Original Article

Compressive Strength of Highly Filled Flowable, Conventional, and Combinations of Flowable as a Liner with Conventional Resin Composite

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Abstract

This study aimed to compare the compressive strength of highly filled flowable resin composites, conventional resin composites, and combinations of flowable resin composite liners of different thicknesses with conventional resin composites. One hundred and twenty-one cylindrical specimens (3 mm diameter, 6 mm height) were fabricated from eleven different material combinations, including two highly filled flowable resin composites, three conventional resin composites, and six combinations of flowable resin composite liners (1.5 mm and 3 mm thicknesses) with conventional resin composites. After 24-hour storage in distilled water at 37°C, specimens underwent compressive strength testing using a universal testing machine. One-way ANOVA and Tukey's multiple comparison test were used for statistical analysis, with significance set at $P < 0.05$. Results revealed significant differences in compressive strength among the groups. Clearfil AP-X Esthetic Flow demonstrated the highest mean compressive strength (251.80 MPa), while G-aenial universal injectable 3 mm with G-aenial Posterior showed the lowest (155.62 MPa). No significant differences were found between highly filled flowable resin composite groups or among conventional resin composite groups. The combination groups showed comparable compressive strength to conventional resin composites, regardless of liner thickness. However, 3 mm thick flowable resin composite liners exhibited significantly lower compressive strength than Clearfil AP-X Esthetic Flow alone. The study concluded that highly filled flowable resin composites demonstrate promising compressive strength and can be considered for stress-bearing areas, noting that their combination with conventional resin composites as liners neither enhances nor compromises strength significantly.

Keywords: Compressive strength, Dental restoration materials, Flowable resin composite liner, Highly filled flowable resin composite

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Introduction

Resin composite restorations have gained popularity in dental practice due to their aesthetic, tooth-colored appearance, ability to bond directly to teeth using an adhesive system, requiring minimal need for tooth structure removal,[1] and used to replace amalgam fillings due to concerns about mercury toxicity. These materials also reinforce the remaining tooth structure. Dental resin composites consist of an organic resin matrix and organic/inorganic fillers. Resin composites are classified into two main categories based on their viscosity: conventional resin composites and flowable resin composites. Conventional resin composites, known for their high viscosity and moldability, are suitable for load-bearing areas requiring strength and durability. Flowable resin composites, with reduced filler content ranging from 37% to 53% by volume compared to 50% to 70% in conventional composites resulting in lower viscosity and enhanced flowability. This improved flowability allows for better adaptation to tooth cavities, especially in areas with irregular surfaces.[2,3] However, despite their ease of use, flowable resin composites have limitations. They exhibit reduced mechanical properties, including lower strength, wear resistance, and increased polymerization shrinkage,[2,3,4] restricting their application in load-bearing areas. Conversely, conventional resin composites have more strength and durability, making them suitable for both anterior and posterior restorations. The performance of these materials in the oral environment is often assessed through key mechanical properties, including compressive and flexural strength, which reflect their ability to withstand forces during mastication. Studies have shown that conventional resin composites consistently outperform flowable resin composites in these aspects, offering greater longevity and reliability in restorations.[5] Resin composite materials are used for the restoration of both anterior and posterior teeth, particularly conventional resin composites, which offer great strength and durability. One of the factors affecting the success of restorations is the strength of the restorative material. Compressive strength are key indicators of the durability of a material under the forces present in the oral cavity. Numerous studies have tested the physical properties of conventional resin composites, revealing that these materials exhibit high compressive strength, particularly when compared to flowable resin composites which offer better flowability and ease of use but have lesser strength.

The use of conventional flowable composite resin as a liner beneath conventional composite resin has gained attention due to its ability to improve dental restoration outcomes. This liner layer effectively distributes stress and minimizes the formation of air bubbles during the restorative process, because of its superior flowability. Such properties enable the material to fill gaps and adapt to tooth surfaces more effectively than conventional composite resin, which is more viscous.[6] Research indicates that a flowable resin liner with a thickness of 0.8–1.2 mm can substantially enhance the fracture resistance of the overlying conventional composite resin layer.[7] This improvement is attributed to the stress reduction within the restoration layer. Additionally, the liner provides greater flexibility in restorations, especially in regions with uneven tooth surfaces, thereby reducing the likelihood of gaps forming between the material and the tooth structure.[8] These benefits are crucial for ensuring the long-term success of dental restorations.

Recently, advancements in resin composite technology have aimed to address the growing demands of more complex dental treatments. The development of highly filled flowable resin composites feature increased filler content exceeding 50% by volume,[9] along with improved surface coatings and reduced filler particle sizes.[10] Such improvements, as claimed by the manufacturers, make these composites both strong and aesthetically suitable for anterior and posterior restorations.

Studies have shown that highly filled flowable resin composites exhibit good flexural strength compared to conventional resin composites.[11] However, concerns persist regarding their mechanical strength compared to conventional resin composites, which are more viscous and known for their superior durability and load-bearing capacity. There are no comparative studies of the compressive strength of this group of materials. The compressive strength of materials remains a critical parameter for evaluating their long-term performance in restorations.[11,12] Compressive test determines the sustained resistance (strength and modulus) of a material against to longitudinal heavy load (mastication).[13] Compressive strength relates to the ability of the material to withstand the forces of mastication, when chewing, teeth experience significant compressive forces, particularly in the posterior teeth due to the higher occlusal forces, and a resin composite with sufficient compressive strength can withstand these forces without breaking or chipping, making it a crucial factor in determining the longevity and success of a dental restoration, as a composite with higher compressive strength is less likely to fracture or fail under biting pressure. Strength as well as adhesive properties play an important role in preventing microleakage, secondary decay and filling dislodgement. This assessment helps determine the most effective and suitable materials for various restorative purposes.

Consequently, this study aims to compare the compressive strength of three types of resin composite materials: 1. highly filled flowable resin composites, 2. conventional resin composites, and 3. combinations of flowable resin composite as a liner in different thickness layered with conventional resin composite. The findings will provide dentists with evidence-based insights to select the most appropriate materials for specific dental restoration scenarios, enhancing the efficiency, durability, and success of restorations over time. The null hypothesis states that no significant differences exist among: 1. highly filled flowable resin composites, 2. conventional resin composites, and 3. combinations of flowable resin composite as a liner in different thicknesses with conventional resin composite.

Materials and Methods

This is an *in-vitro* laboratory study. Six resin composite materials (Table1) were used in the experiment and were divided into the following groups:

1. Highly filled flowable resin composites group
    - 1.1 G-aenial Universal Injectable® (GC, Japan)
    - 1.2 Clearfil AP-X Esthetic Flow® (Kuraray Noritake Dental, Japan)
2. Conventional resin composite group
    - 2.1 G-aenial Posterior® (GC, Japan)
    - 2.2 Clearfil AP-X ® (Kuraray Noritake Dental, Japan)
    - 2.3 Filtek Z350 XT® (Solventum, USA)
3. Combinations group of flowable resin composite in different thicknesses layered with conventional resin composite
    - 3.1 G-aenial universal injectable® 1.5 mm thickness with G-aenial Posterior® (GC, Japan)
    - 3.2 G-aenial universal injectable® 3 mm thickness with G-aenial Posterior® (GC, Japan)
    - 3.3 Clearfil AP-X Esthetic Flow® 1.5 mm thickness with Clearfil AP-X ® (Kuraray Noritake Dental, Japan)
    - 3.4 Clearfil AP-X Esthetic Flow® 3 mm thickness with Clearfil AP-X ® (Kuraray Noritake Dental, Japan)
    - 3.5 Filtek Supreme XTE® Flowable 1.5 mm thickness with Filtek Z350 XT® (Solventum, USA)
    - 3.6 Filtek Supreme XTE® Flowable 3 mm thickness with Filtek Z350 XT® (Solventum, USA)

Groups 3.1 to 3.4 were combinations of highly filled flowable resin composite and conventional resin composite. While groups 3.5 to 3.6 were combinations of conventional flowable resin composite and conventional resin composite.

Table 1 Resin composites used in this study

Materials	type	% of filler	Compositions	shade	Manufacturer	Lots
G-aenial Universal Injectable	highly filled flowable resin composite	69% by weight 50% by volume	UDMA, Bis-MEPP, TEGDMA, silanated barium glass, silanated silica (0.15 µm)	A2	GC, Japan	2406201

Table 1 *Resin composites used in this study (cont.)*

Materials	type	% of filler	Compositions	shade	Manufacturer	Lots
Clearfil AP-X Esthetic Flow	highly filled flowable resin composite	75% by weight 59% by volume	TEGDMA, hydrophobic aromatic dimethacrylate, silanated barium glass, silanated colloidal silica (0.18-3.5 μm)	A2	Kuraray Noritake Dental, Japan	810444
G-aenial Posterior	conventional resin composite	7% by weight 65% by volume	UDMA, dimethacrylate comonomers, pre-polymer silica, lanthanoid fluoride fluoraaluminosilicate, silica (16-17 μm)	A2	GC, Japan	2402051
Clearfil AP-X	conventional resin composite	85% by weight 70% by volume	Bis-GMA, TEGDMA, camphorquinone, barium glass, colloidal silica (3 μm)	A2	Kuraray Noritake Dental, Japan	6R0172
Filtek Z350 XT	conventional resin composite	78.5% by weight 63% by volume	Bis-GMA, PEGDMA, BIS-EMA, UDMA, silica (0.02 μm), zirconia (0.004-0.11 μm)	A2	Solventum, USA	11104544
Filtek Supreme XTE Flowable	conventional flowable resin composite	65% by weight 46% by volume	Bis-GMA, TEGDMA, Bis-EMA, ytterbium trifluoride (0.1-5 μm), silane-treated ceramic, silica (0.02 μm), zirconium oxide (0.6-1.4 μm)	A2	Solventum, USA	10951722

UDMA: urethane dimethacrylate; Bis-MEPP: 2,2-Bis (4-methacryloxypolyethoxyphenyl) propane; TEGDMA: triethylene glycol dimethacrylate; Bis-GMA: bisphenol A glycidyl methacrylate; Bis-EMA: ethoxylated bisphenol A glycol dimethacrylate; PEGDMA: poly (ethylene glycol) dimethacrylate

Specimen Preparation

Cylindrical resin composite specimens with a diameter of 3 mm and a height of 6 mm were fabricated using a brass split mold.[13] Prior to specimen preparation, the mold was assembled and coated with a separating medium to facilitate removal. The mold was then completely filled with resin composite material, with a 1mm clear acrylic plate serving as the base, and the top part of the mold was secured in place. Light curing (Demi™ Plus, Kerr, USA) was performed from both the top and bottom surfaces of the mold for 40 seconds each. After initial curing, one half of the split mold was carefully removed, leaving the other half attached to the specimen. The exposed lateral surface of the specimen was subsequently light-cured for an additional 40 seconds. The fully cured specimen was inspected for voids with a magnifying glass and dental explorer no.5. The specimens with voids, those that are not homogeneous, or those with incomplete resin composite materials will be discarded. Any excess material, such as fins, was trimmed using a No. 11 blade to ensure uniform dimensions of all the specimens.

For the test groups of a combination of flowable and conventional resin composites, the procedure began with the placement of conventional composite resin into the mold. A plastic instrument and an amalgam plugger marked at 1.5 mm and 3.0 mm depths were used to condense the material to achieve the desired thicknesses of 4.5 mm and 3.0 mm, respectively. Once the conventional resin composite was in place, flowable resin composite was injected to fill the remaining space in the mold. Light curing for these combined specimens followed the same protocol as described for the other groups. Specimen dimensions for single and combination materials are illustrated in Figure 1.

A total of 121 cylindrical specimens (3 mm in diameter and 6 mm in height) were prepared, with 11 specimens assigned to each material group. Following fabrication, all specimens were immersed in distilled water at 37°C for 24 hours to simulate oral conditions. After immersion, the specimens were blotted dry and subjected to compressive strength testing.

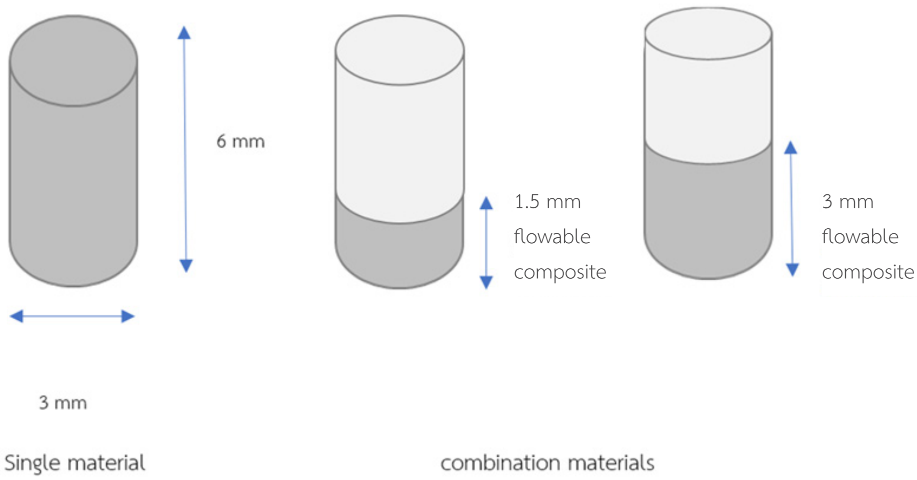

Figure 1 Specimen dimensions

Compressive strength test

A universal testing machine (Lloyd Instruments, LRX-Plus, AMETEK Lloyd Instruments Ltd., UK) was used to test the cylindrical specimens by applying a vertical cylindrical load of 5 kN at a rate of 1.0 mm/min, according to ADA Specification No.27-1993, using a load unit with a 15 mm diameter until a fracture occurred.[14] In the combination groups, the specimens were placed with flowable resin composite side down on the base of the testing machine. A digital vernier caliper was used to measure the dimensions of each specimen. Compressive strength values were calculated from the force applied. The compressive strength was calculated using the following formula.[14]

$$\text{Compressive strength in Megapascals (MPa)} = \frac{F}{d^2}$$

Where F = maximum force in Newtons exerted on the specimen

d = diameter of the specimens in millimeters

Statistical Analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS, v15.0; Chicago, IL) and are presented as means ± standard deviations (SDs) One-way ANOVA and Tukey's multiple comparison tests were used to compare the compressive strength values among the eleven groups of materials. Differences were considered statistically significant at $p < 0.05$.

Results

There was a statistically significant difference in compressive strength among the 11 experimental groups. Therefore, the null hypothesis was rejected. The mean and standard deviation are shown in Table 2, and the differences between groups are illustrated in Figure 2. Clearfil AP-X Esthetic Flow had the highest mean compressive strength (251.80 MPa), while G-aenial universal injectable 3 mm with G-aenial Posterior group had the lowest (155.62 MPa). Clearfil AP-X Esthetic Flow had the highest compressive strength, significantly higher than G-aenial

Posterior, Clearfil AP-X, G-aenial universal injectable 1.5 mm with G-aenial Posterior, G-aenial universal injectable 3 mm with G-aenial Posterior, Clearfil AP-X Esthetic Flow 3 mm with Clearfil AP-X, and Filtek Supreme XTE Flowable 3 mm with Filtek Z350 XT. G-aenial Universal Injectable had a mean compressive strength (226.46 MPa) that was significantly higher than G-aenial universal injectable 3 mm with G-aenial Posterior (155.62 MPa) and Filtek Supreme XTE Flowable 3 mm with Filtek Z350 XT (160.20 MPa). There was no significant difference between the highly filled flowable resin composite groups (G-aenial Universal Injectable and Clearfil AP-X Esthetic Flow). Similarly, there was no significant difference among conventional resin composite groups (G-aenial Posterior, Clearfil AP-X, and Filtek Z350 XT), Additionally, there was no significant difference among combinations group of flowable resin composite in 1.5 mm and 3 mm thicknesses layered with conventional resin composite. There were no significant differences in compressive strength between the conventional resin composite groups (G-aenial Posterior, Clearfil AP-X, and Filtek Z350 XT) and combinations of flowable with conventional resin composite groups.

Table 2 *Mean and standard deviation of compressive strength for all groups*

Groups	Mean ± SD (MPa)
1.1 G-aenial Universal Injectable	226.46 ± 41.88^{AC}
1.2 Clearfil AP-X Esthetic Flow	251.80 ± 58.57^{A}
2.1 G-aenial Posterior	176.22 ± 43.60^{BC}
2.2 Clearfil AP-X	182.09 ± 44.57^{BC}
2.3 Filtek Z350 XT	212.83 ± 63.40^{ABCD}
3.1 G-aenial universal injectable 1.5 mm with G-aenial Posterior	177.94 ± 50.07^{BC}
3.2 G-aenial universal injectable 3 mm with G-aenial Posterior	155.62 ± 31.67^{BD}
3.3 Clearfil AP-X Esthetic Flow 1.5 mm with Clearfil AP-X	190.17 ± 18.95^{ABCD}
3.4 Clearfil AP-X Esthetic Flow 3 mm with Clearfil AP-X	185.58 ± 35.17^{BC}
3.5 Filtek Supreme XTE Flowable 1.5 mm with Filtek Z350 XT	199.21 ± 38.78^{ABCD}
3.6 Filtek Supreme XTE Flowable 3 mm with Filtek Z350 XT	$160.20 + 43.91^{BD}$

Difference superscript letters (A, B, C, D) indicate statistically significant difference by the Tukey's test (p<0.05).

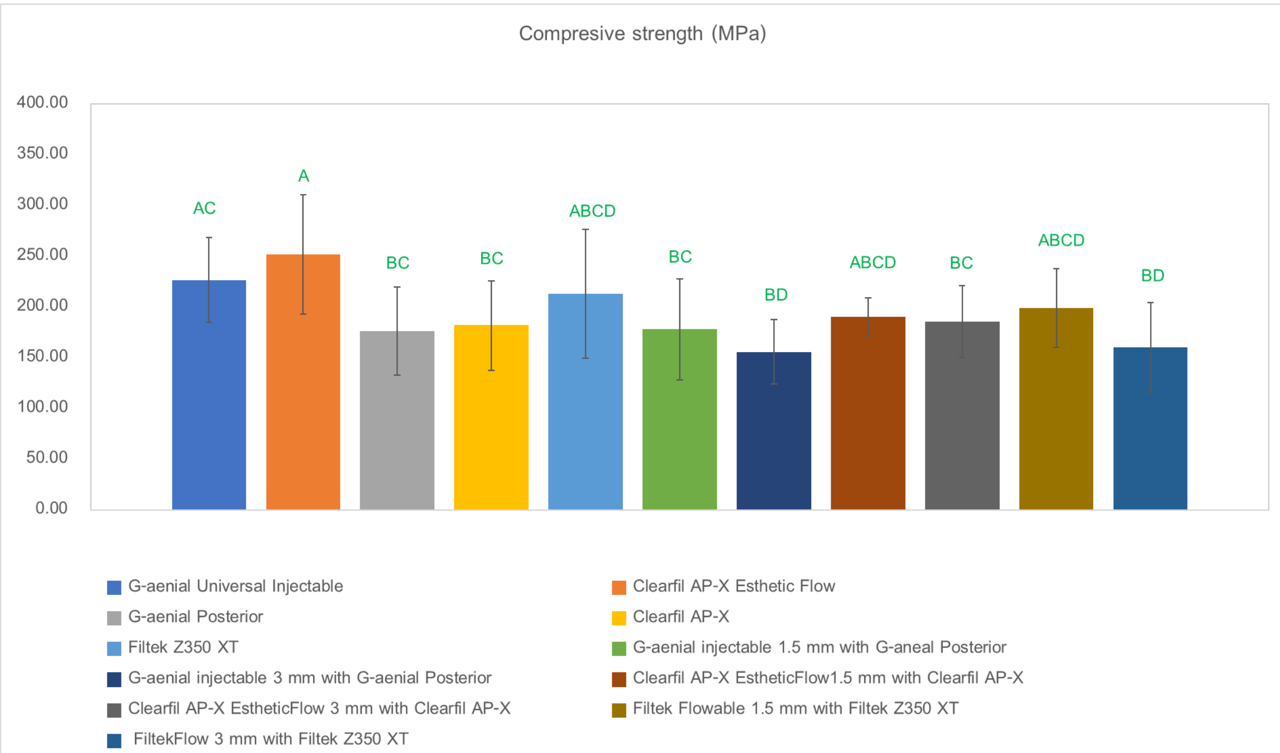

Figure 2 *Compressive strength of all groups*

Difference letters (A, B, C, D) indicate statistically significant differences by the Tukey's test (p<0.05).

Discussion

Within the limitations of this study, the null hypothesis is rejected that the compressive strength of the highly filled resin composite is the same as that of the conventional resin composite and the combinations of flowable liner with conventional resin composite. This study demonstrated differences in compressive strength among highly filled flowable, conventional resin composite materials and combinations of flowable resin composites layered with conventional resin composites. Common causes of composite failure include recurrent caries and bulk fracture, with at least 5% experiencing bulk fracture and 12% significant wear within ten years. Advances in dental composites include low shrinkage monomers, antibacterial monomers, and enhanced fillers to improve performance and longevity.[1] Compressive strength, one of the key measures of a material's strength under different force conditions, is particularly important due to chewing forces. An increased value indicates greater strength of the material.[15] However, available standard resin composites restorative materials do not have certain values of compressive strength meanwhile, the flexural strength of resin composite materials should be higher than 80 MPa according to ISO 4049 standard.[16] Compressive strength was influenced by several factors in composite materials, including type of resin matrix, degree of crosslinking and polymerization, in addition to type, size and amount of filler loading.[17,18,19] Generally, increased filler loading of the conventional resin composites enhances both the material strength and elastic modulus. However, this study did not find the pattern mentioned when comparing the results of highly filled flowable resin composites and conventional resin composites. Highly filled flowable resin composites' compressive strength showed the highest among all groups, especially the Clearfil AP-X Esthetic Flow. The compressive strength of highly filled flowable resin composite was high despite having lower filler load than conventional resin composite. This finding is consistent with the study by Rajabi *et al.* (2024), which reported that highly filled flowable composites showed significantly lower wear and higher flexural strength compared to conventional flowable and paste resin composites. Previous studies suggest that factors such as filler size, distribution, bonding to the resin matrix, and the type of resin matrix used may influence differences in mechanical properties.[20] The smaller filler size in highly filled resin composite (Clearfil AP-X Esthetic Flow 0.18–3.5 μm) compared to conventional resin composites (Clearfil AP-X 3 μm) may contribute to its higher compressive strength. Additionally, these differences may be due to filler modification through silanization, as previous studies found that silanization of filler can significantly improve mechanical properties (compression strength, angular flexural strength, flexural strength, and elasticity modulus).[16] Different resin matrices vary in molecular weight, viscosity, and backbone structure. The Bis-GMA (bisphenol A glycerolate dimethacrylate) monomer was the first dental dimethacrylate resin and is known for its high viscosity and rigid backbone. The extremely high viscosity of Bis-GMA limits the degree of conversion and decreases the possibility of filler incorporation. The viscosity of Bis-GMA can be lowered by admixing low molecular weight dimethacrylates. Oligoethylene glycol dimethacrylates may be used for this purpose, of which TEGDMA (triethylene glycol dimethacrylate) is the most popular. The lower the viscosity of the mixture, the higher the degree of conversion and the more filler can be incorporated. There was a need to enhance flowability, and low viscosity, flowable resin composites have to contain a much lower molecular weight resin monomers such as TEGDMA to dilute the matrix.[21] In response to Bis-GMA flaws, UDMA (urethane dimethacrylate) monomers were developed. These monomers have similar molecular weights to Bis-GMA but are less viscous. Due to the good mechanical properties of the UDMA, it is the only dimethacrylate that can be used alone in resin composites. It can also be combined with Bis-GMA, acting as a viscosity reducer.[22] The study by Imai *et al.* (2019) suggested that the resin matrix composition, rather than filler content, is the primary factor influencing the flexural properties of flowable resin composites.[23] The study by Pfeifer *et al.* (2009) found that the strong crosslinking of the polymer chains affects the fracture resistance of the material and results in minimal degradation. Dental resin composites containing TEGDMA as a monomer promote the highest degree of polymer crosslinking, followed by UDMA and the combination of TEGDMA with UDMA, respectively.[24] In this study, Clearfil AP-X Esthetic Flow exhibited the highest compressive strength, which contains TEGDMA in its resin matrix. G-aenial Universal Injectable showed the second highest compressive strength which contains UDMA and TEGDMA. The result of previous studies highlighted the possible suitability of these highly filled flowable composite resins to be used in occlusal load-bearing areas.[20] This can be implied that this material can be applied in any cavity classification, including stress-bearing areas. These areas are subject to various directions and magnitudes of force. The use of highly filled flowable resin composites in these high-stress areas is desirable, as they can provide the necessary strength and adaptability to withstand the loading conditions. The ability of these materials to flow or be injectable and adapt to the cavity shape, while maintaining adequate compressive strength. The adaptability of flowable composite to cavity shapes enhances the durability of the restoration and reduces voids, as demonstrated in earlier studies.[6] This aligns with previous research by Basheer *et al.* (2024) that highlighted the improved mechanical properties of high-strength injectable dental composites.[11] The higher compressive strength of highly filled flowable composites compared to conventional composites can be attributed to several material properties and factors. Highly filled flowable composites are designed with a higher filler content (>50% by volume) compared to conventional flowable composites. The high filler content provides enhanced mechanical properties, including improved compressive strength, as fillers bear the majority of the applied forces during mastication. Fillers also reduce polymerization shrinkage, which could otherwise weaken the material under load. Optimized filler size and distribution, advances in manufacturing processes for highly filled flowable composites have led to reduced filler particle sizes and uniform distribution of fillers within the resin matrix.[23] A study by Ludovichetti *et al.* (2022) suggested that filler type also contributes the difference between compressive strength, as each filler material has different mechanical and physical properties and may influence material behavior differently.[25] This optimization contributes to better load distribution within the composite, enhancing its ability to withstand compressive forces. Other factors may be due to material homogeneity. This is a limitation of the study in the specimen preparation process, as flowable resin composites are designed to have better adaptability and flow, ensuring fewer voids or defects during placement. Reduced porosity and a more homogeneous structure contribute to the ability of the composite to resist compressive stresses. Conventional resin composites that exhibit slightly lower compressive strength may be due to their higher viscosity. The lack of flowability in conventional composites might limit their adaptability to cavity surfaces, potentially introducing structural inconsistencies that reduce overall compressive strength.

The study revealed that the combination of a 3 mm thick highly filled flowable with a conventional resin composite from the same manufacturer resulted in a decrease in compressive strength compared to using the highly filled flowable resin composite alone. This result highlights a potential trade-off when using highly filled flowable resin composites as liners, while they improve marginal adaptation and reduce voids, the overall mechanical strength may be compromised if the thickness of the highly filled flowable composite exceeds optimal levels. A previous study discussed how different composite layers can create stress concentration points, particularly in restorations.[7] Micro-gaps or interfaces between flowable and conventional composites may create areas of mechanical weakness, variations in polymerization shrinkage between different materials, leading to reduced overall compressive strength. In this study, the compressive strength of the highly filled flowable resin composite was higher than the conventional resin composite. When layered, the overall mechanical properties tend to be dominated by the weaker material.

Additionally, it was found that the compressive strength of the conventional resin composite and the combination groups from the same manufacturer showed no significant difference, regardless of the flowable resin thickness being 1.5 mm or 3 mm. This study conducted experiments with a flowable resin composite layer thickness greater than previous studies, which were typically around 1–1.2 mm. Previous research recommended testing at thicknesses greater than 1 mm, leading to the idea of investigating layer thicknesses of 1.5 mm and 3 mm in this study. The results of this study are consistent with the study by Gömeç *et al.* (2005), which found that the compressive strength of the group with a conventional flowable resin composite liner of no more than 1.2 mm was not significantly different from that of the group using only conventional resin composites.[7] These findings also align with an earlier study by Cavalheiro *et al.* (2018), which reported that the use of flowable liners does not consistently enhance the compressive strength of Class II restorations.[26] Furthermore, they are fairly consistent with the study by Ozgünaltay & Görücü (2005), which found that using a 1 mm thick flowable liner does not significantly affect fracture resistance.[27] This could be interpreted to mean that flowable resin composite can be used as a liner layered in restorations combined with conventional resin composite without reducing or enhancing the compressive strength of conventional resin composite. Nevertheless, flowable resin composites still offer clinical advantages, such as improved cavity adaptation, particularly in areas with complex geometries.

The sample dimensions used in this study were 3 mm in diameter and 6 mm height, ensuring clinical relevance of the experimental design. The dimensions were carefully chosen to match the depth of the cavity in natural teeth, which the depth from the tip of the cusp to the roof of the pulp chamber is typically around 6 mm. The depth from the tip of the cusp to the bottom of the pulp chamber can be measured up to 8 mm, while the height of the normal pulp chamber ranges from 1.5 to 2 mm.[28]

The current study supports the potential of highly filled flowable resin composites as a viable option for dental restorations, particularly in areas requiring both strength and adaptability. A clinical study by Kitasako *et al.* (2016) showed that a highly filled flowable composite demonstrated comparable clinical effectiveness to the conventional paste composite in posterior restorations over 36 months. The study highlighted several benefits associated with using injectable composites, including easier handling, improved cavity wall adaptation, and reduced time required for placing the restoration.[29] The research also supports previous observations about the role of flowable composites as an intermediate layer in restorations. While these materials can serve as effective liners, they may not necessarily enhance the overall mechanical performance of the restoration.[6,26] However, for large restorations requiring layering, careful consideration should be given to the liner thickness to avoid reductions in mechanical performance. The application of flowable resin composites should be considered by their intended clinical function. For areas requiring superior adaptation and minimal voids, thin flowable liners remain a valuable tool. Conversely, in restorations where compressive strength is important, materials such as highly filled flowable composites or conventional composites should be prioritized. Overall, this study provides evidence that supports material selection strategies in restorative dentistry, helping to optimize clinical outcomes and the longevity of restorations. Future research should explore the long-term clinical performance of these materials under dynamic loading conditions to better simulate oral environments. Moreover, selecting dental filling materials must also consider other material factors such as elastic modulus, flexural strength, wear resistance and surface roughness, polymerization shrinkage as these impact microbial plaque formation and potential tooth decay.[1] Materials with high wear resistance maintain their structural integrity and aesthetic properties over time, reducing the need for frequent replacements. However, this study has limitations as it was conducted in a laboratory setting and may not fully replicate real clinical conditions that could affect polymerization and material strength. Factors such as light curing that does not precisely mimic clinical practice, bulk filling techniques, and the effect of bonding agents were not fully simulated. Therefore, the findings should be considered as preliminary guidelines for material selection rather than definitive clinical recommendations.

Conclusion

Highly filled flowable resin composites demonstrate promising compressive strength. Dentists may consider these materials for restorations in stress-bearing areas, with the understanding that the combination with conventional resin composites as liners does not significantly enhance or compromise strength. However, the selection of materials in terms of strength should also consider their flexural strength, elastic modulus, and other mechanical properties. Further research should evaluate other mechanical properties as well as the clinical performance of these materials.

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Conflict of interest

This research received the following support in the form of resin composite testing materials: G-aenial Universal Injectable and G-aenial Posterior were provided by GC Asia. Filtek Z350 XT and Filtek Supreme XTE Flowable were provided by Solventum Thailand. As for Clearfil AP-X Esthetic Flow and Clearfil AP-X, these materials were purchased by the researchers with a discount provided by Nuvodent Thailand to support this research.

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