release of newly developed composites should be performed. Additionally, the effectiveness of aging methods on dental composites can be explored using various aging techniques.

Conclusion

Despite the apparent superiority of the recently introduced dental composites - Myra and Pergamon - over Gradia Direct Posterior - in terms of surface roughness and surface microhardness values, the recently introduced dental composites have demonstrated somewhat inferior performance in comparison to Z250. It should be noted that the surface roughness values do not exhibit a direct correlation with the average particle size.

Declarations

Author Contributions: *Conception/Design of Study- M.Y.Ü., M.K.Ü.; Data Acquisition- M.Y.Ü., M.K.Ü.; Data Analysis/Interpretation- M.Y.Ü., M.K.Ü.; Drafting Manuscript- M.K.Ü.; Critical Revision of Manuscript- M.Y.Ü., M.K.Ü.; Final Approval and Accountability- M.Y.Ü., M.K.Ü.; Material and Technical Support- M.K.Ü.; Supervision- M.Y.Ü., M.K.Ü.*

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