Australian Dental Journal
The official journal of the Australian Dental Association

AUSTRALIAN DENTAL ASSOCIATION INC.

Australian Dental Journal 2024; 69: 40–48

doi: 10.1111/adj.12982

# A comparison of the effects of incremental and snowplow techniques on the mechanical properties of composite restorations

Y Ölçer Us,* A Aydınoğlu,† Ş Erşahan,‡ Y Erdem Hepşenoğlu,‡ K Sağır,§ A Üşümez¶

*Department of Prosthodontics, School of Dental Medicine, Bahçeşehir University, Istanbul, Turkey.
†Department of Metallurgical and Materials Engineering, Yıldız Technical University, Istanbul, Turkey.
‡Faculty of Dentistry, Department of Endodontics, Istanbul Medipol University, Istanbul, Turkey.
§Department of Materials Science and Technology, Turkish-German University, Istanbul, Turkey.
¶Dentalplus Implantology Clinic, Istanbul, Turkey.

## ABSTRACT

***Background:*** Glass fibre-reinforced composite (GFRC) has the potential to enhance the mechanical properties of resin-based restorations. Nevertheless, the application technique can influence the cervical margin porosity, potentially reducing the mechanical strength of restorations.
***Methods:*** In an *in vitro* setup, mould specimens underwent six different treatments to assess the effects of snowplow and incremental curing techniques on the properties of GFRC (EverX) and universal resin composite (Filtek). Mechanical properties, namely flexural strength (FS), compressive strength (CS) and Vickers hardness (VH), were evaluated following ISO 4049 standards. Data interpretation utilized the Kruskal–Wallis tests.
***Results:*** No significant difference emerged across groups for FS. CS in the snowplow method with lesser EverX thickness (SnPl_1) was comparable with only EverX and Filtek ($P > 0.05$). The CS was reduced in the snowplow technique with greater EverX thickness (SnPl_2) ($P < 0.05$) and further decreased with the incremental method ($P < 0.001$). VH results showed that EverX Posterior was consistently softer than Filtek, with specific patterns of hardness variations among different application methods.
***Conclusions:*** Applying EverX and Filtek using the snowplow technique delivers superior CS and VH for restorations in contrast to the incremental method. Utilizing the snowplow approach in high-stress areas can make restorations more fracture-resistant.

***Keywords:*** Compressive strength, flexural strength, glass fibre-reinforced composite, incremental, resin composite, restorative composites, snowplow, surface roughness, Vickers hardness.

***Abbreviations and acronyms:*** CS = compressive strength; DCs = dental composites; FS = flexural strength; GFRC = glass fiber reinforced composite; VH = Vickers hardness.

*(Accepted for publication 15 September 2023.)*

## CLINICAL RELEVANCE

Prior to this research, the influence of different application techniques on the mechanical strength of restorations using GFRC and universal resin composite remained ambiguous. This study illuminates that the snowplow technique offers superior mechanical properties, specifically in high-stress areas, compared to the incremental method. Clinicians should discern that optimizing their application approach, particularly in stress-prone regions, can enhance restoration durability. In practice, for those employing GFRC in tandem with universal resin composites, the snowplow technique may be the preferred choice to maximize restoration longevity.

## INTRODUCTION

Dental composites (DCs) have been in use in dentistry for over 50 years,[1] consisting of a polymeric matrix like dimethacrylate, reinforced fillers, silane coupling agents for better adhesion and various additives that aid the polymerization reaction.[2] They are versatile materials used for sealing, luting and restoration procedures.[3] However, despite advancements that have enhanced their physical and mechanical properties, they still have certain limitations. These include suboptimal mechanical properties, shrinkage during polymerization, low fracture strength, susceptibility to secondary caries due to fractures and high wear rates.[2,4] To overcome such shortcomings, GFRCs have been introduced for dentin replacement.[5] GFRCs are intended for use in high-stress-bearing areas, especially in molars, with improved properties such as stress-bearing capacity and FS as compared with conventional composites.[6–11] The greatest mechanical advantage of GFRC derives from its unique short-fibre structure.[12] When any crack occurs in the composite's resin structure, the fibres pull the surfaces together, consequently preventing the progression of the crack.[9] A bulk-fill material EverX Posterior (by GC Europe)[13] has been one of the most popular[14] GFRC brands in recent years. It is designed as a substructure material containing 25% short fibre by weight, developed to mimic the stress-absorption property of natural dentin tissue in large and deep cavities.[15]

In routine applications, conventional composite resin is placed over EverX, as the latter adheres well to cavity walls and overlapping composites and also transmits occlusal loads homogeneously to the tooth.[10,11,16] Placing a composite on EverX after its curing is an example of bilayer curing. Yet, after curing, bond strength may decrease due to oxygen inhibition occurring on the cured surface during the placement of the composite. The principle of molecular interaction suggests that an oxygen-inhibited layer may enhance interfacial bonding between contacting polymers.[17] However, reports on how the oxygen-inhibited layer affects bond strength have been inconsistent. According to three previous studies,[18–20] oxygen-inhibited layers increase bond strength. On the contrary, it was also reported that it makes no significant difference in bond strength.[21,22] Moreover, it was also determined that the presence of such a layer was, in fact, destructive to bonding additional composite layers.[17,21–23] Despite many studies, the effect of oxygen on the bonding properties of EverX Posterior is also still unknown.

In recent years, various studies[18,24–27] found that curing different types of layered materials in one go instead of curing them one by one can be quite effective in preventing this inhibition zone and increasing the restoration's mechanical performance. This relatively new technique is called snow plough[19] or alternatively snowplow.[20] The snowplow technique was first used for a flowable composite, and a viscous composite resin moulded together in an unpolymerized state, followed by final polymerization of both materials.[28] This technique is actually a variation of the closed sandwich composite resin placement method in which a flowable composite with a thickness of 0.25 to 0.5 mm is placed as an intermediate layer on the cavity floor up to the cavosurface margin, followed by packable composite resin on top. Both materials are then cured simultaneously.[4] This technique was proposed to be more efficient than light-curing each layer separately, by reducing the thickness of flowable composites that exhibit higher shrinkage due to their lower filler content (37%–53% by volume).[4] Moreover, several studies suggest that the snowplow technique is more effective in reducing microleakage than the open-sandwich technique using flowable and packable Beautifil II giomer.[29–31] In contrast, Nematollahi *et al.*[32] reported that the snowplow technique results in more microleakage than the closed-sandwich technique with resin-modified glass ionomer cement and flowable composite as liner. The authors[32] explain that the displacement of uncured flowable composite into the overlying bulk of composite leads to increased resin content in the bulk, thus increasing polymerization shrinkage and microleakage. Consequently, layered curing of two restorative structures with close viscosities could eliminate the disadvantages experienced with flowable composites in practice.

To the best of our knowledge, our study is the first one to implement the snowplow technique using EverX Posterior. The effect of snowplow technique on FS, CS and microhardness on materials features, is investigated. The null hypothesis is that snowplow technique would not improve the mechanical properties of the restoration.

## MATERIALS AND METHODOLOGY

A2 shades of GFRC and universal resin composite were used in this study, as detailed in Table 1.

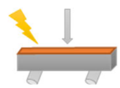
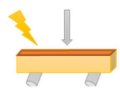
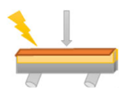
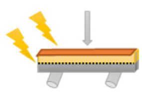
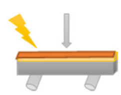
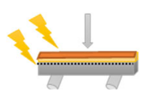
Specimens for FS testing were prepared using Teflon moulds, as outlined in Table 2, according to ISO 4049 to ensure standardization of shape and size. Totally 60 three-point bending test specimens (n = 10 per group) were prepared using 2 × 2 × 25 mm rectangular moulds. Since the mould thickness recommended by the standard is 2 mm, this was the thickness used for FS assessment. In the first two groups, single layers of EverX or URC alone were placed in the moulds. Then, to compare placement techniques effect on the material, the snowplow technique was applied in the SnPl_1 group and the incremental one in Inc_1. Briefly, in SnPl_1, after EverX of 1 mm thickness was placed in the mould, Filtek of same size was placed on it, and later, both layers were cured from the top in one go. On the contrary, in SnPl_2, Filtek was placed after the bottom EverX layer had been cured from the top, following which

**Table 1. The commercial materials used**

| Group | Material | Composition | Type | Filler loading | Manufacturer |
|---|---|---|---|---|---|
| EverX | GFRC – 'EverX Posterior' | BisGMA, TEGDMA, PMMA Barium borosilicate glass fibre, E-glass fibre | Fiber-reinforced composite | 74.2 wt % | (GC, Tokyo, Japan) |
| Filtek | Universal Restorative Composite – 'Filtek Ultimate' | BisGMA, TEGDMA, BisEMA, UDMA, silica/zirconia cluster filler (0.6–10 µm), zirconia particles (4–11 nm) | Hybrid composite | 74.2 wt % | (3M ESPE, St. Paul, MN, USA) |

Bis-GMA = bisphenol-A-glycidyl dimethacrylate; TEGDMA = triethylene glycol dimethacrylate; UDMA = urethane dimethacrylate; Bis-EMA = ethoxylated bisphenol-A-dimethacrylate; PMMA = poly methyl methacrylate; wt% = weight percentage.

**Table 2. Schematic illustrations of treatment groups for FS measurement**

| Group | Application thickness (mm) EverX: Filtek | Curing protocol | Schematic demonstration |
|---|---|---|---|
| EverX | 2:0 | Cured from the top |  |
| Filtek | 0:2 | Cured from the top |  |
| SnPl_1 | 1:1 | Step 1: EverX placed at the bottom Step 2: Filtek placed on top Step 3: The whole cured from the top |  |
| Inc_1 | 1:1 | Step 1. EverX placed at the bottom and cured Step 2. Filtek placed on top Step 3. Cured from the top |  |
| SnPl_2 | 1.5:0.5 | Same as SnPl_1 |  |
| Inc_2 | 1.5:0.5 | Same as Inc_1 |  |

: EverX,
: Filtek,
: cured surface,
: curing direction.

Filtek was cured from the top again. In the SnPl_2 and Inc_2 groups, the layering and curing protocols mirrored those of SnPl_1 and Inc_1, respectively, with the difference that EverX was 50% thicker and Filtek 50% thinner. Schematic illustrations of flexural test specimens and their treatments can be seen in Table 2.

Final polymerization of all specimens was done with light curing at 500 mW/cm$^2$ using Blue-LED light (Elipar S10, 3M ESPE). Polymerization protocol was done for 20s in five separate overlapping portions in accordance with ISO 4049. The assembly was placed in the water bath (37 ± 1) °C for 15 min. Then the specimens were removed from the mould and carefully abraded with 320 grit abrasive paper. Then samples were stored at 37°C in distilled water for 24 h prior to testing according to ISO 4049.

The three-point bending test was carried out using a universal testing machine (AGX-V, 100 kN, Shimadzu, Japan), under a crosshead speed of 0.75 mm/min, with a span length of 20 mm and an indenter diameter of 2 mm. FS ($\sigma_f$) was calculated according to the formula

$$\sigma_f = \frac{3 \times F \times l}{2 \times b \times h^2}$$

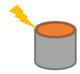
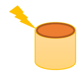
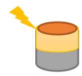
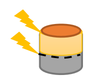
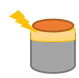
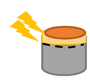
where $F$ is the load applied (N) at the top of the load-deflection curve, $l$ is the span length, $b$ is the width of the test specimen, and $h$ is its thickness.

Coming to the CS test, again 10 specimens per treatment group (N=60 in total) were prepared using Teflon moulds (4 mm in diameter and 6 mm in depth). Layering and curing protocols are illustrated in Table 3. Samples were cured on top and then the assembly was placed in the water bath (37 ± 1) °C for 15 min. Then the specimens were removed from the mould and were polished with 320-grit abrasive paper and stored in distilled water at 37°C for 24 h. After that, they were let dry at room temperature and their dimensions were measured with a digital pair of callipers (500-151-30 Mitutoyo, 0.01 mm resolution). Finally, the specimens were tested in a universal testing machine (AGX-V, 100 kN, Shimadzu, Japan) at a crosshead speed of 0.75 mm/min. The data were obtained in Newtons and transformed into MPa using the formula:

$$CS = \frac{4 \times F}{\pi \times d^2}$$

where CS is compressive strength (N/mm$^2$), $F$ is the maximum load at failure (N), and $d$ is the diameter of the specimen (mm).

**Table 3. Schematic illustrations of treatment groups for CS measurement**

| Group | Application thickness (mm) EverX:Filtek | Curing protocol | Schematic demonstration |
|---|---|---|---|
| EverX | 6:0 | Cured from top |  |
| Filtek | 0:6 | Cured from top |  |
| SnPl_1 | 3:3 | Step 1: EverX placed at the bottom<br>Step 2: URC placed on top<br>Step 2: The whole cured from the top |  |
| Inc_1 | 3:3 | Step 1. EverX is placed on bottom and cured<br>Step 2. URC was placed on the top<br>Step 3. Cured from top |  |
| SnPl_2 | 4:2 | Same as SnPl_1 |  |
| Inc_2 | 4:2 | Same as Inc_1 |  |

: EverX,
: Filtek,
: cured surface,
: curing direction.

As for the VH test, specimen preparation followed the same protocols as the CS test. Further, top (polymerized) and bottom (non-polymerized) surfaces were marked as such for the test. The hardness test itself was performed with a Microvickers Hardness Tester (MICROBUL 1000 DN, Bulut Makina) under a force of 100 g for 10 s. 55 specimens were tested three times for each group on both surfaces and VH values were measured.

Heterogeneity and normality test were determined using the Kolmogorov–Smirnov test. According to homogeneity and normality results Kruskal–Wallis analysis was applied to assess the statistical significance of the between-group differences. Two separate Kruskal–Wallis analysis were applied to VH values measured on top and at the bottom of the specimens. Subsequently, the Mann–Whitney *U*-test was used for multiple comparisons. In all the analyses the level of significance was set at $P < 0.05$.

## RESULTS

FS data are summarized in Table 4. Accordingly, the two single-layer groups yielded the highest FS mean values as part of this study, but the Kruskal–Wallis test indicated that FS values of all six groups are not significantly different ($P = 0.089$). Using EverX and Filtek as two layers seems to reduce FS regardless of application method, though the FS loss is relatively smaller with the SnPl_1. Further, using a thicker EverX bottom layer (SnPl_2) appears to worsen FS loss, which is again dampened when snowplowing is used. Incremental technique for Inc_1 and Inc_2 samples demonstrated the lowest FS values compared to SnPl_1.

CS values are reported in Table 4. The Kruskal–Wallis revealed that groups are differed significantly ($P \le 0.000$). Intergroup comparisons of CS were given in Fig. 1. EverX showed similar CS strength with Filtek ($P = 0.739$) and SnPl_1 ($P = 0.123$), and it was not significantly different. On the contrary, increasing thickness of SnPl_2 reduced CS ($P = 0.023$). Moreover, incremental technique [Inc_1 ($P = 0.000$) and Inc_2 ($P = 0.000$)] adversely reduced the CS of EverX. An interesting divergence is that this time Filtek produced higher average strength when used alone and both snowplow [SnPl_1 ($P = 0.019$) and SnPl_2 ($P = 0.023$)] and incremental [Inc_1 ($P = 0.000$) and Inc_2 ($P = 0.000$)] techniques reduced its CS statistically. SnPl_1 and SnPl_2 showed

**Table 4. Descriptive statistics of FS, CS and VH of specimens**

| | EverX | Filtek | SnPl_1 | Inc_1 | SnPl_2 | Inc_2 | *P** |
|---|---|---|---|---|---|---|---|
| CS | | | | | | | |
| Mean | 126.82 | 117.92 | 116.06 | 104.92 | 104.30 | 101.87 | 0.089 |
| SD | 18.81 | 21.23 | 25.13 | 17.40 | 24.03 | 14.92 | |
| CS | | | | | | | |
| Mean | 829.50 | 840.11 | 777.81 | 607.51 | 751.53 | 522.20 | 0.000 |
| SD | 52.86 | 38.71 | 59.11 | 168.80 | 96.87 | 99.42 | |
| VH top | | | | | | | |
| Mean | 39.67 | 51.85 | 59.22 | 45.30 | 65.01 | 31.40 | 0.000 |
| SD | 9.99 | 11.05 | 7.25 | 6.03 | 13.22 | 6.39 | |
| VH bottom | | | | | | | |
| Mean | 16.19 | 30.68 | 37.25 | 25.60 | 34.09 | 16.96 | 0.000 |
| SD | 4.08 | 6.54 | 4.56 | 3.41 | 4.62 | 2.30 | |

*According to Kruskal–Wallis test.

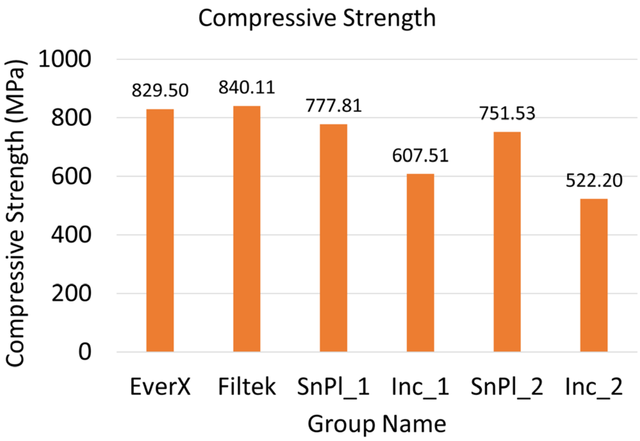



**Fig. 1** Descriptive statistics of CS of specimens.

similar CS results ($P = 0.190$). Similarly, CS values of Inc_1 and Inc 2 were not significantly different from each other ($P = 0.190$). On the contrary, with two layers, incremental technique seems to affect CS more adversely than snowplow does, regardless of relative layer thickness. CS values of SnPl_1 were significantly higher than Inc_1 ($P = 0.015$) and Inc_2 ($P = 0.000$). Similarly, SnPl_2 demonstrated better CS than Inc_1 ($P = 0.684$) and Inc_2 ($P = 0.000$).

Intergroup comparisons of VHs were given in Fig. 2.

The VH value of Filtek ($P = 0.012$), SnPl_1 ($P = 0.000$), Inc_1 ($P = 0.039$) and SnPl_2 ($P = 0.000$) was significantly greater than EverX. Inc_2, however, displayed VH values like those of EverX ($P = 0.212$). Filtek, demonstrated similar VH values on the top surface with SnPl_1 ($P = 0.128$) and Inc_1 ($P = 0.143$). An interesting finding was that the VH values of Filtek improved significantly with an increase in GFRC thickness in the SnPl_2 group ($P = 0.045$). Contrarily, in the Inc_2 group, the increasing GFRC thickness was associated with a significant decrease in the VH values of Filtek ($P = 0.000$).

In terms of technique, the snowplow technique significantly increased VH values compared to the incremental technique. VH values of SnPl_1 ($P = 0.000$; $P = 0.000$) and SnPl_2 ($P = 0.000$; $P = 0.000$) were significantly higher than Inc_1 and Inc_2, respectively. Additionally, SnPl_1 and SnPl_2 exhibited similar VH values ($P = 0.410$). In contrast, in the incremental technique, the VH value in the Inc_2 group significantly decreased compared to that in the Inc_1 group ($P = 0.000$).

The comparison of hardness results obtained from the bottom surface among different groups were also presented in the Fig. 2. The VH value of Filtek ($P = 0.000$), SnPl_1 ($P = 0.000$), Inc_1 ($P = 0.000$) and SnPl_2 ($P = 0.000$) was significantly greater than those of EverX. However, Inc_2 showed similar VH values to EverX ($P = 0.231$). Moreover, Filtek displayed similar VH values with SnPl_2 ($P = 0.755$) and Inc_1 ($P = 0.078$). In the Inc_2 group, an increase in the GFRC thickness led to a decrease in hardness ($P = 0.000$). However, SnPl_1 demonstrated significantly higher VH compared to Filtek ($P = 0.010$).

When comparing techniques, the snowplow technique resulted in a significant increase in VH values compared to the incremental technique. VH values on the bottom of SnPl_1 ($P = 0.000$; $P = 0.000$) and SnPl_2 ($P = 0.006$; $P = 0.000$) were significantly higher than Inc_1 and Inc_2, respectively. In the case of the thickness snowplow ($P = 0.017$) and incremental ($P = 0.000$) techniques showed similar results. In

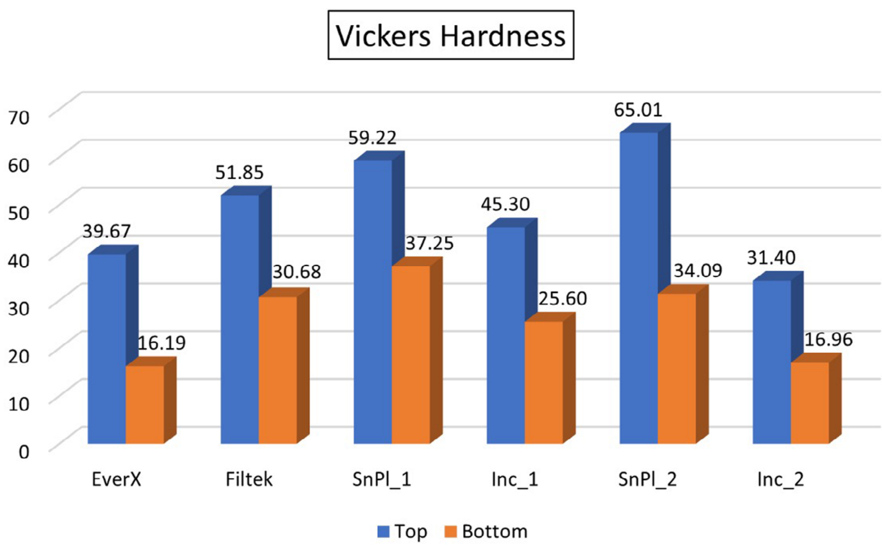



**Fig. 2** Vicker's Hardness test results for top and bottom surfaces.

both cases increasing the thickness of GFRC decreased the bottom microhardness values of the samples.

## DISCUSSION

Effect of snowplow and incremental techniques and varying levels of thickness on the mechanical properties of bulk-fill composites EverX Posterior and nanofill composite Filtek Ultimate were evaluated in this study. As the statistical analyses revealed the existence of statistically significant differences among the tested composites regarding CS and VH. Therefore, the null hypothesis that snowplow technique would not improve the mechanical properties of the restoration is rejected.

Restorative materials used in dentistry are subjected to various occlusal forces.[33] Using EverX is usually recommended[32,34] in order to prevent crack formation or arrest crack propagation, especially in direct posterior composite restorations. Furthermore, EverX's FS is similar to that of dentin, which enables it to absorb stress and dissipate energy.[35,36] In this research, mean FS was found to be higher than 80 MPa, set forth in ISO 4049/2019 for polymer-based restorative materials for restorations involving occlusal surfaces, in all treatment groups.[37] Use of EverX alone yielded the highest FS (126.82 MPa) as in another study by Garoushi *et al*.[16] Similarly, previous studies have shown that EverX produces higher FS than bulk fill and Filtek.[35,38–40] Yet Huang et. al found lower FS with EverX than with Filtek.[41] In this study, mean FS was not significantly different across groups, however ($P > 0.05$). The discrepancy between current results and the literature might be explained by differences in experimental design, such as the direction of force, crosshead speed and application method. It might be also relevant that FS was measured on 2 mm, 1.5 mm and 1 mm thick layers for EverX in this study, while in clinical practice bulk-fill composites are applied in thicker ones.[42] In line with its natural properties, the inorganic filler matrix of bulk-fill materials yields greater FS than the organic polymer matrix. From this perspective, as EverX and Filtek contained similar proportions of the inorganic matrix, it might not have affected restoration FS significantly.

The CS test evaluates the masticatory strength of the restorative material, especially for posterior composites.[43] It was applied in this study to compare another stress-bearing property across different kinds of treatment. Considering the application thickness, the CS test simulates clinical practice better than the FS in this study. Accordingly, EverX and Filtek exhibited similar compressive strength ($P = 0.739$). CS values of EverX were also similar to SnPl_1 ($P = 0123$). On the contrary, Filtek yielded higher CS than all other groups ($P \leq 0.05$). In a recent study evaluating the inclusion of fibre in composites, Sonam Behl *et al*. found that it did not cause a significant increase in CS,[44] in accordance with our findings. Accordingly, under CS, beyond elastic deformation, fillers (including fibres) reduce the area under which the cohesive forces of the matrix will be affected. The fibres thus act as a focal point of stress, joining to form a crack and further breakdown.[45] Therefore, their inclusion does not actually help improve strength, and indeed CS may decrease with fibre content.[37] Another useful way to improve CS is increasing filler proportion which reduces crack formation and deflection in composites, making the material more resistant to fracture. However, a study by Tekçe *et al*. revealed the clinical performances of EverX and Gaenial Posterior restorations not to be significantly different, with EverX Posterior exhibiting a higher failure rate.[46] Similarly, because EverX and Filtek contain similar proportions of filler, no significant difference was not observed in terms of CS according to our findings ($P = 0.739$). On the contrary, when compared in terms of application technique, it was determined that the snowplow method up to 3 mm as in SnPl_1, which we experimentally apply in EverX applications, significantly increased the CS compared to the incremental [Inc_1 ($P = 0.015$) and Inc_2 ($P = 0.000$)] method used in practice, and it did not decrease the CS of EverX ($P = 0.123$). However, the increased thickness significantly decreased the CS in the SnPl_2 group where EverX was applied as 4 mm ($P = 0.023$). Similarly, both incremental [Inc_1 ($P = 0.000$) and Inc_2 ($P = 0.000$)] and snowplow [SnPl_1 ($P = 0.019$) and SnPl_2 ($P = 0.000$)] technique was reduced CS of Filtek. As it was expected, this decrease is much higher in incremental method compared to snowplow.

Admittedly, microhardness values of resin composite restorations are considerably influenced by the dentist's finishing and polishing skills.[47] Other practical factors such as the patient's diet and dental hygiene can also impact surface characteristics.[48] Empirically, a resin composite's hardness is commonly correlated with mechanical strength, rigidity and resistance to occlusal degradation in the oral cavity.[49] Structurally, the hardness of the resin materials is closely related to filler size, shape and fraction in the inorganic phase, generally increasing with filler content.[50] Moreover, the composition and structure of the organic matrix are also notable factors.[51] As concerns clinical practice, the extent of a material's deformation, generally accepted as an important feature, is determined by its hardness. In order to achieve a clinically desirable restoration performance, hardness values of resin materials should at least parallel dentin's microhardness (80 MPa).[52] As presented above, VH of both top and bottom surfaces were found to be significantly lower with EverX than with Filtek. This finding is compatible with those of previous studies[41,53,54] and can be explained by the chemical structure of the resin monomer. Si/Zr nanocluster and $ZrO_2$ nanoparticles exhibit higher hardness than those of EverX fillers including PMMA Barium borosilicate glass filler and E-glass fibre. Also, UDMA and BisEMA tend to decrease the resin's hardness. As materials with lower surface hardness are more vulnerable to scratching[55] and EverX offers relatively low hardness, we can conclude that it should be covered with Filtek to withstand chewing forces.[56]

Since EverX is placed on the bottom in routine application, it is very important for the success of the application that the hardness value of the substrate is as high as possible.

For this reason, when compared to the VH values of EverX, it was seen that the snowplow technique [SnPl_1 ($P = 0.000$), SnPl_2 ($P = 0.000$)] allowed to significantly increase the hardness value measured from the bottom surface of EverX at different thicknesses. On the contrary, incremental technique at low thicknesses [Inc_1 ($P = 0.000$)] increased the hardness of EverX, while 4 mm of thickness [Inc_2 ($P = 0.231$)] did not make a significant difference in the hardness value. In clinical practice, due to the presence of Filtek on the top surface, its hardness should not be adversely affected for polishability.

In this sense, at low thicknesses, snowplow SnPl_1 ($P = 0.128$) and Inc_1 ($P = 0.143$) did not affect Filtek hardness. On the contrary, with decreasing thicknesses, the snowplow technique [SnPl_2 ($P = 0.045$)] significantly increased the Filtek hardness, while the incremental technique [Inc_1 ($P = 0.000$)] decreased it. With EverX introduced as a bulk layer, the mechanical properties of the bottom or top layer could be affected.[57] In this study, compared to incremental technique, snowplow was significantly increased VHs of specimen's both on top and bottom surfaces in all thickness for EverX. Moreover, SnPl_1 had similar VH with SnPl_2 on top but SnPl_2 had lower VH on bottom. On the other in case of incremental technique VH was significantly decreased in Inc_2 compared to Inc_1 on both surfaces.

Consistent with literature studies it is found that EverX is not used alone because of poor hardness in resulting restorations.[58–61] However, surprisingly it is found that because Filtek Ultimate is exceptionally strong, it may not require EverX, which would just mean additional cost without corresponding benefit. Moreover, since the currently used incremental method reduces the clinical success of EverX, the use of alternative methods such as snowplow may be beneficial in increasing the success and life of the restoration by providing superior mechanical properties in practice.

Limitations of this study primarily include that Filtek Ultimate was used in combination with only EverX and no other options. The application of EverX with the snowplow technique, together with composites with lower mechanical strength instead of Filtek, may allow much more successful restorations compared to the incremental method. Determination of bonding strength and oxygen inhibition zone as further research can be helpful to fully explore and characterize the snowplow technique's effect on the mechanical properties of total restorations. Additionally, studying the effect of incremental and snowplow techniques on the mechanical properties of the restoration *in vitro* on extracted human teeth can strengthen the evidence about which of these two techniques may be more beneficial in the use of EverX.

## CONCLUSION

Within the limits of this *in vitro* study, it is found that for clinical applications requiring the use of EverX, the snowplow curing technique may be more advantageous than the incremental method. Snowplow and incremental techniques are suitable for dentistry as they do not reduce the FS of Filtek and EverX, moreover, snowplow technique may be more advantageous in terms of time. Considering CS and hardness, the snowplow technique was found to be better than the incremental technique. On the contrary, combinations of EverX and Filtek using snowplow and incremental technique was decreased the CS values of self-used materials. Nevertheless, application of EverX at 4 mm thickness (SnPl_2) resulted in a significantly higher CS than the incremental technique and did not decrease the CS of the materials. EverX reaches lower hardness than Filtek on top as well as bottom surfaces. These findings could provide valuable insights into clinical practices and future research concerning restorative dentistry involving these specific materials and techniques.

## ACKNOWLEDGEMENTS

The authors would like to thank GC Europe for providing EverX Posterior composite resin.

## AUTHOR CONTRIBUTIONS

**Y Ölçer Us:** Methodology; conceptualization; investigation; funding acquisition. **A Aydınoğlu:** Writing – original draft; visualization; writing – review and editing; formal analysis; software. **Y Erdem Hepşenoğlu:** Methodology; supervision; writing – original draft. **Ş Erşahan:** Supervision; methodology. **K Sağır:** Data curation; software; validation. **A Üşümez:** Supervision; resources; project administration.

## CONFLICT OF INTEREST

GC firm donated part of the materials used.


## FUNDING INFORMATION

No funding was received for this study.


## REFERENCES


1. Ferracane JL. Placing dental composites—a stressful experience. Oper Dent 2008;33(3):247–257.
2. Sadowsky SJ. An overview of treatment considerations for esthetic restorations: a review of the literature. J Prosthet Dent 2006;96(6):433–442.
3. Nagas E, Cekic-Nagas I, Egilmez F, Ergun G, Vallittu PK, Lassila LVJ. Bond strength of fiber posts and short fiber-reinforced composite to root canal dentin following cyclic loading. J Adhes Sci Technol 2017;31(13):1397–1407.
4. Bijelic-Donova J, Garoushi S, Lassila LVJ, Vallittu PK. Oxygen inhibition layer of composite resins: effects of layer thickness and surface layer treatment on the interlayer bond strength. Eur J Oral Sci 2015;123(1):53–60.
5. Petersen RC. Discontinuous fiber-reinforced composites above critical length. J Dent Res 2005;84(4):365–370.
6. Bijelic-Donova J, Garoushi S, Lassila LVJ, Keulemans F, Vallittu PK. Mechanical and structural characterization of discontinuous fiber-reinforced dental resin composite. J Dent 2016;52:70–78.
7. Garoushi S, Vallittu PK, Lassila LVJ. Fracture toughness, compressive strength and load-bearing capacity of short glass fibre-reinforced composite resin. Chin J Dent Res 2011;14(1):15–19.
8. Garoushi S, Vallittu PK, Watts DC, Lassila LVJ. Polymerization shrinkage of experimental short glass fiber-reinforced composite with semi-inter penetrating polymer network matrix. Dent Mater 2008;24(2):211–215.
9. Garoushi S, Säilynoja E, Vallittu PK, Lassila L. Physical properties and depth of cure of a new short fiber reinforced composite. Dent Mater 2013;29(8):835–841.
10. Fráter M, Lassila L, Braunitzer G, Vallittu PK, Garoushi S. Fracture resistance and marginal gap formation of post-core restorations: influence of different fiber-reinforced composites. Clin Oral Investig 2020;24(1):265–276. https://doi.org/10.1007/s00784-019-02902-3.
11. Par M, Gamulin O, Marovic D, Klaric E, Tarle Z. Raman spectroscopic assessment of degree of conversion of bulk-fill resin composites–changes at 24 hours post cure. Oper Dent 2015;40(3):E92–E101.
12. Garoushi S, Tanner J, Vallittu PK, Lassila L. Preliminary clinical evaluation of short fiber-reinforced composite resin in posterior teeth: 12-months report. Open Dent J 2012;6:41–45.
13. Abouelleil H, Pradelle N, Villat C, Attik N, Colon P, Grosgogeat B. Comparison of mechanical properties of a new fiber reinforced composite and bulk filling composites. Restor Dent Endod 2015;40(4):262–270.
14. Shah JR, Raghavendra SS, Gathani KM, Wadekar SI. A practical approach in conservative management of vertical coronal fracture in molar: a case report. IIOAB J 2016;7(6):42–47.
15. Yadav K, de Ataide IDN, Fernandes M, Lambor R, Alreja D. Endodontic management of a mandibular first molar with radix entomolaris and conservative post-endodontic restoration with CAD/CAM onlay: a novel clinical technique. J Clin Diagn Res 2016;10(11):ZD13.
16. Keulemans F, Garoushi S, Lassila L. Fillings and core build-ups. A clinical guide to fibre reinforced composites (FRCs) in dentistry. Elsevier, Woodhead Publishing, 2017. 131–163.
17. Ferracane JL. Resin composite—state of the art. Dent Mater 2011;27(1):29–38.
18. Ghivari S, Chandak M, Manvar N. Role of oxygen inhibited layer on shear bond strength of composites. J Conserv Dent 2010;13(1):39–41.
19. Kupiec KA, Barkmeier WW. Laboratory evaluation of surface treatments for composite repair. Oper Dent 1996;21:59–62.
20. Finger WJ, Lee KS, Podszun W. Monomers with low oxygen inhibition as enamel/dentin adhesives. Dent Mater 1996;12(4):256–261.
21. Bajraktarova-Valjakova E, Korunoska-Stevkovska V, Kapusevska B, Gigovski N, Bajraktarova-Misevska C, Grozdanov A. Contemporary dental ceramic materials, a review: chemical composition, physical and mechanical properties, indications for use. Open Access Maced J Med Sci 2018;6(9):1742–1755.
22. Moldovan M, Balazsi R, Soanca A, *et al*. Evaluation of the degree of conversion, residual monomers and mechanical properties of some light-cured dental resin composites. Materials 2019;12(13):2109.
23. Nouh I, Kern M, Sabet AE, Aboelfadl AK, Hamdy AM, Chaar MS. Mechanical behavior of posterior all-ceramic hybrid-abutment-crowns versus hybrid-abutments with separate crowns—a laboratory study. Clin Oral Implants Res 2019;30(1):90–98. https://doi.org/10.1111/clr.13395.
24. Lassila L, Keulemans F, Säilynoja E, Vallittu PK, Garoushi S. Mechanical properties and fracture behavior of flowable fiber reinforced composite restorations. Dent Mater 2018;34(4):598–606. https://www.sciencedirect.com/science/article/pii/S0109564117310205.
25. Rueggeberg FA, Margeson DH. The effect of oxygen inhibition on an unfilled/filled composite system. J Dent Res 1990;69(10):1652–1658.
26. Munksgaard EC, Irie M, Asmussen E. Dentin-polymer bond promoted by Gluma and various resins. J Dent Res 1985;64(12):1409–1411.
27. Eliades GC, Caputo AA. The strength of layering technique in visible light-cured composites. J Prosthet Dent 1989;61(1):31–38.
28. Suh BI. Oxygen-inhibited layer in adhesion dentistry. J Esthet Restor Dent 2004;16(5):316–323.
29. Panchal AC, Asthana G. Oxygen inhibition layer: a dilemma to be solved. J Conserv Dent 2020;23(3):254–258.
30. Frese C, Wolff D, Staehle HJ. Proximal box elevation with resin composite and the dogma of biological width: clinical R2-technique and critical review. Oper Dent 2014;39(1):22–31.
31. Muscholl C, Zamorska N, Schoilew K, *et al*. Retrospective clinical evaluation of subgingival composite resin restorations with deep-margin elevation. J Adhes Dent 2022;24(1):335–344.
32. Opdam NJ, Roeters JJ, de Boer T, Pesschier D, Bronkhorst E. Voids and porosities in class I micropreparations filled with various resin composites. Oper Dent 2003;28(1):9–14.
33. Borouziniat A, Khaki H, Majidinia S. Retrospective evaluation of the clinical performance of direct composite restorations using the snow-plow technique: up to 4 years follow-up. J Clin Exp Dent 2019;11(11):e964.
34. Moosavi H, Maleknejad F, Forghani M, Afshari E. Evaluating resin-dentin bond by microtensile bond strength test: effects of various resin composites and placement techniques. Open Dent J 2015;9:409–413.
35. Patil BS, Kamatagi L, Saojii H, Chabbra N, Mutsaddi S. Cervical microleakage in giomer restorations: an in vitro Study. J Contemp Dent Pract 2020;21(2):161–165.
36. Soto-Montero J, Giannini M, Sebold M, *et al*. Comparison of the operative time and presence of voids of incremental and bulk-filling techniques on Class II composite restorations. Quintessence Int (Berl) 2022;53(3):200–208.

37. Nematollahi H, Bagherian A, Ghazvini K, Esmaily H, Mehr MA. Microbial microleakage assessment of class V cavities restored with different materials and techniques: a laboratory study. Dent Res J (Isfahan) 2017;14(5):344–350.
38. Meenakumari C, Bhat KM, Bansal R, Singh N. Evaluation of mechanical properties of newer nanoposterior restorative resin composites: an in vitro study. Contemp Clin Dent 2018;9(Suppl 1):S142–S146.
39. Moharam LM, El-Hoshy AZ, Abou-Elenein K. The effect of different insertion techniques on the depth of cure and vickers surface micro-hardness of two bulk-fill resin composite materials. J Clin Exp Dent 2017;9(2):e266.
40. Thomaidis S, Kakaboura A, Mueller WD, Zinelis S. Mechanical properties of contemporary composite resins and their interrelations. Dent Mater 2013;29(8):e132–e141. Available at: https://www.sciencedirect.com/science/article/pii/S0109564113001279.
41. Heintze SD, Ilie N, Hickel R, Reis A, Loguercio A, Rousson V. Laboratory mechanical parameters of composite resins and their relation to fractures and wear in clinical trials—a systematic review. Dent Mater 2017;33(3):e101–e114. Available at: https://www.sciencedirect.com/science/article/pii/S0109564116306923.
42. Quinn G. NIST recommended practice guide: fractography of ceramics and glasses. 2nd edn.. Gaithersburg, MD: Special Publication (NIST SP), National Institute of Standards and Technology, 2016.
43. Kim KH, Okuno O. Microfracture behaviour of composite resins containing irregular-shaped fillers. J Oral Rehabil 2002;29(12):1153–1159. https://doi.org/10.1046/j.1365-2842.2002.00940.x.
44. Tsujimoto A, Barkmeier WW, Takamizawa T, *et al*. Relationship between mechanical properties and bond durability of short fiber-reinforced resin composite with universal adhesive. Eur J Oral Sci 2016;124(5):480–489. https://doi.org/10.1111/eos.12291.
45. Fráter M, Forster A, Keresztúri M, Braunitzer G, Nagy K. In vitro fracture resistance of molar teeth restored with a short fibre-reinforced composite material. J Dent 2014;42(9):1143–1150. Available at: https://www.sciencedirect.com/science/article/pii/S0300571214001389.
46. Söderholm KJ. Relationship between compressive yield strength and filler fractions of PMMA composites. Acta Odontol Scand 1982;40(3):145–150. https://doi.org/10.3109/00016358209012723.
47. Miletic V, Pongprueksa P, de Munck J, Brooks NR, van Meerbeek B. Curing characteristics of flowable and sculptable bulk-fill composites. Clin Oral Investig 2017;21(4):1201–1212. https://doi.org/10.1007/s00784-016-1894-0.
48. Garoushi S, Lassila LVJ, Tezvergil A, Vallittu PK. Load bearing capacity of fibre-reinforced and particulate filler composite resin combination. J Dent 2006;34(3):179–184. Available at: https://www.sciencedirect.com/science/article/pii/S0300571205001181.
49. Huang Q, Qin W, Garoushi S, *et al*. Physicochemical properties of discontinuous S2-glass fiber reinforced resin composite. Dent Mater J 2018;37(1):95–103.
50. Bijelic-Donova J, Garoushi S, Vallittu PK, Lassila LVJ. Mechanical properties, fracture resistance, and fatigue limits of short fiber reinforced dental composite resin. J Prosthet Dent 2016;115(1):95–102. Available at: https://www.sciencedirect.com/science/article/pii/S0022391315004394.
51. van Noort R, Barbour M. Introduction to dental materials-e-book. Elsevier Health Sciences, Mosby Ltd, 2014.
52. Tekçe N, Aydemir S, Demirci M, Tuncer S, Sancak Eİ, Baydemir C. Clinical performance of direct posterior composite restorations with and without short glass-fiber-reinforced composite in endodontically treated teeth: 3-year results. J Adhes Dent 2020;22:127–137. Available at: http://europepmc.org/abstract/MED/32322834.
53. Behl S, Rajan G, Ellakwa A, Farrar P, Prusty BG. Physical and mechanical characterisation of flowable dental composites reinforced with short aspect ratio micro-sized S-Glass fibres. Mater Sci Eng C Mater Biol Appl 2020;111:110771.
54. Munoz CA, Bond PR, Sy-Munoz J, Tan D, Peterson J. Effect of pre-heating on depth of cure and surface hardness of light-polymerized resin composites. Am J Dent 2008;21(4):215–222.
55. Kim KH, Ong JL, Okuno O. The effect of filler loading and morphology on the mechanical properties of contemporary composites. J Prosthet Dent 2002;87(6):642–649.
56. Yikilgan İ, Kamak H, Akgul S, Ozcan S, Bala O. Effects of three different bleaching agents on microhardness and roughness of composite sample surfaces finished with different polishing techniques. J Clin Exp Dent 2017;9(3):e460.
57. Marghalani HY. Resin-based dental composite materials. Handbook of bioceramics and biocomposites. Cham: Springer, 2016. 357–405.
58. Chinelatti MA, Chimello DT, Ramos RP, Palma-Dibb RG. Evaluation of the surface hardness of composite resins before and after polishing at different times. J Appl Oral Sci 2006;14:188–192.
59. Nagi SM, Moharam LM, Zaazou MH. Effect of resin thickness, and curing time on the micro-hardness of bulk-fill resin composites. J Clin Exp Dent 2015;7(5):e600.
60. Leprince JG, Palin WM, Vanacker J, Sabbagh J, Devaux J, Leloup G. Physico-mechanical characteristics of commercially available bulk-fill composites. J Dent 2014;42(8):993–1000.
61. Pala K, Tekce N, Tuncer S, Serim ME, Demirci M. Evaluation of the surface hardness, roughness, gloss and color of composites after different finishing/polishing treatments and thermocycling using a multitechnique approach. Dent Mater J 2016;35(2):278–289.



*Address for correspondence:*
*Yelda Erdem Hepsenoglu*
*Department of Endodontics*
*Istanbul Medipol University*
*34250 Istanbul*
*Turkey*
*Email: yelda_erdem89@hotmail.com*