EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 71, 1801:1809, April, 2025

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 23-01-2025 • Accept Date : 17-02-2025 • Available online: 25-04-02025 • DOI : 10.21608/edj.2025.354870.3354

THE IMPACT OF GASTRIC ACID ON THE SURFACE MICROHARDNESS OF UNIVERSAL INJECTABLE RESIN COMPOSITES

Ahmed Abbas Rhaif* , Hoda Saleh Ismail**,
Tawakol Ahmed Enab*** *and* Nadia Mohamed Zaghloul****

ABSTRACT

Introduction: The G-aenial Universal Injectable, a novel resin composite for the repair of decaying and worn teeth, is being examined for its potential microhardness in response to stomach acid exposure.

Objective: This *in vitro* study aimed to evaluate the surface microhardness of universal injectables and investigate the impact of hydrochloric acid (HCL) and thermal cycling on microhardness.

Materials and methods: Eight (G-aenial Universal—G-aenial Universal Injectable, GC)—and eight (3M Filtek Universal—3M Filtek Z350 XT Universal Restorative, 3M) specimens with a total number of 32 specimens (2 × 10 mm) were used. Based on the aging condition, the tested material was divided into two subgroups (n = 8): one was kept in deionized water (Water) (pH = 7) at 37°C for 24 hours, and the other in HCL solution (pH = 1.2) for 3 hours. Following light curing, finishing, polishing, immersion in HCL, and thermal cycling, a digital display Vickers microhardness tester is used to evaluate the surface microhardness.

Results: The study found a significant difference in Vickers microhardness between G-aenial Universal and 3M Filtek Universal for Water ($p < 0.001$), with G-aenial Universal having the highest microhardness and 3M Filtek Universal having the lowest. No significant difference was found for HCL+TC composites. However, there was a significant difference in Vickers microhardness between the aging conditions, with Water having the highest microhardness.

Conclusions: The G-aenial Universal can replace 3M Feltik Universal for healthy patients with near-neutral oral conditions, but not for recurrent gastric reflux patients due to their preferred microhardness.

KEYWORDS: G-aenial Universal, HCL, Thermal cycling, Microhardness

* Msc Student, Conservative Dentistry Faculty of Dentistry Mansoura University
** Instructor, Conservative Dentistry Faculty of Dentistry Mansoura University
*** Professor, Department of Production and Mechanical Design Faculty of Engineering, Mansoura University, Egypt
**** Professor, Conservative Dentistry Faculty of Dentistry Mansoura University

INTRODUCTION

Recently, there has been a significant rise in interest in minimally invasive dentistry. This approach focuses on keeping the maximum amount of the tooth's healthy structure to enhance the stability and durability of adhesive restorations. [1–3] Resin-based composites, usually consisting of filler particles and a resin matrix, are among the most prevalent direct restorative materials.[4] dental manufacturers developed highly loaded composite materials utilizing nanotechnology, with an efficiency of up to 79.5 wt.%. This procedure diminishes bacterial infiltration, colour alterations, curing contraction, and marginal leakage, leading to more refined fillings and enhanced finishing. Nanosized fillers exist in two forms: discrete individual particles and aggregated main nanoparticle clusters. [5–7]

A novel flowable resin composite including a substantial filler component has been created, exhibiting elevated viscosity and enhanced mechanical properties. [8] This "injectable composite" is characterized by a high concentration of nanosized filler particles (69 wt.%), rendering it comparable to traditional composite repair materials. Surface-modified, nanosized fillers are included to reduce viscosity, facilitate insertion, and provide compatibility for load-bearing dental restorations. [8,9]

Microhardness is a critical determinant of a material's resistance to plastic deformation and abrasion. [10,11] Numerous variables, including the kind of resin matrix and the degree of crosslinking after polymerization, govern this feature. Moreover, the surface hardness of composite materials is affected by the kind, size, and volume of the filler component. Consequently, the degree of conversion during polymerization can be affected by any of these factors, thereby influencing the material's hardness.[11,12] Materials having a higher degree of cross-linking and greater filler content typically demonstrate enhanced surface hardness. [10] Additionally, the digital display Vickers microhardness tester was employed to determine the specimens' Vickers hardness number (VHN), recognized as the most accurate and dependable method for assessing microhardness in the evaluation of the mechanical characteristics of resin composites. [13] Thermal cycling can enhance water sorption in resin composites due to the plasticizing impact of water and the hydrolysis of silane coupling agents, which may compromise the material's surface integrity. [14]

Acidic erosion can deteriorate the organic matrix and expose the inorganic fillers, compromising the mechanical and physical characteristics of the composite. [15] The surface exhibits increased softness and roughness as an *in vitro* consequence of these alterations, hence reducing the restoration's longevity. To maintain the longevity of the functioning, it is essential to utilize materials appropriate for restoring the teeth of patients with gastroesophageal reflux, since contact with hydrochloric acid may induce superficial alterations in composite resin. [16]

The pH of pure hydrochloric acid ranges from 0.9 to 1.5, and following episodes of vomiting in the oral cavity, this pH does not decrease below 1.5 due to esophageal buffering and saliva dilution, resulting in a significant and high-risk situation for the development and advancement of erosive lesions.[17,18] Gastroesophageal reflux, which occurs when gastric contents regurgitate into the esophagus or oral cavity, has been associated with tooth erosion in both adults and children. Vomiting and gastroesophageal reflux disease (GERD) can decrease saliva pH levels below 5.5, the essential threshold for enamel demineralization, resulting in tooth erosion absent bacterial influence. [19] The reduction in surface microhardness of resin composite heightens sensitivity to scratches and roughness, leads to discoloration and diminished gloss, and facilitates plaque accumulation following bacterial adherence.[20] Alp *et al.* (2022)[20], indicate that methacrylate ester linkages in polymeric materials undergo hydrolysis in acidic pH environments, leading to rapid degradation of the polymer network and a reduction in physical qualities such as smoothness and microhardness.

Upon reviewing the literature, it is evident that scientific studies are deficient in information on the impact of acidic environments and thermal cycling on the surface microhardness of the newly developed universal injectable resin composite. The objective of this *in vitro* study was to evaluate the surface microhardness of universal injectable composites with regular consistency resin composites subjected to HCL and thermal cycling. The null hypotheses posited that 1) there were no significant variations in microhardness between the evaluated restorative materials, regardless of the aging process; 2) the aging conditions would not influence the softness of the assessed restorative materials.

MATERIALS AND METHODS

Materials

This study employed two distinct resin composite materials, each distinguished by their respective brands. The materials used were as follows: universal injectable composite (G-aenial Universal Injectable) (G-aenial Universal) and regular consistency composite (3M Filtek Z350 XT Universal Restorative) (3M Filtek Universal). The attributes considered for each material included shade, specification, manufacturer, composition, application technique, and lot number. **Table 1** presents comprehensive details regarding the tested materials. The protocols specified by the manufacturers were strictly followed during the handling of all materials**.**

TABLE (1) Restorative materials used in the study.

Restorative materials	Shade	Specification	Manufacturer	Composition	Application technique	Lot number
G-aenial Universal Injectable (G-aenial Universal)	A2	Nanofilled, universal injectable resin composites	GC Corporation, Tokyo, Japan.	**Matrix:** (31%) in weight Bis-GMA, Bis-EMA, methacrylate monomer **Fillers:** (16 nm silica and 150 nm barium glass) make up 69% in weight(wt.). Ultra-fine particles combined with a silane coupling agent serve as a filler. Pigment, photoinitiator, barium glass, strontium glass, and silicon dioxide.	1-Turn the syringe counter clockwise to remove the cap while holding it upright. 2- Keeping the syringe upright, take off the cap by turning it. 3- The dispensing tip should be positioned as close to the mold as possible. Then gradually press the plunger to force the material out. 4- Light curing for 20 seconds at a minimum intensity of >700 mW/ cm^2. The light guide tip was kept in direct contact with the glass slide.	2305101
3M Filtek Z350 XT Universal Restorative (3M Filtek Universal)	A2B	Nanofilled, regular consistency resin composites	3M ESPE Dental Products; St. Paul, MN, USA.	**Matrix**: Bis-GMA, UDMA, TEGDMA, PEGDMA, and Bis-EMA. **Fillers:** a blend of 4–11 nm non-agglomerated zirconia, 20 nm non-agglomerated/non-aggregated silica, and an agglomerated zirconia/silica clusters filler (consisting of 4–11 nm zirconia particles and 20 nm silica). Cluster particles typically range in size from 0.6 to 10 microns. (63.3% by volume and 78.5% wt. of payload).	1. Condense the resin composites to fit the mold surfaces and apply them in small increments. 2. Light cure for 20 seconds at a minimum intensity of 550–1000 mW/cm2. Light guides should be positioned as near to the composites' surface as feasible. Maintain the light guidance as near the surface as you can.	9456930

Abbreviations: ***Bis-GMA, or bisphenol A-glycidyl methacrylate; Bis-EMA, or ethoxylated bisphenol A dimethacrylate; UDMA, or urethane dimethacrylate; TEGDMA, or triethylene glycol dimethacrylate; DMA, or dimethacrylate; PEGDMA, or polyethylene glycol dimethacrylate.***

METHODS

Sample size calculation

The sample size calculation approach used in the previous study was applied to determine the sample size for the microhardness tests.[11] Mean and standard deviation data of G-aenial Universal Injectable and Filtek Bulkfill Flowable Restorative (64.40±1.14 and 61.4±2.51, respectively) were employed in the calculation. Parameters considered included a two-tailed test, an effect size of 1.54, a significance level (α) of 0.05, 80% power, and an allocation ratio of 1. The calculated sample size per subgroup was eight.

Ethical considerations

The ethics committee of the Faculty of Dentistry, Mansoura University, approved this investigation (ID: A02012023CD). This investigation included 32 specimens created from several restorative materials, including G-aenial Universal and 3M Filtek Universal. Each material group was randomly divided into two subgroups according to testing circumstances, obtaining eight specimens for each subgroup (Water and HCL+TC). This study subjected the samples from each restorative material category to the following testing conditions:1) Storage in deionized water for 24 hours (Water). 2) Storage in an intrinsically erosive solution (HCL) (HCL+TC) followed by thermal cycling (TC) (10,000 cycles).

Specimens' preparation

To create the G-aenial Universal specimens, the experiment used a cylindrical plastic split mold with a central hole that was 10 mm in diameter and 2 mm deep, with a glass slide and mylar strip underneath. the needle tip was placed on a mylar strip at the mold space margins and move toward the center to prevent air bubble entrapment. While a gold-plated tool was used to apply 3M Filtek Universal, ensuring uniformity and filling the entire mold space. Then, the mold was covered with a mylar strip and a glass slide. Using a polywave light dental curing lamp (Eighteeth, Curingpen-E, Changzhou Sifary Medical Technology Co., Ltd., China) for 20 seconds at 1200 mW/cm^2, any extra material was then removed. Each specimen's bottom surface was exposed to an additional light curing after the specimens were positioned in direct contact with the glass slide.

The specimen was polished using aluminum oxide discs (Tor V M, Russia) using a handpiece with a low speed. Each experimental group was wet-finished and polished in a single direction using a multi-step procedure. To maintain uniformity, the same operator did the Finishing/polishing every time. All specimens were subjected to the same timing and direction. Debris was eliminated from surfaces during ten minutes of ultrasonic cleaning.

The specimens of each examined material were categorized into two subgroups, each including 16 specimens, according to the aging process. The first subgroup of specimens was immersed in deionized water within an incubator at 37°C for 24 hours, whereas the subsequent subgroup was submerged in 2.16% HCL acid (pH = 1.2), generated at the (Faculty of Pharmacy, Mansoura University), for 3 hours.[21,22] To prevent contamination, distilled water was used to clean the specimens. The HCL for the second subgroup of specimens was changed every hour after the cleaning process. As seen in **Figure 1**, the specimens of the second subgroup of the tested materials underwent 10,000 cycles of thermal cycling utilizing a ROBOTA automated thermal cycle (Robota automated thermal cycle, BILGE, Turkey). The dwell time was 25 seconds at 5°C and 55°C, and the transfer time was 10 seconds. This *in vitro* thermal cycling provides an approximation of the clinical effects observed over a year.[23]

Measurement of surface microhardness

For the microhardness test, a total of 32 specimens—16 from each brand—were employed. The specimens' Vickers hardness number (VHN) was determined using a digital display Vickers microhardness tester (Model HVS-50, Laizhou Huayin Testing Instrument Co., Ltd., China).[24] The specimens' surface microhardness was tested using

Fig. (1) Showing the thermocycling machine used in the study.

a Vickers diamond indenter and an objective lens with a magnification of ×20. Each specimen was subjected to a 100-gram weight on its surface for 15 seconds.[25] Each specimen's surface was indented three times, with the indentations spaced at least 0.5 mm apart, in the center of the specimen, and 2 mm from the edge.[24] The diagonal lengths of the indentations were measured using an integrated scaled microscope, and the Vickers values were translated into microhardness values. The VHN readings were derived by averaging the three measurements taken from each specimen. The following formula was used to calculate the Vickers number (VHN):

$$VHN = 1.854\ (P / D^2)$$

where 1.854 was a constant value, P was the indentation load in (g), D^2 was the diagonal average length in (μm^2), and HV was the Vickers hardness in ($g/\mu m^2$).[26]

Statistical analysis

The data were analyzed with SPSS® version 25 (SPSS Inc., Chicago, IL, USA). Shapiro Wilk tests were employed to determine the normality of the data distribution for all variables. The data were parametric and followed a normal distribution. As a result, descriptive statistics were given using the mean and standard deviation. The Vickers microhardness number (VHN) of composites (G-aenial Universal and 3M Filtek Universal) and aging conditions (Water, HCL+TC) was compared using two-way ANOVA followed by the Bonferroni test for multiple comparisons. Data was graphically presented using clustered bar charts. P-values <0.05 were considered statistically significant.

RESULTS

Means and standard deviations were used to characterize the Vickers microhardness characteristics, and descriptive statistics were presented individually for each group.

Summary of two-way ANOVA

The factor of composite was significant ($p=0.004$). Additionally, the factor of aging condition was significant ($p<0.001$), and the interactions between both variables were significant ($p = 0.003$).

Effect of type of composite

A comparison of the Vickers microhardness between types of composites for each aging condition is presented in **Table 2** and **Figure 2**. For the Water ($p < 0.001$), there was a significant difference between G-aenial Universal and 3M Filtek Universal, with the highest Vickers microhardness observed in the G-aenial Universal and the lowest Vickers microhardness in the 3M Filtek Universal. For the HCL+TC, there was no significant difference between G-aenial Universal and 3M Filtek Universal.

TABLE (2) Showed the Vickers microhardness values of all tested composite groups between conditions and include the multiple comparisons, means, standard deviations and p-values results.

g/μm²	Water	HCL+TC	Water -HCL+TC
	Mean, (SD)	Mean, (SD)	
G-aenial Universal	70.49, (1.12)	65.72, (0.95)	<0.001*
3M Filtek Universal	68.52, (1.21)	65.71, (0.88)	<0.001*

SD; standard deviation; *p is significant at 5% level.

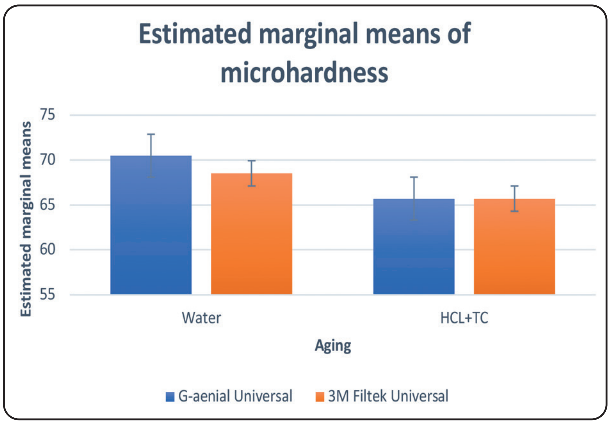

Fig. (2) Comparison of microhardness between types of composites for each aging condition.

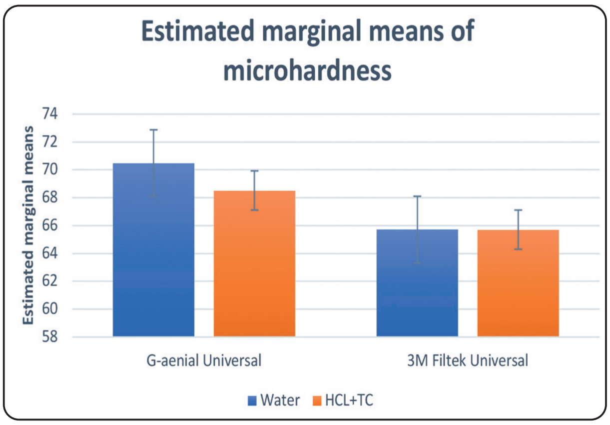

Fig. (3) Comparison of microhardness between aging conditions for each type of composite.

Effect of aging conditions

A comparison of the Vickers microhardness between types of aging conditions for each composite is presented in **Table 2** and **Figure 3**. For both composites, there was a significant difference in the Vickers microhardness between aging conditions ($p<0.001$), with the highest Vickers microhardness observed in Water, and the lowest Vickers microhardness in the HCL + TC. For both composites, there was a significant difference between HCL+TC and Water aging conditions.

DISCUSSION

One of the universal injectable composites, the G-aenial Universal, is relatively new, but previous research has provided excellent results,[27,28] for this reason, this study needed to investigate the effect of HCL on microhardness, while the 3M Filtek Universal was tested and used as a control in the current study because it is widely utilized as a direct restorative material that has been nanofilled to prevent erosion from HCL due to its well-established excellent mechanical and physical properties.[26,29]

When acidic environments are present, the polymer matrix may deteriorate and hydrolyze. In resin composites, this can lead to greater erosion, surface roughness, and lower hardness. [30] since a result, evaluating resin composites with HCL is critical for determining their resistance to acidic environments, particularly in people suffering from digestive disorders, since it can induce erosion of tooth hard tissues and deterioration of restorative materials. [31] In the current investigation, the specimens were preserved in hydrochloric acid to replicate stomach acid (pH=1.2) for 3 hours, which can give an approximation of the effects noticed clinically over the period of one year. [21,22]

Thermal cycling is particularly helpful as a tool for imitating temperature fluctuations in the oral environment. The specimens in the current investigation underwent 10,000 cycles. Over the course of a year, 10,000 cycles of *in vitro* thermal cycling can roughly replicate the clinical consequences observed.[23]Assessing the mechanical integrity of composites in functional scenarios is essential for determining the materials' suitability for clinical applications, and this requires an understanding of how thermal cycling affects microhardness. By plasticizing water and forcing silane coupling agents to hydrolyze, thermal cycling can enhance water sorption and degrade resin composites' surfaces.[30]

Microhardness is an essential component in determining a material's resistance to plastic deformation and wear. [10,11] This feature is influenced by a variety of parameters, including the kind of resin matrix and the degree of crosslinking achieved during the polymerization process. The type, size, and amount of the filler component also have an impact on the surface hardness of composite materials. As a result, each of these factors can influence the degree of conversion during polymerization, which can subsequently affect the material's hardness.[11,12]Materials with a higher degree of cross-linking and filler content show increased surface hardness. [10] The Vickers microhardness tester was used to calculate the specimens' Vickers hardness number (VHN), the most accurate and reliable method for analyzing the mechanical properties of resin composites.[32]Materials with reduced hardness are more susceptible to fracture and breakdown on the surface. In contrast, materials with a high microhardness have higher wear resistance, showing a link between mechanical qualities and clinical life.[32]

The first null hypothesis was rejected in light of the results of the current study, which demonstrated that the type of composite for the same aging situation affected the microhardness data. In the Water subgroup, G-aenial Universal had the highest microhardness and 3M Filtek Universal the lowest. The dispersed nanosized barium particles (150 nm) in G-aenial Universal, which are firmly bonded into the resin matrix through FSC technology, may have ensured a solid and stable filler-matrix bond that can significantly higher in VHN of G-aenial Universal.[33]For HCL+TC aging conditions, the lowest microhardness was discovered with G-aenial Universal, while the maximum microhardness was noted with 3M Filtek Universal. This could be attributed to the larger filler loading for 3M Filtek Universal (78.5% wt.) than for G-aenial Universal (69% wt.). The decrease in VHN after immersion in simulated gastric juice could be explained by the acid attacking the resin matrix, softening Bis-GMA, which could be caused by diluent agent leaching. Furthermore, a hydrolytic breakdown of the link between silane and the filler particles may result in filler matrix debonding.[34] The current study discovered that G-aenial Universal had a greater surface microhardness than 3M Filtek Universal, which is in disagreement with Basheer R. *et al.* (2024) [26]. This discrepancy may be explained by the fact that the results of the current study were for the Water subgroup, which did not have thermal cycling.

The second null hypothesis was rejected in accordance with the results of the current study, which demonstrated that the aging circumstances affected the microhardness data of tasting composites. The Vickers microhardness varied significantly between aging conditions for both composites, with Water having the greatest Vickers microhardness and HCL+TC having the lowest. In general, a resin composite is a heterogeneous product that is composed of a polymeric matrix, reinforcing filler, silane, and chemical components. Also, differences in resin matrices and filler particles cause variations in surface properties such as microhardness.[35] Resistance to matrix disintegration and water absorption, which are impacted by meals and acidic beverages, is a crucial property of resin composite durability.[36] The resin matrix was dissolved by the acids in these drinks, softening the Bis-GMA and making it easier for the unreacted monomers to be liberated. UDMA, TEGDMA, and Bis-GMA have the ability to soften and break down the resin matrix because of their high absorption and solubility.[37]

Additionally, silica is included in 3M Feltik Universal. Silica and barium glass are also present in G-aenial Universal. Filler particles like silica and barium glass may deteriorate as a result of the environment's lowering pH. Furthermore, because barium is electropositive and reacts with water, it may undergo hydrolytic degeneration, which would reduce the structure's mechanical qualities. Moreover, barium glass loses surface microhardness because they dissolve more readily in acidic liquids than silica. This would explain why resin composites are susceptible to a drop in Vickers microhardness followed by a drop in pH.[20]The findings of the study contrasted with those of Alencar M. F. *et al*. (2020)[38], who came to the conclusion that resin composites with nanofill were impervious to intrinsic acids eroding their surface hardness.

A limitation of the study was its inability to reproduce the complex oral environment, which includes saliva, infections, enzymes, thermal cycling, and other components. This may have limited the ways in which the tested composites might approximate microhardness. These *in vitro* findings demand additional research into intraoral effects.

CONCLUSIONS

Within the limitations of this study, the G-aenial Universal can replace 3M Feltik Universal for healthy patients with near-neutral oral conditions, but not for recurrent gastric reflux patients due to their preferred microhardness.

REFERENCES

1. Azouzi I., Kalghoum I., Hadyaoui D., Harzallah B., Cherif M. Principles and guidelines for managing tooth wear: a review. Int Med Care 2018; 2:1–9.
2. Fradeani M, Barducci G, Bacherini L. Esthetic rehabilitation of a worn dentition with a minimally invasive prosthetic procedure (MIPP). Int J Esthet Dent 2016; 11:16–35.
3. Meyers IA. Minimum intervention dentistry and the management of tooth wear in general practice. Aust Dent J 2013;58 Suppl 1:60–5.
4. Chiang Y-C, Lai E H-H, Kunzelmann K-H. Polishing mechanism of light-initiated dental composite: Geometric optics approach. J Formos Med Assoc 2016; 115:1053–60.
5. Kowalska A, Sokolowski J, Bociong K. The photoinitiators used in resin based dental composite-a review and future perspectives. Polymers (Basel) 2021;13.
6. Cramer N B, Stansbury J W, Bowman C N. Recent advances and developments in composite dental restorative materials. J Dent Res 2011; 90:402–16.
7. Alzraikat H, Burrow M F, Maghaireh G A, Taha N A. Nanofilled Resin Composite Properties and Clinical Performance: A Review. Oper Dent 2018;43: E173–90.
8. Terry D, Powers J. Using injectable resin composite: part two. Int Dent Afr. 2014; 5:64-72.
9. Terry D, Powers J. Using injectable resin composite: part one. Int Dent Afr. 2014; 5:52-62.
10. Yılmaz A P, Doğu K B, Manav Ö A, Tarçın B, Şenol A A, Tüter B E, et al. Assessment of Micro-Hardness, Degree of Conversion, and Flexural Strength for Single-Shade Universal Resin Composites. Polymers (Basel) 2022;14.
11. Ludovichetti FS, Lucchi P, Zambon G, Pezzato L, Bertolini R, Zerman N, et al. Depth of cure, hardness, roughness and filler dimension of bulk-fill flowable, conventional flowable and high-strength universal injectable composites: an in vitro study. J Nanomater 2022;12.
12. Alzahrani B, Alshabib A, Awliya W. Surface hardness and flexural strength of dual-cured bulk-fill restorative materials after solvent storage. BMC Oral Health 2023; 23:306.
13. Scribante A, Bollardi M, Chiesa M, Poggio C, Colombo M. Flexural Properties and Elastic Modulus of Different Esthetic Restorative Materials: Evaluation after Exposure to Acidic Drink. Biomed Res Int 2019; 2019:5109481.
14. El-Rashidy AA, Shaalan O, Abdelraouf RM, Habib NA. Effect of immersion and thermocycling in different beverages on the surface roughness of single- and multi-shade resin composites. BMC Oral Health 2023; 23:367.
15. Lima V P, Machado J B, Zhang Y, Loomans B A C, Moraes R R. Laboratory methods to simulate the mechanical degradation of resin composite restorations. Dent Mater 2022; 38:214–29.
16. Roque A C C, Bohner L O L, de Godoi A P T, Colucci V, Corona S A M, Catirse A B C E B. Surface roughness of composite resins subjected to hydrochloric acid. Braz Dent J 2015; 26:268–71.

17. Donovan T, Nguyen-Ngoc C, Abd Alraheam I, Irusa K. Contemporary diagnosis and management of dental erosion. J Esthet Restor Dent 2021; 33:78–87.

18. Guedes A P A, Moda M D, Suzuki T Y U, Godas A G, Sundfeld R H, Briso A L F, et al. Effect of Fluoride-Releasing Adhesive Systems on the Mechanical Properties of Eroded Dentin. Braz Dent J 2016; 27:153–9.

19. Sulaiman T A, Abdulmajeed A A, Shahramian K, Hupa L, Donovan T E, Vallittu P, et al. Impact of gastric acidic challenge on surface topography and optical properties of monolithic zirconia. Dent Mater 2015; 31:1445–52.

20. Alp C K, Gündogdu C, Ahısha C D. The effect of gastric acid on the surface properties of different universal composites: A SEM study. Scanning 2022; 2022:9217802.

21. Yang H, Yang S, Attin T, Yu H. Effect of acidic solutions on the surface roughness and microhardness of indirect restorative materials: a systematic review and meta-analysis. Int J Prosthodont 2023; 36:81–90.

22. Backer AD, Münchow EA, Eckert GJ, Hara AT, Platt JA, Bottino MC. Effects of simulated gastric juice on CAD/CAM resin composites-morphological and mechanical evaluations. J Prosthodont 2017; 26:424–31.

23. Shilpa-Jain D P, Krithikadatta Jogikalmat, Kowsky Dinesh, Natanasabapathy Velmurugan. Effect of cervical lesion centered access cavity restored with short glass fibre reinforced resin composites on fracture resistance in human mandibular premolars- an in vitro study. J Mech Behav Biomed Mater 2021; 122:104654.

24. Prochnow F H O, Kunz P V M, Correr G M, Kaizer M da R, Gonzaga C C. Relationship between battery level and irradiance of light-curing units and their effects on the hardness of a bulk-fill composite resin. Restor Dent Endod 2022;47: e45.

25. Degirmenci A, Bilgili D. Pre-heating effect on the microhardness and depth of cure of bulk-fill composite resins. ODOVTOS-Int J Dental Sc 2022; 24:99–112.

26. Basheer RR, Hasanain FA, Abuelenain D A. Evaluating flexure properties, hardness, roughness and microleakage of high-strength injectable dental composite: an in vitro study. BMC Oral Health 2024; 24:546.

27. Takamizawa T, Ishii R, Tamura T, Yokoyama M, Hirokane E, Tsujimoto A, et al. Handling properties and surface characteristics of universal resin composites. Dent Mater 2021; 37:1390–401.

28. G-ænial® Universal Injectable Technical Manual. https://campaigns-gceurope.com/g-aenial-universal-injectable/. 2018.

29. Marovic D, Par M, Macan M, Klarić N, Plazonić I, Tarle Z. Aging-dependent changes in mechanical properties of the new generation of bulk-fill composites. Materials (Basel) 2022;15.

30. El-Rashidy AA, Shaalan O, Abdelraouf RM, Habib NA. Effect of immersion and thermocycling in different beverages on the surface roughness of single- and multi-shade resin composites. BMC Oral Health 2023; 23:367.

31. Tărăboanță I, Buhățel D, Brînză Concită C A, Andrian S, Nica I, Tărăboanță-Gamen A C, et al. Evaluation of the Surface Roughness of Bulk-Fill Composite Resins after Submission to Acidic and Abrasive Aggressions. Biomedicines 2022;10.

32. Bayraktar E T, Atali P Y, Korkut B, Kesimli E G, Tarcin B, Turkmen C. Effect of Modeling Resins on Microhardness of Resin Composites. Eur J Dent 2021; 15:481–7.

33. Elsahn N A, El-Damanhoury H M, Shirazi Z, Saleh A R M. Surface properties and wear resistance of injectable and computer-aided design/computer aided manufacturing-milled resin composite thin occlusal veneers. Eur J Dent 2023; 17:663–72.

34. Tărăboanță I, Buhățel D, Brînză Concită C A, Andrian S, Nica I, Tărăboanță-Gamen A C, et al. Evaluation of the Surface Roughness of Bulk-Fill Composite Resins after Submission to Acidic and Abrasive Aggressions. Biomedicines 2022;10.

35. Ferracane J L. Resin composite--state of the art. Dent Mater 2011; 27:29–38.

36. Rahim T N A T, Mohamad D, Md Akil H, Ab Rahman I. Water sorption characteristics of restorative dental composites immersed in acidic drinks. Dent Mater 2012;28: e63-70.

37. Abouelmagd D M, Basheer R R. Microhardness evaluation of microhybrid versus nanofilled resin composite after exposure to acidic drinks. J Int Soc Prev Community Dent 2022; 12:353–9.

38. Alencar M F, Pereira M T, De-Moraes M D R, Santiago S L, Passos V F. The effects of intrinsic and extrinsic acids on nanofilled and bulk fill resin composites: Roughness, surface hardness, and scanning electron microscopy analysis. Microsc Res Tech 2020; 83:202–7.