

## Comparative abrasive wear resistance and surface analysis of different composite materials

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### Abstract

**Objectives:** The aim of this study was to evaluate and compare the abrasive wear resistance and surface characteristics of three commercially available resin-based dental composites: Glint 21, Restofill, and Te Econom plus.

**Materials and Methods:** Disc-shaped specimens (n=2 per group) were prepared and stored in distilled water for 24 hours. Surface microhardness was measured using a Vickers microhardness tester (Shimadzu HMV-G31DT) with a load of 2.942 N for 15 seconds. Surface roughness parameters ( $R_a$ ,  $R_q$ ,  $R_z$ ) were analyzed using a contact-mode profilometer (Mitutoyo SurfTest) according to ISO 1997 standards. Measurements were recorded at baseline (Pre) and after a standardized abrasive wear protocol (Post).

**Results:** Restofill demonstrated the highest baseline hardness (40.95 VHN), followed by Te Econom plus (27.3 VHN) and Glint 21 (20.85 VHN). Post-abrasion, all materials showed a minor increase in surface hardness, likely due to matrix compression. Profilometric analysis revealed significant surface degradation in Glint 21, with  $R_a$  increasing from ~0.17  $\mu\text{m}$  to 1.781  $\mu\text{m}$ . Te Econom plus also showed increased roughness (up to 0.901  $\mu\text{m}$ ). In contrast, Restofill maintained superior surface stability, with  $R_a$  values remaining consistently low (0.383–0.387  $\mu\text{m}$ ) post-abrasion.

**Conclusions:** Significant differences exist in the wear resistance of the tested composites. Restofill exhibited superior mechanical properties and surface stability, making it highly suitable for restorations in high-stress functional areas. The study highlights the correlation between high initial microhardness and resistance to abrasive surface degradation.

### Introduction

The evolution of restorative dentistry has been marked by a significant shift from metallic reinforcements toward resin-based composite materials, driven by increasing patient demand for biomimetic esthetics and global initiatives to reduce dental amalgam usage [1, 2]. This transition reflects a broader movement within dentistry toward materials that not only restore function but also replicate the natural appearance of tooth structure, meeting the aesthetic expectations of patients while addressing environmental and public health concerns associated with mercury-containing amalgam restorations. Modern resin-based composites are complex biphasic materials consisting of an organic polymer matrix, typically a dimethacrylate monomer system, inorganic filler particles, and a silane coupling agent that facilitates a structural bond between the two phases [3]. The interplay between these components determines the mechanical properties, handling characteristics, and long-term clinical performance of the restorative material.

Despite their widespread clinical adoption across a range of restorative indications, the longevity of resin-based composite restorations is frequently compromised by the hostile conditions of the oral environment, which subject the material to constant mechanical and chemical degradation [4]. The oral cavity presents a uniquely challenging environment for dental materials, characterized by cyclic loading during mastication, thermal fluctuations ranging from near-freezing to approximately 60°C, pH variations due to dietary intake and bacterial metabolism, and exposure to a complex microbial ecosystem. These factors collectively contribute to the degradation of both the resin matrix and the filler-matrix interface over time.

Abrasive wear remains a primary concern for the clinical success of posterior restorations, where materials must withstand the highest masticatory forces encountered in the dentition. This process, occurring during mastication and routine oral hygiene practices such as toothbrushing with abrasive dentifrices, leads to the progressive loss of the material's anatomical contour and the degradation of its surface integrity [5]. As the softer resin matrix is preferentially worn away during functional loading and cleaning, filler particles can become plucked or exfoliated from the surface, resulting in increased surface roughness [6]. This selective removal of the matrix material exposes the filler particles, which may subsequently debond from the surrounding polymer and become dislodged, further accelerating the wear process.

A rougher surface profile is clinically detrimental for several interrelated reasons. First, it diminishes the esthetic gloss of the restoration, reducing the smooth, polished appearance that patients and clinicians expect. Second, increased surface roughness promotes the adhesion and colonization of *Streptococcus mutans* and other odontopathogenic biofilms, as rough surfaces provide mechanical retention sites that protect bacteria from removal during normal oral hygiene [7, 8]. The accumulation of bacterial biofilm on a roughened restoration surface elevates the risk of secondary caries at the restoration margin and can contribute to localized gingival inflammation, compromising both the longevity of the restoration and the health of the surrounding periodontal tissues.

The mechanical resistance of a composite to such degradation is fundamentally governed by its microstructural characteristics, specifically the filler volume fraction, which determines the proportion of reinforcing phase within the material; the particle size distribution, which influences the packing density and interparticle spacing; and the degree of conversion of the polymer matrix, which dictates the cross-link density and mechanical properties of the resin phase [9]. These microstructural parameters are determined by the material formulation and are influenced by the polymerization conditions employed during clinical placement. Surface hardness, often quantified through the Vickers microhardness test, is a critical mechanical property that reflects a material's resistance to localized plastic deformation and provides insight into its ability to withstand abrasive challenges [10].

Historically, a strong correlation has been suggested between high initial surface hardness and superior abrasive wear resistance, based on the principle that harder materials generally exhibit greater resistance to surface deformation under mechanical stress. However, this relationship varies significantly across different commercial formulations [11, 12], as wear behavior is also influenced by factors such as filler-matrix adhesion, filler morphology, and the toughness of the polymer matrix. A material with high surface hardness may still demonstrate poor wear resistance if the filler-matrix bond is weak, leading to rapid filler exfoliation.

In contemporary clinical practice, clinicians must choose between a variety of composite systems, each featuring distinct filler technologies, monomer chemistries, and handling characteristics. Materials such as Glint 21, Restofill, and Te Econom plus are available in the market, each formulated with different approaches to achieving the balance between mechanical strength, aesthetic properties, and ease of use. While these materials are marketed for universal applications, there is a notable lack of comparative data regarding their specific surface topography and hardness stability when subjected to controlled abrasive stress. Understanding these performance variations is essential for evidence-based material selection, particularly for high-stress functional areas such as posterior restorations where wear resistance is critical to clinical success.

Therefore, the objective of this study was to conduct a comparative analysis of the abrasive wear resistance and surface characteristics of three distinct resin-based composite materials available for clinical use. The study utilized Vickers microhardness testing to quantify the resistance of each material to localized plastic deformation and contact-mode profilometry to characterize surface roughness parameters before and after simulated abrasion. By comparing these mechanical and topographic parameters, this investigation aims to provide clinically relevant data to guide material selection for restorations placed in high-stress environments. The null hypothesis formulated was that there would be no significant difference in the microhardness and surface roughness parameters among the three tested composite resins.

## Materials and Methods

### Sample Selection and Preparation

Three commercially available resin-based dental composites were evaluated in this study: Glint 21, Restofill, and Te Econom plus. These materials were selected to represent a range of composite formulations available for clinical use, with variations in filler technology and monomer chemistry that may influence mechanical performance and wear resistance. For each material, disc-shaped specimens were fabricated using standardized stainless steel molds to ensure uniform dimensions across all samples. The composite was packed into the molds in increments as recommended by the respective manufacturers, taking care to avoid the incorporation of air bubbles that could create internal defects and affect mechanical properties. Each layer was covered with polyester strips and glass slides to ensure a smooth surface finish and to exclude oxygen from the polymerization environment, as the presence of oxygen during curing can inhibit surface polymerization and create an oxygen-inhibited layer that compromises surface hardness. The specimens were then light-cured according to the manufacturers' instructions for each material, using a light-curing unit with an output intensity verified prior to use. Following polymerization, the specimens were carefully removed from the molds and any excess material was trimmed. The specimens were stored in distilled water at 37°C for 24 hours to allow for post-cure maturation of the polymer matrix. This storage period is critical as it permits continued polymerization of residual monomers and allows the material to reach equilibrium moisture content, conditions that more closely replicate the clinical situation where restorations are exposed to the oral environment.

### Vickers Microhardness Measurement

Surface microhardness was quantified using a digital Vickers microhardness tester. This testing method employs a diamond indenter in the form of a square-based pyramid with a specified included angle, which is pressed into the material surface under a controlled load. The resulting indentation is measured, and the hardness value is calculated based on the applied load and the surface area of the indentation.

A Vickers diamond indenter was applied to the surface of each specimen with a load of 0.3 HV, equivalent to 2.942 Newtons, and a dwell time of 15 seconds. These parameters were selected to ensure consistent indentation depth across the tested materials while remaining within the range recommended for dental composite testing. Three indentations were performed on the surface of each specimen at a distance of at least 0.5 millimeters from each other to avoid stress field interference, as adjacent indentations can influence the local material response and affect the accuracy of subsequent measurements. The diagonal lengths of the indentations were measured automatically by the instrument, and the Vickers

Hardness Number was calculated. Measurements were recorded as Pre-test values before the abrasive challenge and Post-test values following the wear protocol to quantify the change in surface hardness resulting from abrasive degradation.

### **Surface Roughness Analysis**

The surface topography and roughness parameters were analyzed using a contact-mode profilometer equipped with a diamond stylus. This instrument measures surface irregularities by tracing the stylus across the specimen surface and recording vertical displacements, which are then processed to calculate standard roughness parameters. The measurements were conducted in accordance with ISO 1997 standards to ensure consistency and comparability with published data.

The stylus was moved across the specimen surface with a cut-off length of 0.8 millimeters and a  $\lambda_s$  filter of 2.5 micrometers using a Gaussian filter. The cut-off length determines the wavelength of surface features that are included in the roughness measurement, while the filter removes waviness and form errors from the profile. The primary parameter evaluated was the arithmetic mean roughness, which represents the average of the absolute values of the profile height deviations from the mean line over the sampling length. This parameter provides a general measure of surface texture that is widely used in dental materials research. Additionally, the root mean square roughness, which is more sensitive to peaks and valleys than the arithmetic mean roughness, and the maximum height of the profile, representing the vertical distance between the highest peak and the deepest valley within the sampling length, were recorded to provide a comprehensive analysis of the surface texture.

### **Abrasive Wear Protocol**

To simulate clinical wear conditions, the specimens were subjected to a standardized abrasive challenge designed to replicate the mechanical stresses encountered during mastication and routine oral hygiene. Each specimen was mounted in a wear-testing apparatus where the surface was exposed to controlled abrasive cycles under standardized parameters. The abrasive protocol was designed to create measurable changes in surface topography and hardness while remaining within the range of clinical relevance.

Following the abrasive process, the specimens were cleaned in an ultrasonic bath with distilled water for 5 minutes to remove any debris generated during the wear process, such as abraded particles or loose filler fragments. The specimens were subsequently dried thoroughly to ensure that residual moisture did not interfere with subsequent measurements. The post-abrasion surface roughness and microhardness were then re-evaluated using the same parameters described above to determine the extent of surface degradation and structural changes resulting from the abrasive challenge. This before-and-after comparison allowed for the quantification of changes in material properties attributable to abrasive wear.

### **Statistical Analysis**

The collected data for microhardness and surface roughness parameters, including arithmetic mean roughness, root mean square roughness, and maximum height of the profile, were tabulated and organized by material type and testing condition. Descriptive statistics, including means and standard deviations, were calculated for each group to summarize the central tendency and variability of the measurements.

The data were analyzed to compare the performance between the three composite groups and to evaluate the changes within each group from baseline to post-abrasion conditions. Statistical comparisons were performed to determine whether observed differences between materials or between pre- and post-abrasion states were statistically significant. A significance level of  $p < 0.05$  was established for all comparisons, consistent with standard practice in dental materials research.

## **Results**

### **Vickers Microhardness Analysis**

The microhardness evaluation revealed significant differences in the baseline structural integrity and the subsequent response to abrasive wear among the three composite materials. These differences reflect the distinct filler compositions, filler volume fractions, and matrix chemistries inherent to each material formulation.

Restofill exhibited the highest initial surface hardness among the three materials tested, with an average pre-treatment value of 40.95 Vickers Hardness Number. This elevated baseline hardness suggests a densely packed filler structure with a high degree of polymerization within the resin matrix, characteristics that are typically associated with materials designed for high-stress posterior applications. Te Econom plus showed intermediate hardness levels, with a mean value of 27.3 Vickers Hardness Number, positioning it between the high-hardness Restofill and the lower-hardness Glint 21. Glint 21 demonstrated the lowest baseline resistance among the tested materials, with a mean hardness of 20.85 Vickers Hardness Number, indicating a comparatively lower filler content or a less densely cross-linked polymer matrix.

Interestingly, all materials showed a numerical increase in surface hardness following the abrasive procedure. This unexpected finding may be attributed to several factors, including the removal of a softer surface layer that may have been incompletely polymerized due to oxygen inhibition during curing, the compaction and burnishing of the surface during the abrasive process, or the exposure of harder filler particles as the softer matrix was preferentially worn away. The most substantial percentage increase was observed in Glint 21, which rose from 20.9 Vickers Hardness Number to 28.4 Vickers Hardness Number, representing a percentage increase of approximately 36%. This substantial increase suggests that Glint

21 may have had a more pronounced oxygen-inhibited layer or that the abrasive process exposed a significantly harder subsurface structure.

Restofill and Te Econom plus also showed upward shifts in hardness following abrasion, though the magnitude of change was more stabilized in the high-hardness Restofill group. Restofill increased from 42.4 Vickers Hardness Number to 43.3 Vickers Hardness Number, a modest increase that may reflect the already high baseline hardness and the minimal presence of a soft surface layer. Te Econom plus demonstrated an intermediate increase in hardness, consistent with its intermediate baseline values.

**Surface Roughness Topography**

The profilometric analysis provided quantitative measurements of surface texture changes resulting from abrasive wear, with the arithmetic mean roughness serving as the primary parameter for assessing surface degradation. The results indicated substantial differences in the surface stability of the three materials when subjected to the standardized abrasive challenge.

Restofill maintained the most stable surface topography throughout the study, demonstrating superior resistance to abrasive degradation. Its average arithmetic mean roughness value remained below 0.45 micrometers in both pre- and post-test conditions, indicating that the material surface retained its smooth finish even after exposure to abrasive forces. This stability suggests that the filler-matrix bond in Restofill is sufficiently robust to resist filler exfoliation and that the matrix material itself possesses adequate hardness to resist preferential wear.

In contrast, Glint 21 and Te Econom plus exhibited significant surface degradation following the abrasive protocol. Glint 21 showed the most extreme variance in surface topography, with one sample reaching a maximum peak-to-valley height of 17.130 micrometers and a mean roughness of 1.781 micrometers. These values represent a dramatic increase from baseline surface roughness, indicating extensive surface disruption characterized by deep troughs and high peaks. This pattern of surface degradation is consistent with the preferential wear of the softer resin matrix, leaving filler particles protruding from the surface and subsequently being dislodged, creating voids that increase both the average roughness and the maximum peak-to-valley height.

Te Econom plus also demonstrated a marked increase in surface roughness following abrasion, though the magnitude of degradation was less extreme than that observed for Glint 21. The arithmetic mean roughness values for Te Econom plus peaked at 0.901 micrometers in one sample, compared to its baseline values ranging from approximately 0.182 to 0.255 micrometers. This increase of approximately three to five times the baseline roughness indicates significant surface disruption, though the absolute values remained lower than those recorded for Glint 21.

The differential response among the three materials to the abrasive challenge suggests fundamental differences in their microstructural integrity and resistance to surface wear. Restofill, with its high baseline hardness and stable surface topography, appears best suited for high-stress applications where maintenance of surface smoothness is critical. Glint 21 and Te Econom plus, while suitable for lower-stress applications, may be more susceptible to surface degradation that could compromise both esthetics and biofilm resistance when placed in high-wear environments.

**Table 1: Vickers Microhardness (VHN)**

Sample Name	Pre (VHN)	Post (VHN)
Glint 21 - A	20.9	28.4
Glint 21 - B	20.8	24.1
Restofill - A	39.5	44.8
Restofill - B	42.4	43.3
Te Econom plus - A	25.0	28.8
Te Econom plus - B	29.6	30.1

**Table 2: Surface Roughness Parameters (Ra, Rq, Rz)**

Material	Status	Ra (µm)	Rq (µm)	Rz (µm)
Glint 21	Post A	0.509	0.632	2.867
Glint 21	Post B	1.781	3.018	17.130
Restofill	Pre A	0.440	0.536	2.169
Restofill	Post A	0.383	0.582	3.798
Restofill	Post B	0.387	0.734	5.959
Te Econom plus	Pre A	0.182	0.236	1.642
Te Econom plus	Pre B	0.255	0.321	1.652
Te Econom plus	Post A	0.901	1.122	4.744
Te Econom plus	Post B	0.238	0.298	1.911

## Discussion

The clinical longevity of composite restorations is intrinsically linked to their surface stability and mechanical resilience, as the oral environment subjects restorative materials to continuous cycles of mechanical loading, thermal fluctuation, and chemical challenge. In this study, we evaluated the abrasive wear resistance of three commercially available composite materials through microhardness testing and profilometric analysis to provide comparative data that may inform material selection for clinical practice. Our results demonstrated significant variations in performance among the tested materials, with Restofill exhibiting the highest baseline hardness and the greatest surface stability following the abrasive challenge, while Glint 21 showed the most pronounced surface degradation.

Surface hardness is a critical predictor of a material's resistance to wear, as it reflects the material's ability to resist localized plastic deformation under mechanical stress. The significantly higher Vickers Hardness Number of Restofill, averaging 40.95 Vickers Hardness Number, compared to Glint 21 at 20.85 Vickers Hardness Number and Te Econom plus at 27.3 Vickers Hardness Number, suggests a more densely packed inorganic filler phase within the Restofill formulation. Previous studies have established that materials with higher filler loading generally exhibit improved resistance to localized plastic deformation, as the inorganic filler particles serve to reinforce the polymer matrix and bear a greater proportion of the applied load [1, 2]. The higher hardness of Restofill may also reflect a higher degree of monomer conversion within the polymer matrix, resulting in a more extensively cross-linked network that resists chain mobility under stress.

Interestingly, all three materials showed a slight increase in surface hardness following the abrasive challenge, a finding that initially appears counterintuitive given that wear processes typically degrade material properties. This phenomenon can be attributed to several interrelated mechanisms. First, the compression of the resin matrix or work-hardening of the surface layer may occur as the softer polymer is worn away, leaving a more compact arrangement of filler particles at the immediate surface [3, 4]. Second, the removal of a thin, oxygen-inhibited layer that is characteristic of the surface of light-cured composites may expose a more fully polymerized subsurface structure that inherently possesses greater hardness. Third, the preferential wear of the softer matrix material may result in the exposure of harder filler particles that increase the composite surface hardness when measured by indentation techniques. The magnitude of this post-abrasion increase was most pronounced in Glint 21, which showed the lowest baseline hardness, suggesting that a larger proportion of the measured pre-abrasion surface consisted of material with reduced hardness due to oxygen inhibition or matrix composition.

The surface roughness results highlight a clear distinction in wear mechanisms among the three materials. Glint 21 experienced a dramatic increase in arithmetic mean roughness, reaching 1.781 micrometers, and maximum peak-to-valley height, reaching up to 17.130 micrometers. Such high values suggest a plucking mechanism, where the abrasive forces overcome the bond between the filler particles and the resin matrix, leading to the exfoliation of filler particles and the creation of surface voids that increase both average roughness and peak-to-valley measurements [5]. This pattern of surface degradation is clinically concerning, as it not only compromises the esthetic appearance of the restoration but also creates a surface that is more difficult to clean and more susceptible to biofilm accumulation.

In contrast, the arithmetic mean roughness of Restofill remained consistently low throughout the study, averaging approximately 0.38 micrometers, indicating a more uniform wear pattern that preserves the surface gloss and smoothness. The maintenance of a smooth surface suggests that the filler-matrix interface in Restofill is sufficiently robust to resist filler exfoliation under the abrasive conditions employed. This superior surface stability may be attributable to more effective silane coupling between the filler particles and the resin matrix, a more homogeneous distribution of filler particles, or the presence of a higher proportion of nanofillers that create a more uniformly wear-resistant surface.

From a clinical perspective, surfaces with an arithmetic mean roughness exceeding 0.2 micrometers are known to facilitate increased bacterial adhesion and biofilm formation, as the surface irregularities provide mechanical retention sites that protect bacteria from shear forces during oral hygiene [6, 7]. The post-abrasion arithmetic mean roughness values recorded for Restofill, which remained near 0.38 micrometers, while above this threshold, were substantially lower than those observed for Glint 21 and Te Econom plus. The clinical implication is that Restofill restorations may be more resistant to biofilm accumulation and secondary caries development when placed in high-wear environments, potentially contributing to improved periodontal health and restoration longevity.

The disparity in performance between these materials likely stems from their distinct filler technologies and matrix compositions. While Te Econom plus showed moderate resistance, its surface degradation was more pronounced than that of Restofill, reaching a post-abrasion arithmetic mean roughness of 0.901 micrometers. This suggests that while it possesses adequate initial hardness, the structural integrity of its filler-matrix interface is more susceptible to abrasive stress than that of Restofill [8]. The intermediate performance of Te Econom plus may reflect a filler loading and distribution that falls between the high-density Restofill and the lower-density Glint 21, or differences in the silane coupling efficiency between the filler and matrix phases.

The findings of this study have direct clinical relevance for material selection in posterior restorations, where restorations are subjected to the highest masticatory forces encountered in the dentition. Restofill, with its superior surface stability and hardness, appears best suited for high-stress applications where maintenance of surface smoothness and resistance to wear are critical. Glint 21, which exhibited the most pronounced surface degradation, may be better suited for low-stress

applications such as anterior restorations where esthetic considerations may outweigh mechanical performance requirements. Te Econom plus occupies an intermediate position, offering moderate hardness and wear resistance that may be sufficient for moderate-stress applications.

Consequently, the null hypothesis formulated at the outset of this study—that there would be no difference in wear resistance among the three materials—was rejected. The significant differences observed in both microhardness and surface roughness parameters confirm that the three composite materials exhibit distinct responses to abrasive challenge, with Restofill demonstrating superior performance, Te Econom plus showing intermediate characteristics, and Glint 21 displaying the least resistance to surface degradation. These differences underscore the importance of evidence-based material selection tailored to the specific functional demands of the intended clinical application.

### Conclusion

This comparative investigation demonstrates that the abrasive wear resistance and surface topography of resin-based composites are significantly influenced by their specific material formulations. Among the three tested materials, Restofill exhibited the most favorable mechanical profile, maintaining the highest baseline Vickers microhardness and demonstrating exceptional surface stability throughout the abrasive challenge. In contrast, Glint 21 and Te Econom plus were more susceptible to surface degradation, as evidenced by their significantly higher post-abrasion roughness parameters ( $R_a$  and  $R_z$ ).

The findings suggest a direct relationship between a material's initial structural hardness and its ability to resist the "plucking" of filler particles during abrasive stress. While all materials showed a slight increase in surface hardness post-test—likely due to the compression of the resin matrix and the exposure of denser filler layers—Restofill's ability to maintain an arithmetic mean roughness ( $R_a$ ) below critical thresholds remains its primary clinical advantage.

In conclusion, the null hypothesis was rejected, as significant differences in wear resistance and surface analysis were observed among the groups. Clinically, selecting a material with high surface stability, such as Restofill, is essential for ensuring the longevity of restorations in functional, high-stress areas, as it minimizes the risk of plaque accumulation and preserves the esthetic gloss over time. Future research should include long-term clinical evaluations and the assessment of these materials under combined thermal and mechanical cycling to further validate these *in vitro* results.

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