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Comprehensive Evaluation of Six Flowable Composite Resins in the Market: A Comparative Study

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A B S T R A C T

Objectives: This study aimed to comprehensively evaluate the mechanical and physical properties of six commercially available flowable dental composite resins, providing critical insights for informed material selection.

Materials and Methods: Six flowable composite resin materials namely Edge Flow (EDF), Opallis Flow (OPF), Els Flow (ELF), Denfil Flow (DFF), DX Flow (DXF), and Charisma Flow (CHF) were tested according to ISO 4049 standards. Each material underwent evaluation of depth of cure, flexural strength, solubility, water sorption, and radiopacity. Statistical analyses with ANOVA and post-hoc Tukey test were conducted to identify significant differences among the six study groups (alpha=0.05).

Results: Significant material-specific differences were noted in depth of cure and flexural strength among the six study groups ($P<0.05$). Solubility and water sorption profiles were also significantly different among the study groups ($P<0.05$). All tested composite resins met the required radiopacity standards, ensuring accurate radiographic diagnosis and monitoring. However, none of the composite groups achieved an exact color match with the A2 reference shade.

Conclusion: This study revealed significant differences in mechanical properties of flowable composites, particularly in depth of cure and flexural strength, underscoring the importance of selecting the appropriate material. Shade matching presented ongoing challenges, emphasizing the need for careful material selection. Future research should explore long-term clinical performance and standardized methods for handling of pre-test failures.

Keywords: Composite Resins; Flowable Hybrid Composite; Mechanical Tests

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INTRODUCTION

Dental composite resins have significantly contributed to the advancement of restorative dentistry, offering a diverse range of options for clinicians to address various clinical scenarios. Among these materials, flowable composite resins have emerged as a popular choice due to their low viscosity, which facilitates flow and accelerates filling, enhanced delivery by using a syringe, and superior cavity adaptation [1].

However, the mechanical and physical properties of flowable composites, including depth of cure, flexural strength, solubility, water sorption, and radiopacity, are critical determinants of their clinical performance and long-term success. Understanding the differences in these properties among different flowable composites is essential for informed material selection and successful restorative outcomes [2,3].

Depth of cure refers to the maximum thickness of a material that can be effectively cured, ensuring adequate polymerization of the entire restoration [4]. It is a fundamental property that influences the clinical effectiveness, longevity, and durability of light-cure restorations while a reduction in curing depth could potentially lead to reduced mechanical properties and increased risk of secondary caries [3].

Flexural strength is another key property of dental composites, reflecting their ability to resist deformation and fracture under loading, which is particularly important for restorations in stress-bearing areas, as in the posterior region. Comparative evaluation of the flexural strength of different flowable composites is essential to identify materials that can meet the demanding mechanical requirements of various restorative applications [5].

Excessive solubility and water sorption can lead to material degradation, discoloration, and compromised mechanical properties over time, potentially undermining the success of restorations [6,7]. Additionally, radiopacity of a composite resin ensures proper detection of secondary caries, and enables the assessment of restoration integrity through diagnostic imaging. Therefore, accurate characterization and comparison of the radiopacity of different flowable composites are essential for their appropriate clinical use and ensuring reliable outcomes [8]

Considering the inherent variability in the composition and mechanical properties of flowable composites, a thorough evaluation of these materials is imperative for evidence-based clinical decision-making. This investigation is pivotal to ensure selection of materials that align with specific clinical needs, ultimately enhancing the overall quality and longevity of dental treatments. Thus, this comprehensive study was conducted on six dental flowable composite resins to find possible differences in their depth of cure, flexural strength, solubility, water sorption, and radiopacity to contribute to the advancement of evidence-based clinical practice and facilitate the development of more effective and durable dental restorations.

MATERIALS AND METHODS

Six flowable composite resins, including nano-hybrid and micro-hybrid formulations, namely Edge Flow (EDF), Opallis Flow (OPF), Els Flow (ELF), Denfil Flow (DFF), DX Flow (DXF), and Charisma Flow (CHF) were selected to represent a range of dental materials with diverse chemical compositions. The composite resins were prepared and handled according to their respective manufacturer's instructions to maintain consistency. Testing was conducted according to ISO 4049:2019 standards [9], for evaluation of dental composite properties. To enhance the accuracy and robustness of flexural strength comparisons, the number of specimens was increased to 10 per group, doubling the ISO-recommended 5 specimens. The specific brands and types of composite resins used in this study are listed in Table 1.

Depth of cure:

The curing process and subsequent removal of excess material were performed by two experienced researchers to ensure consistency in sample handling, which is crucial for achieving accurate and reproducible results. Composites were cured using a calibrated LED curing light (BluePhase, Ivoclar Vivadent, Liechtenstein) with an intensity of 700mW/cm^2, adhering to ISO specifications. According to ISO 4049 [9], three specimens per group were prepared by filling a mold placed between transparent films on glass slides, carefully eliminating air bubbles. The mold was slightly overfilled, pressed between the slides to remove excess material, and light-cured as recommended by the manufacturer. After irradiation, uncured material was removed with a spatula, and the height of polymerized cylinders of composite resin was measured using a digital micrometer (Mitutoyo, Japan) with 0.1mm accuracy, and divided by 2 as per ISO guidelines.

Table 1. Flowable composite resins with A2 shade used in this study

Product (Abbr.)	Type	Lot	Resin Content	Filler Composition	Particle Size	Filler Load	Manufacturer (Origin)
Edge Flow (EDF)	Nano-hybrid	00510202010	Bis-GMA, BDDMA, DUDMA	Silica, glass-ceramic	93nm-4µm	55 wt.%	Hamerz Medical Co. (Iran)
Opallis Flow (OPF)	Micro-hybrid	020223	Bis-GMA, Bis-EMA, TEGDMA	Barium-aluminum silicate, silicon dioxide	0.05µm and 5µm	72 wt.%	FGM Dental Group (Brazil)
Els Flow (ELF)	Nano-hybrid	E781	BisGMA, BisEMA	Barium glass, silicon dioxide	0.07µm-2.6µm	NA.	Saremco Dental AG (Switzerland)
Denfil Flow (DFF)	Micro-hybrid	FR2932A2	Bis-GMA, TEGDMA	Barium glass, silica	0.01–2.5µm	60 wt.%	Vericom Co. Ltd. (Korea)
DX Flow (DXF)	Nano-hybrid	BJAIAI	NA.	NA	NA.	NA.	Sino-dentex Co. Ltd. (Taiwan)
Charisma Opal Flow (CHF)	Micro-hybrid	N010218	Bis-GMA, TEGDMA	Barium aluminum fluoride glass, dispersive silicon dioxide	0.02µm-2µm	62 wt.%	Kulzer GmbH (Germany)

Abrr.: Abbreviation; Bis-GMA= bisphenol A-glycidyl methacrylate, BDDMA= 1,4-Butanediol dimethacrylate, DUDMA= Diurethane Dimethacrylate, Bis-EMA= ethoxylated bisphenol A diglycidyl methacrylate, TEGDMA= triethylene glycol dimethacrylate

Flexural strength:

The flexural strength of each composite resin was measured according to ISO 4049:2019 standards to assess mechanical integrity under stress. Ten bar-shaped specimens (25mm×2mm×2mm) were prepared for each group by injecting the composite into standardized molds, avoiding air bubbles. A glass slide replaced one of the mold's metal plates to facilitate light curing. Irradiation of the entire specimen length was performed by the overlapping technique, and repeated for the opposite side. After curing, the specimens were placed in a water bath at 37±1°C temperature for 15 minutes to simulate oral conditions and relieve residual stresses. Next, excess material was removed, and the specimens were stored in distilled water for 24 hours. Before testing, the specimen dimensions were verified with a digital caliper (Mitutoyo, Japan). The specimens were tested using a three-point bending setup on a universal testing machine with a 200 kgf load cell (Bongshin, Seongnam, Korea) at a controlled speed of 0.75±0.25mm/minute. Flexural strength was calculated using the following formula:

$$\sigma = \frac{3Fl}{2bh^2}$$

Where F is the maximum load applied at fracture (in Newtons), l is the support span (20mm), b is the width, and h is the height of the specimen (both in millimeters).

Water sorption and solubility:

Water sorption and solubility of the composite materials were evaluated according to ISO 4049:2019 standards to assess their stability and degradation in an aqueous environment. Composite specimens were prepared in standardized circular molds (15mm diameter, 1mm thickness), ensuring their flat, uniform surface. Each specimen was cured using a calibrated LED curing light from both sides. After curing, excess material was removed with a 1000-grit abrasive paper to achieve smooth edges. The specimens were conditioned in a desiccator at 37±2°C for 22 hours and then at 23±1°C for 2 hours; this process was repeated until a constant dry mass (m_1) was reached. The specimens were then immersed in distilled water at 37±2°C for 7 days, blotted, and weighed to obtain the wet mass (m_2). They were returned to the desiccator until achieving a constant postconditioning mass (m_3). Water sorption (W_{sp}) was calculated in micrograms per cubic millimeter (μg/mm^2) using the following formula:

$$W_{sp} = \frac{m_2 - m_3}{V}$$

The solubility (W_{sl}) was measured accordingly:

$$W_{sl} = \frac{m_1 - m_3}{V}$$

Radiopacity:

Disc-shaped specimens were prepared accordance to ISO 4049:2019, ensuring a standardized thickness within the range of 1.0±0.1mm. The radiopacity of each specimen was evaluated by comparing the optical density of the specimens to that of an aluminum step wedge, providing an aluminum equivalent value that quantifies the material's radiopacity.

Shade assessment:

Disc-shaped specimens were fabricated from each composite type with 1.0±0.1mm thickness to evaluate their shades. A digital spectrophotometer (VITA Easyshade; H. Rauter GmbH & Co. KG, Germany) was used to compare each specimen's color against the Vita shade system, documenting the closest match. The spectrophotometer was calibrated by positioning the probe tip on the calibration port aperture prior to each specimen measurement. For the measurements, the probe tip was held at a 90-degree angle relative to the tooth surface. In line with the manufacturer's guidelines, the readings were considered valid when two consecutive, identical measurements were made for each region. All shade selections were done under D65 light source against a standard white background (measured as L* = 99.0, a* = 0.0, b* = 2.2, C = 2.2, H = 90).

Statistical analysis:

Statistical analysis was performed to evaluate the significance of differences observed among the study groups in various tests. One-way ANOVA was applied for general comparisons, followed by pairwise comparisons with the Tukey's post-hoc test. All data were analyzed using SPSS version 26 (SSPS Inc., Chicago, IL, USA), and the results were considered statistically significant with P values less than 0.05.

RESULTS

Depth of cure:

Figure 1 illustrates the depth of cure of the tested composite resins. The results indicated that OPF and DXF achieved the highest depth of cure (2.65±0.09mm and 2.67±0.11mm, respectively). In contrast, EDF and ELF exhibited the lowest depth of cure (2.2±0.08mm and 2.24±0.06mm, respectively). Statistical analysis showed a significant difference in the depth of curing among the tested materials (P<0.05). Nonetheless, all tested materials showed a depth of cure within the clinically acceptable range of 2mm, underscoring their suitability for dental restorations.

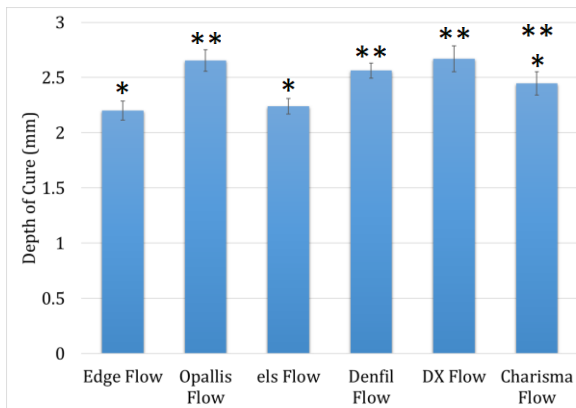

Fig 1. Depth of cure of each composite resin, with OPF and DXF showing the highest, and EDF and ELF showing the lowest depth of cure, all within the clinically acceptable range.

Flexural strength:

Figure 2 presents the flexural strength values of the tested composites, ranging from 69.8±19.3MPa to 91.8±19.9MPa. Despite the observed variations in flexural strength among different materials, statistical analysis revealed that the differences were not significant (P>0.05). It is worth mentioning that a total of 4 pre-test failures were observed in the EDF group, which were accounted for by preparing additional specimens to maintain a consistent sample size across the groups.

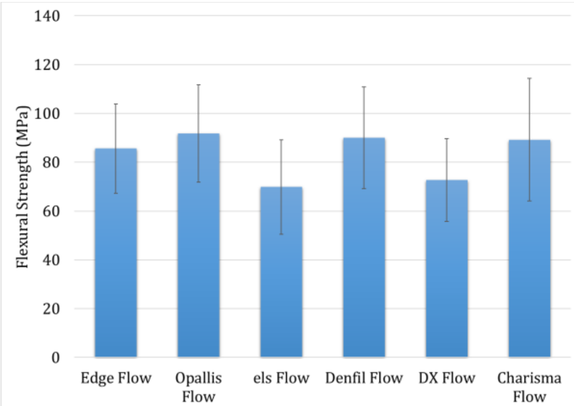

Fig 2. Flexural strength of composite resins. Despite the observed variations in flexural strength among different materials, statistical analysis revealed that these differences were not significant (P>0.05).

Radiopacity:

Table 2 presents the radiopacity values of the tested composite resins. Notably, all groups exhibited radiopacity values surpassing 2.5mm thickness of aluminum, with OPF registering as the most radiopaque, equivalent to 4.5mm thickness of aluminum.

Shade assessment:

The shade assessment results are summarized in Table 2. Despite all the study groups having A2 shade as the reference, none of them achieved a perfect match to A2. Some groups, such as DXF, and CHF, exhibited higher values, indicating a lighter shade than A2, while others, including DFF, EDF, OPF, and ELF, showed lower values, indicating a darker shade than A2.

Table 2. Results of radiopacity and shade assessment

Product	Radiopacity	Shade assessment
Edge Flow	2.5mm	B3
Opallis Flow	4.5mm	A3
Els Flow	2.5mm	B3
Denfil Flow	3mm	B2
DX Flow	2.5mm	A1
Charisma Flow	3.5mm	A1

Water sorption and solubility:

As depicted in Figures 3 and 4, DFF exhibited the highest water sorption among all experimental groups (21.05±0.85μg/mL), and the difference in this regard was statistically significant (P<0.05). Other groups did not show significant differences, except for OPF and CHF (P<0.05). Regarding solubility, the experimental groups were divided into two significantly different categories (P<0.05). EDF, OPF, and DFF demonstrated minimal solubility; whereas ELF, DXF, and CHF did not. Although statistically significant differences were found among the groups, all experimental groups met the specifications outlined by ISO and are therefore suitable for clinical use.

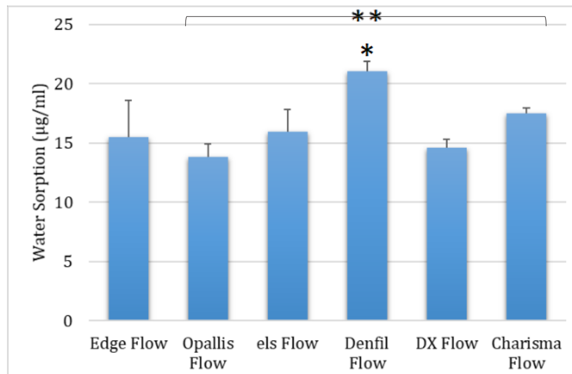

Fig 3. Water sorption of composite resins

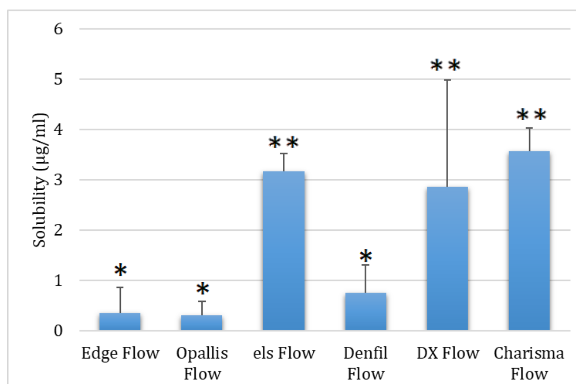

Fig 4. Solubility of composite resins

DISCUSSION

This study revealed significant variations in the mechanical properties of the six flowable composites evaluated, particularly in terms of depth of cure and flexural strength, which are critical for clinical performance and longevity of restorations. OPF and DXF demonstrated the highest depth of cure values, while EDF and ELF exhibited the lowest. The depth of cure is a crucial factor in preventing issues like porosity, polymerization shrinkage, and incomplete curing, and can compromise the integrity of restorations over time, if it is not adequate [9,10]. The depth of cure is influenced by various factors, including the intensity of light, the composition and light transmission properties of composite resins, depth of cavity and restoration, duration of light exposure, and type of light source [11]. Filler volume also plays a significant role in this regard. A previous study reported that higher filler content may increase hardness and depth of cure due to improved structural density [12]; while some other studies suggested that higher filler particles may reduce light penetration by increasing opacity, limiting polymerization at greater depths [13-15]. In the context of the present study, no clear correlation was observed between the filler particle size or composition and depth of cure. Contrary to the findings of a previous study [16], lower filler loading of EDF did not result in an increased depth of cure. In fact, EDF exhibited the lowest depth of cure among all groups. This may be attributed to the presence of bulkier monomers, such as BDDMA and DUDMA in its resin composition, which can scatter and absorb light, further reducing the depth of cure, as opposed to the smaller and more flexible TEGDMA found in other products [17]. Additionally, some formulations with optimized filler types and distributions have shown improved depth of cure by facilitating light transmission despite higher filler levels [18,19].

Flexural strength, which measures a material's ability to withstand forces during mastication, is another critical parameter [20]. While there were no statistically significant differences between the groups, it is noteworthy that some groups, namely ELF and DXF, had mean values below 80 MPa, which is considered as the acceptable threshold according to ISO 4049 [21]. The clinical significance of this finding, however, remains open to debate. While some studies suggest that flowable composites should not be used to restore large cavities that are subjected to considerable stress [22], there is also clinical evidence supporting the successful use of flowable composites in posterior teeth [3,23]. Ultimately, it has been suggested that general practitioners predominantly use flowable composites as liners [24].

As a notable observation in the present study, the EDF group exhibited a considerable rate of specimen pre-test failure compared to the other groups. Pre-test failure handling remains an ongoing challenge in dental material evaluation, particularly in bond strength studies [25,26]. While the occurrence of pre-test failures may reflect certain shortcomings in the material's ability to meet the performance requirements, there is no widely accepted method to address this issue. Additional specimens were fabricated in the present study to compensate for the pre-test failures in the EDF group. However, it is important to recognize that this approach may introduce bias into the study results. Future research should focus on developing standardized methods for handling of pre-test failures to ensure the validity and reliability of data analysis. Additionally, exploring alternative approaches, such as statistical techniques or sensitivity analyses, may help mitigate potential biases related to pre-test failures.

The radiopacity of dental composite resins holds significance for various reasons. Primarily, it plays a critical role in identification of secondary caries and radiographic visualization of the interface between the materials and dental substrate [27-29]. While all study groups demonstrated satisfactory levels of radiopacity, it was observed that composites containing barium-aluminum glass fillers, i.e., OPF and CHF, exhibited higher radiopacity.

Shade assessment was also performed in this study to evaluate the color match of the composites against the A2 reference shade. Despite A2 being the reference shade for all groups, an exact match could not be achieved with any of the tested composite resins. Instead, variations in shade were observed across different composite formulations. These discrepancies highlight the challenges in achieving a precise color match in dental composites and underscore the importance of carful shade selection and customization in clinical practice to ensure optimal esthetic outcomes. This study specifically aimed to investigate whether an A2 shade composite can genuinely correspond to the standard Vita shade and other commercially available products.

The present results revealed notable color discrepancies among products from different manufacturers, despite being marketed under the same shade. This could pose challenges in shade matching and result in inconsistencies when aiming for desired color outcomes in diverse applications. With the increasing trend towards restoring defective restorations, color match becomes a significant challenge [30,31]. It is imperative for the manufacturers to address this issue and provide accurate shade-matching options. Based on the present results, visual observation still emerges as a predictable method for matching the color of restorative materials with the desired substrate, be it a tooth, ceramic, or old composite.

The resin composition notably affects the water sorption and solubility behavior of composite resin materials. Water sorption is closely linked to solubility, which involves the release of residual products such as monomers and oligomers [32]. However, the results of these two assessments did not show a close correlation, as DFF exhibited the highest water sorption while having considerably lower solubility compared to ELF, DXF, and CHF. It is also noteworthy that, despite the low filler loading of EDF (55%), there was no statistical difference in solubility and water sorption between this group and OPF, which had the highest filler loading (72%). This finding may be attributed to the resin composition of EDF, which includes bulkier monomers. EDF, OPF, and DFF demonstrated minimal solubility; whereas ELF, DXF, and CHF did not. This discrepancy cannot be attributed to the filler particle size of these flowable composites, as EDF is a nano-hybrid composite while OPF and DFF are micro-hybrid composite resins.

Overall, this study underscored the importance of selecting composites based on clinical needs, and calls for further research on pre-test failure handling and long-term clinical performance.

CONCLUSION

This study revealed significant differences in depth of cure, flexural strength, and other properties among the tested six flowable composites. OPF and DXF showed superior depth of cure, while EDF and ELF showed lower values, which may highlight the need for incremental application in deeper restorations. Flexural strength results suggest that flowable composites may be best suited for use as liners rather than in large, stress-bearing restorations. Radiopacity was the highest in composites with barium-aluminum fillers, such as OPF and CHF, enhancing diagnostic visibility. Shade matching remained a challenge, highlighting the need for careful selection and customization to achieve optimal esthetic outcomes.

CONFLICT OF INTEREST STATEMENT

The authors declare that this research was funded by Hamerz Medical Company, and that Author 2 is an employee of this company. The funding source did not participate in the study design, data collection, data analysis, interpretation of data, or writing of the manuscript. The authors have no other conflicts of interest to disclose.

REFERENCES

1. Baroudi K, Rodrigues JC. Flowable resin composites: A systematic review and clinical considerations. J Clin Diagn Res. 2015 Jun;9(6):ZE18–24.
2. Shouha P, Swain M, Ellakwa A. The effect of fiber aspect ratio and volume loading on the flexural properties of flowable dental composite. Dent Mater. 2014 Nov;30(11):1234–44.
3. Vouvoudi EC. Overviews on the progress of flowable dental polymeric composites: their composition, polymerization process, flowability and radiopacity aspects. Polymers. 2022 Jan;14(19):4182.
4. Yokesh CA, Hemalatha P, Muthalagu M, Justin MR. Comparative evaluation of the depth of cure and degree of conversion of two bulk fill flowable composites. J Clin Diagn Res. 2017 Aug;11(8):ZC86–9.
5. Par M, Plančak L, Ratkovski L, Tauböck TT, Marovic D, Attin T, et al. Improved flexural properties

of experimental resin composites functionalized with a customized low-sodium bioactive glass. Polymers. 2022 Jan;14(20):4289.
6. Rusnac ME, Prodan D, Cuc S, Petean I, Prejmerean C, Gasparik C, et al. Water sorption and solubility of flowable giomers. Materials (Basel). 2021 May;14(9):2399.
7. Saba DA, Abdel Gawad FKI, Abd Ellatif MA. In vitro assessment of water sorption, solubility, and surface roughness of compomer and giomer materials after immersion in different beverages. Egypt Dent J. 2017 Jan;63(1):205–14.
8. Gul P, Çaglayan F, Akgul N, Akgul HM. Comparison of radiopacity of different composite resins. J Conserv Dent. 2017 Jan;20(1):17–20.
9. Moore BK, Platt JA, Borges G, Chu TMG, Katsilieri I. Depth of cure of dental resin composites: ISO 4049 depth and microhardness of types of materials and shades. Oper Dent. 2008 Jul;33(4):408–12.
10. Lynch CD, Hayashi M, Seow LL, Blum IR, Wilson NHF. The management of defective resin composite restorations: current trends in dental school teaching in Japan. Oper Dent. 2013 Sep;38(5):497–504.
11. Karatas O, Turel V, Bayindir YZ. Temperature rise during polymerization of different cavity liners and composite resins. J Conserv Dent. 2015 Nov;18(6):431–5.
12. Monte Alto RV, Guimarães JGA, Poskus LT, Silva EM da. Depth of cure of dental composites submitted to different light-curing modes. J Appl Oral Sci. 2006 Apr;14:71–6.
13. Halvorson RH, Erickson RL, Davidson CL. The effect of filler and silane content on conversion of resin-based composite. Dent Mater. 2003 Jun;19(4):327–33.
14. Lempel E, Czibulya Z, Kovács B, Szalma J, Tóth Á, Kunsági-Máté S, et al. Degree of conversion and BisGMA, TEGDMA, UDMA elution from flowable bulk fill composites. Int J Mol Sci. 2016 May;17(5):732.
15. Pereira SG, Osorio R, Toledano M, Cabrerizo-Vílchez MA, Nunes TG, Kalachandra S. Novel light-cured resins and composites with improved physicochemical properties. Dent Mater. 2007 Oct;23(10):1189–98.
16. Yadav R, Kumar M. Investigation of the physical, mechanical and thermal properties of nano and microsized particulate-filled dental composite material. J Compos Mater. 2020 Aug;54(19):2623–33.
17. Li W, Wang K, Wang Z, Li B. Optimal resin monomer ratios for light-cured dental resins. Heliyon. 2022 Sep;8(9).
18. Faria-e-Silva AL, Pfeifer CS. Impact of thio-urethane additive and filler type on light-transmission and depth of polymerization of dental composites. Dent Mater. 2017 Nov;33(11):1274–85.
19. Díaz-Rodríguez S de la C, Tarano-Artigas O, Herrera-Kao W, Cauich-Rodríguez JV, Cervantes-Uc JM, Rosa-Sainz A, et al. Effect of the silanization of aerosil OX50 in the properties of light-cured dental composites. Appl Sci. 2024 Jan;14(6):2453.
20. Wang W, Sun X, Huang L, Gao Y, Ban J, Shen L, et al. Structure-property relationships in hybrid dental nanocomposite resins containing monofunctional and multifunctional polyhedral oligomeric silsesquioxanes. Int J Nanomedicine. 2014;9:841–52.
21. International Organization for Standardization. Dentistry-Polymer-based Restorative Materials [Internet]. ISO; 2019. Available from: https://www.iso.org/standard/67596.html
22. Ryou DB, Park HS, Kim KH, Kwon TY. Use of flowable composites for orthodontic bracket bonding. Angle Orthod. 2008 Nov;78(6):1105–9.
23. Shaalan OO, Abou-Auf E, El Zoghby AF. Clinical evaluation of flowable resin composite versus conventional resin composite in carious and noncarious lesions: Systematic review and meta-analysis. J Conserv Dent Endod. 2017 Dec;20(6):380.
24. Seemann R, Pfefferkorn F, Hickel R. Behaviour of general dental practitioners in Germany regarding posterior restorations with flowable composites. Int Dent J. 2020 Nov;61(5):252–6.
25. Sirisha K, Rambabu T, Ravishankar Y, Ravikumar P. Validity of bond strength tests: A critical review-Part II. J Conserv Dent. 2014 Sep;17(5):420–6.
26. Armstrong S, Breschi L, Özcan M, Pfefferkorn F, Ferrari M, Van Meerbeek B. Academy of Dental Materials guidance on in vitro testing of dental composite bonding effectiveness to dentin/enamel using micro-tensile bond strength (μTBS) approach. Dent Mater. 2017 Feb;33(2):133–43.
27. Borges AH, Pedro FL, Semanoff-Segundo A, Miranda CE, Pécora JD, Cruz Filho AM. Radiopacity evaluation of Portland and MTA-based cements by digital radiographic system. J Appl Oral Sci. 2011;19(3):228–32.
28. Anzai M, Yoshihashi K, Hirose H, Mino M, Kitoh K, Narikawa M, et al. Basic studies of radiopaque resin monomer (III). Physical properties of trial composite resins. J Nihon Univ Sch Dent. 1993 Dec;35(4):244–51.
29. Altintas SH, Yildirim T, Kayipmaz S, Usumez A. Evaluation of the radiopacity of luting cements by digital radiography. J Prosthodont. 2013 Jun;22(4):282–6.
30. Blum IR, Lynch CD, Wilson NH. Factors influencing repair of dental restorations with resin

composite. Clin Cosmet Investig Dent. 2014;6:81–7.
31. Alqarni M, Khalil SN, Obied ES, Alshehri MM, Assiri MA, Mualwi SA, et al. Knowledge about composite restorations repair vs replacement- a survey among a subpopulation of saudi dental students. Braz Dent Sci. 2021;24(1):1–8.
32. Arregui M, Giner L, Ferrari M, Vallés M, Mercadé M. Six-month color change and water sorption of 9 new-generation flowable composites in 6 staining solutions. Braz oral res. 2016 Nov;30:e123.