QUALITY IMPROVEMENT IN DENTAL AND MEDICAL KNOWLEDGE, RESEARCH, SKILLS AND ETHICS FACING GLOBAL CHALLENGES

Edited by
Armelia Sari Widyarman, Muhammad Ihsan Rizal,
Moehammad Orliando Roeslan & Carolina Damayanti Marpaung

CRC Press
Taylor & Francis Group

QUALITY IMPROVEMENT IN DENTAL AND MEDICAL KNOWLEDGE, RESEARCH, SKILLS AND ETHICS FACING GLOBAL CHALLENGES

The proceedings of FORIL XIII 2022 Scientific Forum Usakti conjunction with International Conference on Technology of Dental and Medical Sciences (ICTDMS) include selected full papers that have been peer-reviewed and satisfy the conference's criteria. All studies on health, ethics, and social issues in the field of dentistry and medicine have been presented at the conference alongside clinical and technical presentations. The twelve primary themes that make up its framework include the following: behavioral epidemiologic, and health services, conservative dentistry, dental materials, dento-maxillofacial radiology, medical sciences and technology, oral and maxillofacial surgery, oral biology, oral medicine and pathology, orthodontics, pediatrics dentistry, periodontology, and prosthodontics. This proceeding will be beneficial in keeping dental and medical professionals apprised of the most recent scientific developments.

PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON TECHNOLOGY OF DENTAL AND MEDICAL SCIENCES (ICTDMS 2022), JAKARTA, INDONESIA, 8–10 DECEMBER 2022

Quality Improvement in Dental and Medical Knowledge, Research, Skills and Ethics Facing Global Challenges

Edited by

Armelia Sari Widyarman, Muhammad Ihsan Rizal, Moehammad Orliando Roeslan and Carolina Damayanti Marpaung

Universitas Trisakti, Indonesia

CRC Press
Taylor & Francis Group
Boca Raton London New York Leiden

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

A BALKEMA BOOK

First published 2023
by CRC Press/Balkema
4 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

and by CRC Press/Balkema
2385 NW Executive Center Drive, Suite 320, Boca Raton FL 33431

CRC Press/Balkema is an imprint of the Taylor & Francis Group, an informa business

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record has been requested for this book

ISBN: 978-1-032-51441-3 (hbk)
ISBN: 978-1-032-51466-6 (pbk)
ISBN: 978-1-003-40237-4 (ebk)

DOI: 10.1201/9781003402374

Typeset in Times New Roman
by MPS Limited, Chennai, India

Quality Improvement in Dental and Medical Knowledge, Research, Skills and Ethics Facing Global Challenges – Widyarman et al. (Eds)
© 2024 The Editor(s), ISBN 978-1-032-51441-3

Table of Contents

Oral biology

Oral medicine and pathology

Orthodontics

Pediatric dentistry

Periodontology

Prosthodontics

Preface

Faculty of Dentistry Universitas Trisakti (Usakti) presents FORIL XIII 2022 Scientific Forum Usakti conjunction with International Conference on Technology of Dental and Medical Sciences (ICTDMS) on December 8th–10th 2022. The theme of the conference is "Quality Improvement in Dental and Medical Knowledge, Research, Skills and Ethics Facing Global Challenges".

The triennial conference has served as a meeting place for technical and clinical studies on health, ethical, and social issues in field medical and dentistry. It is organized around 12 major themes, including behavioral, epidemiologic, and health services, conservative dentistry, dental materials, dento-maxillofacial radiology, medical sciences and technology, oral and maxillofacial surgery, oral biology, oral medicine and pathology, orthodontics, pediatrics dentistry, periodontology, and prosthodontics.

The most recent findings in fundamental and clinical sciences related to medical and dental research will be presented in the conference that will be published as part of the conference proceeding. This proceeding will be useful for keeping dental and medical professionals up to date on the latest scientific developments.

Dr. Aryadi Subrata
Chairman FORIL XIII conjunction with ICTDMS

Quality Improvement in Dental and Medical Knowledge, Research, Skills and Ethics Facing Global Challenges – Widyarman et al. (Eds)
© 2024 The Editor(s), ISBN 978-1-032-51441-3

Acknowledgements

Prof. Shinya Murakami, D.D.S., Ph.D. (*Department of Periodontology, Osaka University, Japan*)
Prof. Adrian Yap (*Department of Dentistry, Ng Teng Fong General Hospital, Singapore*)
Prof. Dr. Rosnah Binti Mohd Zain (*Department of Oro-Maxillofacial Surgical & Medical Sciences, Malaya University*)
Prof. Chaminda Jayampath Seneviratne, BDS (Hons)., M.Phil., Ph.D (*University of Queensland, Australia*)
Cortino Sukotjo, DDS, Ph.D., MMSc (*Department of Restorative Dentistry, University of Illinois at Chicago, United States*)
Prof. Dr. Nicola De Angelis (*Department of Periodontology, University of Genoa, Italy*)
Prof. Hirotaka Kuwata, D.D.S., Ph.D. (*Department of Oral Microbiology and Immunology, Showa University, Japan*)
Prof. Dr. drg. Tri Erri Astoeti, M.Kes (*Universitas Trisakti, Jakarta, Indonesia*)
Prof. drg. Rahmi Amtha, MDS, Ph.D, Sp.PM(K) (*Department of Oral Medicine, Universitas Trisakti, Jakarta, Indonesia*)
Prof. Dr. Siriwan Suebnukarn, D.D.S (*Thammasat University, Bangkok, Thailand*)

Quality Improvement in Dental and Medical Knowledge, Research, Skills and Ethics Facing Global Challenges – Widyarman et al. (Eds)
© 2024 The Editor(s), ISBN 978-1-032-51441-3

Committee Members

Scientific Committee

Prof. Dr. drg. David Buntoro Kamadjaja, Sp.BM(K) (*Oral Maxillofacial Surgeon, Universitas Hassanudin, Makasar, Indonesia*)
Prof. Dr. drg. Diah Savitri Ernawati, Sp.PM(K)., M.Si (*Oral Medicine, Universitas Airlangga, Surabaya, Indonesia*)
Prof. Dr. drg. Maria Francisca Lindawati Soetanto, Sp.Pros(K) (*Prosthodontic, Universitas Indonesia, Jakarta, Indonesia*)
Prof. drg. Boy Muchlis Bachtiar, M.S., Ph.D., PBO (*Oral Biology, Universitas Indonesia, Jakarta, Indonesia*)
Prof. Dr. drg. Inne Suherna Sasmita, Sp.KGA(K) (*Pediatric Dentistry, Universitas Padjajaran, Bandung, Indonesia*)
Prof. drg. Sondang Pintauli, Ph.D (*Public Health, Universitas Sumatera Utara, Indonesia*)
Prof. Dr. drg. Miesje Karmiati Purwanegara, S.U., Sp.Orto (*Orthodontic, Universitas Indonesia, Indonesia*)
Prof. Dr. drg. Sri Lelyati, S.U, Sp.Perio (K) (*Periodontic, Universitas Indonesia, Indonesia*)
drg. Diatri Nari Ratih, M.Kes., Ph.D., Sp.KG(K) (*Conservative Dentistry, Universitas Gadjah Mada, Indonesia*)

Organizing Committee

Drg. Aryadi Subrata, Sp.KG(K), (*Conservative Dentistry, Universitas Trisakti, Jakarta, Indonesia*)
Dr. drg. Armelia Sari W., M.Kes., PBO (*Microbiology Oral, Universitas Trisakti, Jakarta, Indonesia*)
Dr. drg. Anggraeny Putri Sekar Palupi, Sp.BM (*Oral Maxillofacial Surgeon, Universitas Trisakti, Jakarta Indonesia*)
Dr. drg. Muhammad Ihsan Rizal, M.Kes (*Oral Biology, Universitas Trisakti, Jakarta, Indonesia*)
drg. Isya Hanin, Sp.Pros (*Prosthodontic, Universitas Trisakti, Jakarta, Indonesia*)
drg. Muhammad Orliando Roeslan, M.Kes., PhD (*Oral Biology, Universitas Trisakti, Jakarta, Indonesia*)
drg. Dina Ratnasari, Sp.KG(K) (*Conservative Dentistry, Universitas Trisakti, Jakarta, Indonesia*)
drg. Carolina Damayanti Marpaung, Sp.Pros, PhD (*Prosthodontic, Universitas Trisakti, Jakarta, Indonesia*)

Quality Improvement in Dental and Medical Knowledge, Research,
Skills and Ethics Facing Global Challenges – Widyarman et al. (Eds)
© 2024 The Author(s), ISBN 978-1-032-51441-3

Microhardness of a flowable bulk-fill resin composite in immediate and 24-hour storage

R. Tjandrawinata, D. Pratiwi & F.L. Kurniawan
Department of Dental Materials, Faculty of Dentistry, Universitas Trisakti, Jakarta, Indonesia

A. Cahyanto
Department of Restorative Dentistry, Faculty of Dentistry, University of Malaya, Kuala Lumpur, Malaysia
Department of Dental Materials Science and Technology, Faculty of Dentistry, Universitas Padjadjaran, Bandung, Indonesia

ABSTRACT: Background: Bulk-fill resin composite material gains popularity due to its simple and time-efficient application. However, some dentists question whether the no-light cure side is fully polymerized and the hardness of that side. Objective: This study investigated the microhardness of flowable bulk-fill resin composites on the light-cured/top side and no light-cured/bottom side immediately and after 24 hours immersed in artificial saliva. Methods: Three flowable bulk-fill resin composites were tested: Tetric N-Flow Bulk Fill (TBF), Filtek Bulk Fill (FBF), and Palfique Bulk Flow (PBF). A Vickers microhardness tester was used to determine the microhardness at each cylindrical sample's top and bottom sides. Thirty sam-ples were divided into two groups, Group 1 was tested immediately, and Group 2 was tested after 24 hours of immersion in artificial saliva. Results: The highest microhardness mean value was 47.52 VHN for the PBF top side tested immediately, while the lowest was 25.20 VHN for FBF on the bottom side tested after 24 hours of storage. Two-way ANOVA showed significant differences among the groups ($p<0.05$). There were significant differences ($p<0.05$) between immediate and 24 hours on the top and bottom sides ofTBF and the bottom side of the FBF group. There was no significant difference between the immediate PBF group and 24 hours at the top and bottom sides, and the top side of the FBF group. All groups' bottom/ top ratio was 0.78 or above. Conclusion: The Vickers microhardness has a tendency to decrease on both sides after 24 hours of immersion in artificial saliva.

1 INTRODUCTION

Bulk-fill resin composite (BFRC) is the material of choice in deep cavities and can be an alternative to overcome the difficulties of performing incremental techniques, which may get several failures such as saliva or gingival fluid contamination between layers, failure of bonding between layers, difficulty in filling due to limited access to posterior teeth, and longer time to polymerize every layer. BFRC is also indicated for Class I, II, and VI mesio-occluso-distal/MOD cavities. The bulk-fill technique has been demonstrated to be effective in short-term clinical studies (Powers & Wataha 2017). Bulk fill technique especially using the flowable type represents an induction technique with less pressure and minimal micro-leakage at the edges of preparation. A previous study also showed high viscosity bulk-fill resin composites demonstrated, to some extent, polymerization contraction values and gap formation similar to the conventional resin composites (Benetti et al. 2015). Bulk fill material gains popularity due to its simple and time-efficient application. High depth of cure rates by BFRCs, depends on some factors such as material, irradiance, and exposure time. Light emitting diode (LED) curing devices (polywave or monowave)

DOI: 10.1201/9781003402374-40

isplaying an irradiance ! 1000 mW/cm2 and 20 seconds of exposure time are imperative to accomplish the successful polymerization of most BFRCs (Lima et al. 2018). Typically, flowable composite has a lower filler content and higher volume of resin matrix when compared with condensable composite, so the first-generation flowable composite was applied as a cavity liner or Class V restoration. However, the recent generations of flowable composite have higher filler content and are claimed to have improved mechanical proper-ties; thus, they are indicated not only as a cavity liner but also for larger posterior restora-tions (Ilie et al. 2013; Jang et al. 2015) Microhardness evaluation performed using the Vickers indentation test is suitable for measuring the hardness of small samples. Vickers microhardness study has shown the material resistance to localized plastic deformation. In the microhardness study, the employ load is less than 9.8N, so the resulting indentations are small and limited depths of less than 19 mm (Kermanshah et al. 2022). This study aimed to investigate the microhardness of flowable bulk-fill resin composites on the light cure/top side and no light cure/bottom side immediately and after 24 hours of immersion in artificial saliva.

2 METHODS

Three materials of flowable bulk-fill resin composites, shade A2, as shown in Table 1, were tested: Tetric N-Flow Bulk Fill (Ivoclar Vivadent, Schaan, Liechtenstein) – TBF, Filtek Bulk Fill (3M "ESPE", St Paul, MN, USA) – FBF and Palfique Bulk Flow (Tokuyama, Tokyo, Japan) – PBF. Ten cylindrical samples, 6 mm in diameter and 3 mm in depth, were made for each brand in a stainless-steel mold, according to American Dental Association. In order to get a similar flat surface of the samples, a celluloid strip followed by a glass plate was put on the surface of resin composites, and then the glass plate was removed before the light curing procedure. The bottom surface of the mold was in contact with a glass plate. The tip of the curing light (10 mm diameter) was placed in contact with the celluloid strip. Each sample was polymerized with a light cure intensity of 900 mW/cm2 for 20 seconds on the top surface.

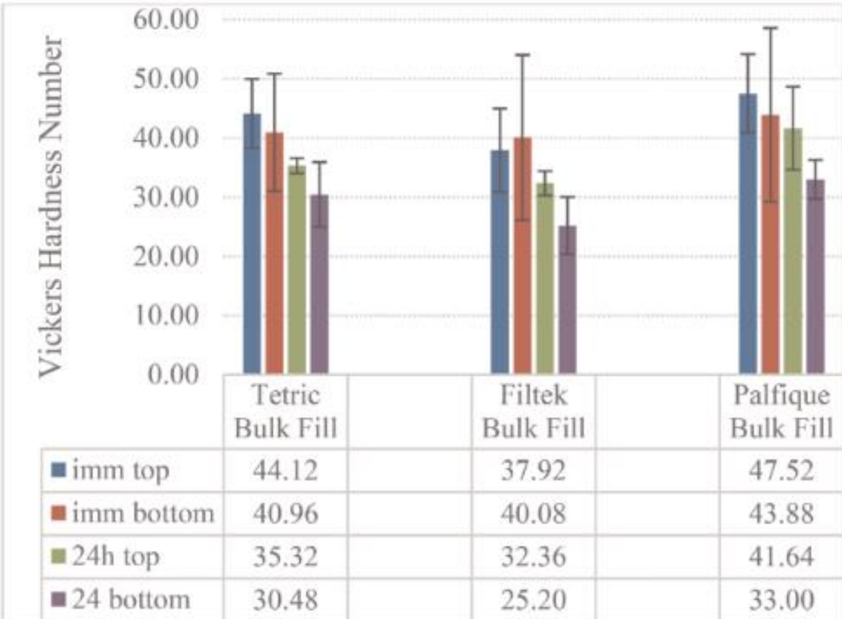
Table 1. Resin composite material used in this study.

Material	Matrix	Filler	Lot no.	Company
Tetric N-Flow Bulk Fill	BisEMA, copolymer, BisGMA, CMPEG-MA	Barium glass, ytterbium trifluoride, DCP. Inorganic filler 0.1-30μm (45-48% by volume),	Z0176H	Ivoclar Viva-dent, Schaan, Liechtenstein
Filtek Bulk Fill	BisGMA, UDMA, BisEMA, Procylat resins.	Combination of zirconia/silica, 0.01-3.5 μm and ytterbium trifluoride filler 0.1-5.0 μm. 64.5% by weight (42.5% by volume)	NA76138	3M "ESPE", St Paul, MN, USA
Palfique Bulk Flow	Bisphenol A di (2-hy-droxyl propoxy) dimethacrylate (Bis-GMA), Triethy-lene glycol dimetha-crylate, Mequinol, Dibutyl hydroxyl to-luene, UV absorber.	Spherical silica-zirconia, 200 nm (100-300 nm). 70 % by weight (56% by volume)	111E41	Tokuyama, Tokyo, Japan

The total number of samples was 30 divided into 2 main groups, 15 samples (5 samples foreach brand) were tested immediately. Another 15 samples were tested after 24 hours of immersion with artificial saliva in an incubator at 37C. Vickers microhardness tester (Shimadzu, Tokyo, Japan) was used to determine the microhardness of each cylindrical sample at the light cure side (top surface) and at the opposite surface, no light cure side (bottom surface). Each sample was indented three times using an indenter load of 25 g for 5 seconds and observed under 40x magnification. The length of two diagonals of each indentation was calculated as the Vickers microhardness of the materials. The sample's bottom/top hardness ratio was then counted and analyzed.

3 RESULTS

Figure 1 shows the Vickers Hardness Number of the samples. The highest and lowest microhardness average value were 47.52 VHN for PBF top side tested immediately and 25.20 VHN for the FBF bottom side tested after 24 hours of storage in artificial saliva. All materials showed decreasing in the ratio after 24 hours of immersion; TBF decreased from 0.92 to 0.86, FBF decreased from 1.14 to 0.78, and PBF decreased from 0.91 to 0.82.



	Tetric Bulk Fill	Filtek Bulk Fill	Palfique Bulk Fill
imm top	44.12	37.92	47.52
imm bottom	40.96	40.08	43.88
24h top	35.32	32.36	41.64
24 bottom	30.48	25.20	33.00

Figure 1. Vickers microhardness number of the samples.

Two-way ANOVA showed significant differences among the groups ($p<0.05$). The inde-pendent t-test showed no significant difference ($p>0.05$) between the group's immediate top and bottom sides. However, there were significant differences ($p<0.05$) between the groups at 24 hours for top-side and bottom-side, between immediate and 24 hours top-side, and between immediate and 24 hours bottom-side.

4 DISCUSSION

Vickers microhardness, defined as the resistance of a material to indentation, is among the physical properties that govern a resin composite's clinical performance (Jafarpour et al. 2022). The factors that affect the surface hardness of resin composite are the quality and technique of polishing, a chemical composition such as organic matrix chemical compo-nents, filler loading, and aging in water and various other media. Surface degradation, margin, and bulk fracture are common reasons that lead to the replacement of restorations (Jafarpour et al. 2022). In this study, a celluloid strip was used to get a smooth surface of samples, while the glass plate gave similar weight to make the surface flat for the Vickers microhardness test. In this study, PBF has spherical silica-zirconia as the highest filler content (56% by volume), and showed the highest Vickers microhardness number among the three groups.

The filler loading of resin composites greatly determines their mechanical and physical properties. A positive correlation between filler loading and surface hardness was established by Chang et al in an extensive study on filler morphology, its influence on filler loading, and the effect of these factors on the mechanical properties of resin composites. It was found that filler morphology affects filler loading (Almozainy 2018). As shown in Table 1 and Figure 1, resin composites containing round particles had the highest filler content and hardness. It was shown that the reduced filler size could alter the organic matrix between the particles and decrease the interparticle distances, leading to improvement in mechanical properties (Powers & Wataha 2017; Jafarpour et al. 2022).

The results showed that the highest microhardness value of flowable BFRC has a filler size of 100–300 nm or 0.1–0.3 mm. The other two brands have a range of filler sizes 0.1–30 mm and 0.01–5.0 mm. The mean filler size and weight have previously been reported to affect the fracture toughness of resin composites, and those with smaller filler particles have been associated with higher toughness. Higher VHN has been reported to correlate with lower material structure porosity. Furthermore, the modified strontium glass reinforces the strength of the filler, offering improved surface hardness. However, similar filler loading yet different matrix content may result in different surface hardness (Powers & Wataha 2017). In this study, there were various matrix compositions. Resin matrix content could be a responsible factor for water sorption. Previous studies confirmed that water uptake increases following an increase in the TEGDMA content in the resin matrix (Anjelia 2021). Other research showed no correlation between the hardness and the filler content or between hardness and the degree of the color change of the resin composites. Another study con-firmed the positive correlation between filler loading and microhardness in their study on the effect of aging in three food-simulating solvents on eight commercial resin composites, including four bulk-fill, two microhybrid, and two nanohybrid resin composites. Vickers microhardness reduced significantly, mainly as a result of storage time and type of solvent used. Additionally, nanohybrid materials showed better mechanical properties and higher hardness values compared to other tested materials, which was speculated by the higher filler loading. Another study on the effect of distilled water on microhardness determined a sig-nificantly lower hardness of the materials after six months of immersion (Jafarpour et al. 2022).

Twenty-four-hour storage of flowable BFRC in artificial saliva showed a trend of decrease in the hardness value. The storage condition had a significant effect on the VHN of resin composites. The VHN was not subjected to aging. In fact, the VHN ofthe materials did not alter significantly after 60 days of storage compared to the first 7 days (Jafarpour et al. 2022). When compared to the dry condition, the lower VHN in the wet condition for the bulk-fill composite could be due to the uptake of the aging liquid in porous intermolecular spaces within the resin composite, which leads to the physical destruction of the material. The storage media significantly influences the resin composites; the storage time does not pose such effects (Jafarpour et al. 2022). However, in a study by Hahnel et al., the authors proposed that both the composite materials and the storage times have a significant effect on the surface hardness (Gornig et al. 2022). Initially, the effect of water in the resin composite may cause softening of the organic matrix by hygroscopic expansion and hydrolysis or hydration of siloxane bonds of the silane layer. The commercial resins absorbed between 5% and 12% water, which was associated with a 19–42% reduction in modulus over 3 days. This reason described the decrease in hardness value after 24 hours of artificial saliva immersion (Zhang et al. 2019; Pedrosa et al. 2021).

The condition and time intervals influence dental resin composite material'sphysical and mechanical properties, while filler weight% significantly affected fracture toughness and this study on the Vickers hardness number. The properties of resin composites mainly rely on their monomer type, filler size, filler volume, and filler-resin interface. Filler content is an important factor affecting the physical and mechanical properties of resin composites (Jun et al. 2013).

Past research has shown that when hardness values are obtained, a mean bottom/top ratio (B/T) hardness value is usually determined to establish the depth of cure. This reflects the relative extent of conversion of the deeper surfaces in relation to the top surface. As an accepted minimum standard, many authors have claimed that a ratio of 0.80 is clinically acceptable (Lima et al. 2018; Kermanshah et al. 2022), which was fulfilled in this study. It has been shown that the value is mostly dependent on the filler content and filler size. This is an accurate method to compare the relative extent of cure between different composites at specified depths. The bottom/top hardness ratio can also predict under-cured resins, leading to early restoration failure, and should be avoided in any clinical technique (Lima et al. 2018). The size and amount of filler content were important in determining the shrinkage, but the shape of the particles could also generate a different outcome (Jun et al. 2013). As shown in this study, the flowable BFRC with spherical silica-zirconia filler showed the highest VHN value. The depth of cure values for all materials could influence clinical outcomes. In this study, all samples were in the same diameter and height so that there would be no influence on the thickness of the sample or depth of cure. Filler size and content in dental composites may reduce light penetration and are directly related to the depth of cure (Kilic 2020).

The presence of pigments in shaded composite materials should also affect the depth of cure because pigments are opaque particles that will limit light penetration and reduce the degree of polymerization at greater depths within a cavity preparation (Jang et al. 2015; Kaisarly et al. 2021; Sidiqa et al. 2018). Numerous studies have defined the depth of cure based on hardness measurements performed on the bottom and top surface of a light-cured resin composite specimen and agree that a ratio of0.80 may be used as a critical minimum acceptable threshold value (Lima et al. 2018). In this study, the range of the bottom/top ratio was 0.78 to 1.14. The hardness of the bottom side is supposed to be lower than the top side. However, in FBF, in immediate conditions, the hardness of the bottom side was higher than the top side. This condition should be studied further since the top side's oxygen-inhibited layer has already been prevented by using a celluloid strip. It was mentioned that the presence of oxygen inhibited layer decreased the hardness of the resin composite (Zakiyah et al. 2018; Kilic 2020).

According to Jun et al., the hardness value of resin composites has a correlation with tensile strength (Jun et al. 2013). The filler of composites influences the hardness and tensile strength. As we know that tensile strength has a correlation also with elastic modulus. As a result, the amount of filler can also influence the elastic modulus of the composite (Zakiyah et al. 2018). Several studies showed that the elastic modulus increases exponentially with increasing filler concentration. Consequently, the strength, hardness, and volumetric shrinkage are strictly dependent on the filler amount (Kilic 2020; Comba et al. 2020). The amount of filler reduces the volume occupied by the resin matrix. As a result, the number of methacrylate groups decreases, leading to lower volumetric shrinkage. It is also mentioned that the viscosity will influence the depth of cure of the BFRC. The low-viscosity bulk-fill materials showed the possibility of layering 4 mm layers, while high-viscosity bulk-fill composites showed an initial decrease of microhardness after 2 mm of depth, suggesting a potential reduction of the mechanical properties and, thus, of the chewing force resistance when employed in load-bearing contact areas (Comba et al. 2020).

The color of BFRC may also influence microhardness. Resin composites have many shades and are divided into translucency and solid color. Translucent materials allow better penetration of light (Yudistian 2021). In this study, the translucent shade color A2 makes polymerization easier. Solid color may create unperfect composite polymerization and also influence the microhardness value, especially at the bottom side. Besides the shade of color, the distance of the sample and light curing tip may interfere with decreasing microhardness after 24 hours of immersion time. In this study, the tip of the light curing unit was set in contact with the celluloid strip to delete the possibility of decreasing sample hardness because of tip distance. Yet, it was reported that the curing distance < 1 cm made no sig-nificant effect on the samples with < 2.5 mm thickness (Kilic 2020).

5 CONCLUSION

Within the limitations of this study, the following conclusions were drawn: the amount of filler reduces the volume occupied by the resin matrix, leading to lower volumetric shrinkage and there was a tendency of decreasing Vickers microhardness values on both sides after 24 hours of immersion in artificial saliva. All materials showed decreasing in the ratio after 24 hours of immersion.

ACKNOWLEDGEMENT

The authors express great appreciation to Universitas Trisakti for supporting the research fund.

REFERENCES

Almozainy, M. 2018. Influence of storage temperature on vickers microhardness of resin composite. Ann Essence Dent.10(1): 1–7.

Anjelia, C., Octarina. 2021. The knowledge level of dental students on color stability composite resin restoration in the COVID-19 pandemic area. Int J Public Health Sci. 10(4): 751–7.

Benetti, A.R., Havndrup-Pedersen C, Honore D, Pedersen MK, Pallesen U. 2015. Bulk-fill resin composites: polymerization contraction, depth of cure, and gap formation. Oper Dent. 40(2): 190–200.

Comba, A., Scotti, N., Maravic, T., Mazzoni, A., Carossa, M., Breschi, L., Cadenaro, M. 2020. Vickers hardness and shrinkage stress evaluation of low and high viscosity bulk-fill resin composite. Polymers (Basel). 2: 1477.

Gornig, D., Maletz, R., Ottl, P., Warkentin, M. 2022. Influence of artificial aging: mechanical and physico-chemical properties of dental composites under static and dynamic compression. Clin Oral Investig. 26: 1491–1504.

Ilie, N., Bucuta, S., Draenert, M. 2013. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Oper Dent. 38(6): 618–25.

Jafarpour, D., Ferooz, R., Ferooz, M. 2022. Physical and mechanical properties of bulk fill and flowable resin composites stored dry and wet. Int J Dent.5:1–12.

Jang, J.H., Park, S.H., Hwang, I.N. 2015. Polymerization shrinkage and depth of cure of bulk-fill resin composites and highly filled flowable resin. Oper Dent. 40(2): 172–80.

Jun, S.K., Kim, D.A., Goo, H.J., Lee, H.H. 2013. Investigation of the correlation between the different mechanical properties of resin composites. Dent Mater J. 32(1): 48–57.

Kaisarly, D., Meierhofer, D., El Gezawi, M., Rösch, P., Kunzelmann, K.H. 2021. Effects of flowable liners on the shrinkage vectors of bulk-fill composites. Clin Oral Investig. 25: 4927–40.

Kermanshah, H., Ahmadi, E., Rafeie, N., Rafizadeh, S., Omrani, L.R. 2022. Vickers micro-hardness study of the effects of fluoride mouthwash on two types of CAD/CAM ceramic materials erosion. BMC Oral Health. 22: 1–8.

Kilic, V. 2020. Academic Studies in health Sciences – II Polymerization and Light Curing Units in Restorative Dentistry: 472–6. Kayseri: Gece.

Lima, R.B.W., Troconis, C.C.M., Moreno, M.B.P., Murillo-Gomes, F., De Goes, M.F. 2018. Depth of cure of bulk fill resin composites: a systematic review. J Esthet Res Dent. 30(6): 492–501.

Pedrosa M da, S., Nogueira, F.N., Balbo, V. De. O., Medeiros, I.S. 2021. Changes in color and contrast ratio of resin composites after curing and storage in water. Saudi Dent J. 33: 1160–5.

Powers, J.M., Wataha, J.C. 2017. Dental Materials : Foundations and Applications.11th ed: 46–52. St. Louis, Missouri: Elsevier.

Sidiqa, A.N., Soerachmann, B., Putri, M.Y. 2018. Evaluasi nilai kekerasan resin komposit bulkfill dengan variasi waktu penyinaran sinar LED (Evaluation of bulkfill composite resin hardness value with LED light curing time variation). JMKG. 7(2): 6–10.

Yudistian, I. 2021. Bulk Fill Composite Resin Restoration Techniques Replace Incremental Techniques. Interdental: Jurnal Kedokteran Gigi. 17(1): 9–14.

Zakiyah, D., Effendy, R., P. Prasetyo, E.A. 2018. The effect of glycerin on the surface hardness and roughness of nanofill composite. Conservative Dentistry Journal. 8(2): 104–11.

Zhang, J., Gao, P., Wei, Q., Yan, M., Xhao, Q., Xu, T., Zhu, S. 2019. Influence of water aging on surface hardness of low-shrinkage light-cured composite resins. J Oral Sci. 61(1): 89–94.

Microhardness of a flowable bulk-fill resin composite in immediate and 24-hour storage

by Rosalina Tjandrawinata FKG

Submission date: 16-May-2024 12:42PM (UTC+0700)
Submission ID: 2380784891
File name: Microhardness_of_a_flowable_bulk.pdf (252.65K)
Word count: 3429
Character count: 18307

Quality Improvement in Dental and Medical Knowledge, Research,
Skills and Ethics Facing Global Challenges – Widyarman et al. (Eds)

Microhardness of a flowable bulk-fill resin composite in immediate and 24-hour storage

R. Tjandrawinata, D. Pratiwi & F.L. Kurniawan
Department of Dental Materials, Faculty of Dentistry, Universitas Trisakti, Jakarta, Indonesia

A. Cahyanto
Department of Restorative Dentistry, Faculty of Dentistry, University of Malaya, Kuala Lumpur, Malaysia
Department of Dental Materials Science and Technology, Faculty of Dentistry, Universitas Padjadjaran, Bandung, Indonesia

ABSTRACT: Background: Bulk-fill resin composite material gains popularity due to its simple and time-efficient application. However, some dentists question whether the no-light cure side is fully polymerized and the hardness of that side. Objective: This study investigated the microhardness of flowable bulk-fill resin composites on the light-cured/top side and no light-cured/bottom side immediately and after 24 hours immersed in artificial saliva. Methods: Three flowable bulk-fill resin composites were tested: Tetric N-Flow Bulk Fill (TBF), Filtek Bulk Fill (FBF), and Palfique Bulk Flow (PBF). A Vickers microhardness tester was used to determine the microhardness at each cylindrical sample's top and bottom sides. Thirty sam-ples were divided into two groups, Group 1 was tested immediately, and Group 2 was tested after 24 hours of immersion in artificial saliva. Results: The highest microhardness mean value was 47.52 VHN for the PBF top side tested immediately, while the lowest was 25.20 VHN for FBF on the bottom side tested after 24 hours of storage. Two-way ANOVA showed significant differences among the groups ($p<0.05$). There were significant differences ($p<0.05$) between immediate and 24 hours on the top and bottom sides ofTBF and the bottom side of the FBF group. There was no significant difference between the immediate PBF group and 24 hours at the top and bottom sides, and the top side of the FBF group. All groups' bottom/ top ratio was 0.78 or above. Conclusion: The Vickers microhardness has a tendency to decrease on both sides after 24 hours of immersion in artificial saliva.

1 INTRODUCTION

Bulk-fill resin composite (BFRC) is the material of choice in deep cavities and can be an alternative to overcome the difficulties of performing incremental techniques, which may get several failures such as saliva or gingival fluid contamination between layers, failure of bonding between layers, difficulty in filling due to limited access to posterior teeth, and longer time to polymerize every layer. BFRC is also indicated for Class I, II, and VI mesio-occluso-distal/MOD cavities. The bulk-fill technique has been demonstrated to be effective in short-term clinical studies (Powers & Wataha 2017). Bulk fill technique especially using the flowable type represents an induction technique with less pressure and minimal micro-leakage at the edges of preparation. A previous study also showed high viscosity bulk-fill resin composites demonstrated, to some extent, polymerization contraction values and gap formation similar to the conventional resin composites (Benetti et al. 2015). Bulk fill material gains popularity due to its simple and time-efficient application. High depth of cure rates by BFRCs, depends on some factors such as material, irradiance, and exposure time. Light emitting diode (LED) curing devices (polywave or monowave)

DOI: 10.1201/9781003402374-40

isplaying an irradiance ! 1000 mW/cm2 and 20 seconds of exposure time are imperative to accomplish the successful polymerization of most BFRCs (Lima et al. 2018). Typically, flowable composite has a lower filler content and higher volume of resin matrix when compared with condensable composite, so the first-generation flowable composite was applied as a cavity liner or Class V restoration. However, the recent generations of flowable composite have higher filler content and are claimed to have improved mechanical proper-ties; thus, they are indicated not only as a cavity liner but also for larger posterior restora-tions (Ilie et al. 2013; Jang et al. 2015) Microhardness evaluation performed using the Vickers indentation test is suitable for measuring the hardness of small samples. Vickers microhardness study has shown the material resistance to localized plastic deformation. In the microhardness study, the employ load is less than 9.8N, so the resulting indentations are small and limited depths of less than 19 mm (Kermanshah et al. 2022). This study aimed to investigate the microhardness of flowable bulk-fill resin composites on the light cure/top side and no light cure/bottom side immediately and after 24 hours of immersion in artificial saliva.

2 METHODS

Three materials of flowable bulk-fill resin composites, shade A2, as shown in Table 1, were tested: Tetric N-Flow Bulk Fill (Ivoclar Vivadent, Schaan, Liechtenstein) – TBF, Filtek Bulk Fill (3M "ESPE", St Paul, MN, USA) – FBF and Palfique Bulk Flow (Tokuyama, Tokyo, Japan) – PBF. Ten cylindrical samples, 6 mm in diameter and 3 mm in depth, were made for each brand in a stainless-steel mold, according to American Dental Association. In order to get a similar flat surface of the samples, a celluloid strip followed by a glass plate was put on the surface of resin composites, and then the glass plate was removed before the light curing procedure. The bottom surface of the mold was in contact with a glass plate. The tip of the curing light (10 mm diameter) was placed in contact with the celluloid strip. Each sample was polymerized with a light cure intensity of 900 mW/cm2 for 20 seconds on the top surface.

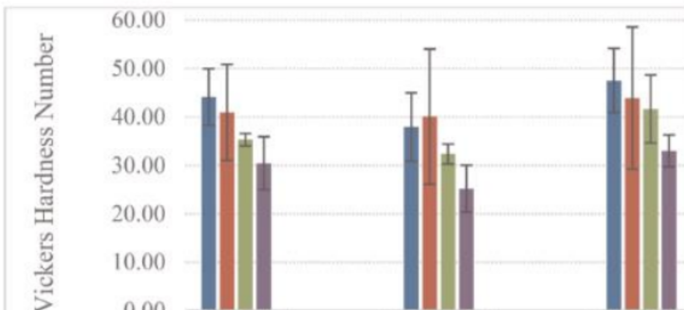
Table 1. Resin composite material used in this study.

Material	Matrix	Filler	Lot no.	Company
Tetric N-Flow Bulk Fill	BisEMA, copolymer, BisGMA, CMPEG-MA	Barium glass, ytterbium trifluoride, DCP. Inorganic filler 0.1-30µm (45-48% by volume),	Z0176H	Ivoclar Vivadent, Schaan, Liechtenstein
Filtek Bulk Fill	BisGMA, UDMA, BisEMA, Procylat resins.	Combination of zirconia/silica, 0.01-3.5 µm and ytterbium trifluoride filler 0.1-5.0 µm. 64.5% by weight (42.5% by volume)	NA76138	3M "ESPE", St Paul, MN, USA
Palfique Bulk Flow	Bisphenol A di (2-hydroxyl propoxy) dimethacrylate (Bis-GMA), Triethylene glycol dimethacrylate, Mequinol, Dibutyl hydroxyl toluene, UV absorber.	Spherical silica-zirconia, 200 nm (100-300 nm). 70 % by weight (56% by volume)	111E41	Tokuyama, Tokyo, Japan

The total number of samples was 30 divided into 2 main groups, 15 samples (5 samples foreach brand) were tested immediately. Another 15 samples were tested after 24 hours of immersion with artificial saliva in an incubator at 37C. Vickers microhardness tester (Shimadzu, Tokyo, Japan) was used to determine the microhardness of each cylindrical sample at the light cure side (top surface) and at the opposite surface, no light cure side (bottom surface). Each sample was indented three times using an indenter load of 25 g for 5 seconds and observed under 40x magnification. The length of two diagonals of each indentation was calculated as the Vickers microhardness of the materials. The sample's bottom/top hardness ratio was then counted and analyzed.

3 RESULTS

Figure 1 shows the Vickers Hardness Number of the samples. The highest and lowest microhardness average value were 47.52 VHN for PBF top side tested immediately and 25.20 VHN for the FBF bottom side tested after 24 hours of storage in artificial saliva. All materials showed decreasing in the ratio after 24 hours of immersion; TBF decreased from 0.92 to 0.86, FBF decreased from 1.14 to 0.78, and PBF decreased from 0.91 to 0.82.



	Tetric Bulk Fill	Filtek Bulk Fill	Palfique Bulk Fill
imm top	44.12	37.92	47.52
imm bottom	40.96	40.08	43.88
24h top	35.32	32.36	41.64
24 bottom	30.48	25.20	33.00

Figure 1. Vickers microhardness number of the samples.

Two-way ANOVA showed significant differences among the groups ($p<0.05$). The inde-pendent t-test showed no significant difference ($p>0.05$) between the group's immediate top and bottom sides. However, there were significant differences ($p<0.05$) between the groups at 24 hours for top-side and bottom-side, between immediate and 24 hours top-side, and between immediate and 24 hours bottom-side.

4 DISCUSSION

Vickers microhardness, defined as the resistance of a material to indentation, is among the physical properties that govern a resin composite's clinical performance (Jafarpour et al. 2022). The factors that affect the surface hardness of resin composite are the quality and technique of polishing, a chemical composition such as organic matrix chemical compo-nents, filler loading, and aging in water and various other media. Surface degradation, margin, and bulk fracture are common reasons that lead to the replacement of restorations (Jafarpour et al. 2022). In this study, a celluloid strip was used to get a smooth surface of samples, while the glass plate gave similar weight to make the surface flat for the Vickers microhardness test. In this study, PBF has spherical silica-zirconia as the highest filler content (56% by volume), and showed the highest Vickers microhardness number among the three groups.

The filler loading of resin composites greatly determines their mechanical and physical properties. A positive correlation between filler loading and surface hardness was established by Chang et al in an extensive study on filler morphology, its influence on filler loading, and the effect of these factors on the mechanical properties of resin composites. It was found that filler morphology affects filler loading (Almozainy 2018). As shown in Table 1 and Figure 1, resin composites containing round particles had the highest filler content and hardness. It was shown that the reduced filler size could alter the organic matrix between the particles and decrease the interparticle distances, leading to improvement in mechanical properties (Powers & Wataha 2017; Jafarpour et al. 2022).

The results showed that the highest microhardness value of flowable BFRC has a filler size of 100–300 nm or 0.1–0.3 mm. The other two brands have a range of filler sizes 0.1–30 mm and 0.01–5.0 mm. The mean filler size and weight have previously been reported to affect the fracture toughness of resin composites, and those with smaller filler particles have been associated with higher toughness. Higher VHN has been reported to correlate with lower material structure porosity. Furthermore, the modified strontium glass reinforces the strength of the filler, offering improved surface hardness. However, similar filler loading yet different matrix content may result in different surface hardness (Powers & Wataha 2017). In this study, there were various matrix compositions. Resin matrix content could be a responsible factor for water sorption. Previous studies confirmed that water uptake increases following an increase in the TEGDMA content in the resin matrix (Anjelia 2021). Other research showed no correlation between the hardness and the filler content or between hardness and the degree of the color change of the resin composites. Another study con-firmed the positive correlation between filler loading and microhardness in their study on the effect of aging in three food-simulating solvents on eight commercial resin composites, including four bulk-fill, two microhybrid, and two nanohybrid resin composites. Vickers microhardness reduced significantly, mainly as a result of storage time and type of solvent used. Additionally, nanohybrid materials showed better mechanical properties and higher hardness values compared to other tested materials, which was speculated by the higher filler loading. Another study on the effect of distilled water on microhardness determined a sig-nificantly lower hardness of the materials after six months of immersion (Jafarpour et al. 2022).

Twenty-four-hour storage of flowable BFRC in artificial saliva showed a trend of decrease in the hardness value. The storage condition had a significant effect on the VHN of resin composites. The VHN was not subjected to aging. In fact, the VHN ofthe materials did not alter significantly after 60 days of storage compared to the first 7 days (Jafarpour et al. 2022). When compared to the dry condition, the lower VHN in the wet condition for the bulk-fill composite could be due to the uptake of the aging liquid in porous intermolecular spaces within the resin composite, which leads to the physical destruction of the material. The storage media significantly influences the resin composites; the storage time does not pose such effects (Jafarpour et al. 2022). However, in a study by Hahnel et al., the authors proposed that both the composite materials and the storage times have a significant effect on the surface hardness (Gornig et al. 2022). Initially, the effect of water in the resin composite may cause softening of the organic matrix by hygroscopic expansion and hydrolysis or hydration of siloxane bonds of the silane layer. The commercial resins absorbed between 5% and 12% water, which was associated with a 19–42% reduction in modulus over 3 days. This reason described the decrease in hardness value after 24 hours of artificial saliva immersion (Zhang et al. 2019; Pedrosa et al. 2021).

The condition and time intervals influence dental resin composite material'sphysical and mechanical properties, while filler weight% significantly affected fracture toughness and this study on the Vickers hardness number. The properties of resin composites mainly rely on their monomer type, filler size, filler volume, and filler-resin interface. Filler content is an important factor affecting the physical and mechanical properties of resin composites (Jun et al. 2013).

Past research has shown that when hardness values are obtained, a mean bottom/top ratio (B/T) hardness value is usually determined to establish the depth of cure. This reflects the relative extent of conversion of the deeper surfaces in relation to the top surface. As an accepted minimum standard, many authors have claimed that a ratio of 0.80 is clinically acceptable (Lima et al. 2018; Kermanshah et al. 2022), which was fulfilled in this study. It has been shown that the value is mostly dependent on the filler content and filler size. This is an accurate method to compare the relative extent of cure between different composites at specified depths. The bottom/top hardness ratio can also predict under-cured resins, leading to early restoration failure, and should be avoided in any clinical technique (Lima et al. 2018). The size and amount of filler content were important in determining the shrinkage, but the shape of the particles could also generate a different outcome (Jun et al. 2013). As shown in this study, the flowable BFRC with spherical silica-zirconia filler showed the highest VHN value. The depth of cure values for all materials could influence clinical outcomes. In this study, all samples were in the same diameter and height so that there would be no influence on the thickness of the sample or depth of cure. Filler size and content in dental composites may reduce light penetration and are directly related to the depth of cure (Kilic 2020).

The presence of pigments in shaded composite materials should also affect the depth of cure because pigments are opaque particles that will limit light penetration and reduce the degree of polymerization at greater depths within a cavity preparation (Jang et al. 2015; Kaisarly et al. 2021; Sidiqa et al. 2018). Numerous studies have defined the depth of cure based on hardness measurements performed on the bottom and top surface of a light-cured resin composite specimen and agree that a ratio of0.80 may be used as a critical minimum acceptable threshold value (Lima et al. 2018). In this study, the range of the bottom/top ratio was 0.78 to 1.14. The hardness of the bottom side is supposed to be lower than the top side. However, in FBF, in immediate conditions, the hardness of the bottom side was higher than the top side. This condition should be studied further since the top side's oxygen-inhibited layer has already been prevented by using a celluloid strip. It was mentioned that the presence of oxygen inhibited layer decreased the hardness of the resin composite (Zakiyah et al. 2018; Kilic 2020).

According to Jun et al., the hardness value of resin composites has a correlation with tensile strength (Jun et al. 2013). The filler of composites influences the hardness and tensile strength. As we know that tensile strength has a correlation also with elastic modulus. As a result, the amount of filler can also influence the elastic modulus of the composite (Zakiyah et al. 2018). Several studies showed that the elastic modulus increases exponentially with increasing filler concentration. Consequently, the strength, hardness, and volumetric shrinkage are strictly dependent on the filler amount (Kilic 2020; Comba et al. 2020). The amount of filler reduces the volume occupied by the resin matrix. As a result, the number of methacrylate groups decreases, leading to lower volumetric shrinkage. It is also mentioned that the viscosity will influence the depth of cure of the BFRC. The low-viscosity bulk-fill materials showed the possibility of layering 4 mm layers, while high-viscosity bulk-fill composites showed an initial decrease of microhardness after 2 mm of depth, suggesting a potential reduction of the mechanical properties and, thus, of the chewing force resistance when employed in load-bearing contact areas (Comba et al. 2020).

The color of BFRC may also influence microhardness. Resin composites have many shades and are divided into translucency and solid color. Translucent materials allow better penetration of light (Yudistian 2021). In this study, the translucent shade color A2 makes polymerization easier. Solid color may create unperfect composite polymerization and also influence the microhardness value, especially at the bottom side. Besides the shade of color, the distance of the sample and light curing tip may interfere with decreasing microhardness after 24 hours of immersion time. In this study, the tip of the light curing unit was set in contact with the celluloid strip to delete the possibility of decreasing sample hardness because of tip distance. Yet, it was reported that the curing distance < 1 cm made no sig-nificant effect on the samples with < 2.5 mm thickness (Kilic 2020).

5 CONCLUSION

Within the limitations of this study, the following conclusions were drawn: the amount of filler reduces the volume occupied by the resin matrix, leading to lower volumetric shrinkage and there was a tendency of decreasing Vickers microhardness values on both sides after 24 hours of immersion in artificial saliva. All materials showed decreasing in the ratio after 24 hours of immersion.

ACKNOWLEDGEMENT

The authors express great appreciation to Universitas Trisakti for supporting the research fund.

REFERENCES

Almozainy, M. 2018. Influence of storage temperature on vickers microhardness of resin composite. Ann Essence Dent.10(1): 1–7.

Anjelia, C., Octarina. 2021. The knowledge level of dental students on color stability composite resin restoration in the COVID-19 pandemic area. Int J Public Health Sci. 10(4): 751–7.

Benetti, A.R., Havndrup-Pedersen C, Honore D, Pedersen MK, Pallesen U. 2015. Bulk-fill resin composites: polymerization contraction, depth of cure, and gap formation. Oper Dent. 40(2): 190–200.

Comba, A., Scotti, N., Maravic, T., Mazzoni, A., Carossa, M., Breschi, L., Cadenaro, M. 2020. Vickers hardness and shrinkage stress evaluation of low and high viscosity bulk-fill resin composite. Polymers (Basel). 2: 1477.

Gornig, D., Maletz, R., Ottl, P., Warkentin, M. 2022. Influence of artificial aging: mechanical and physico-chemical properties of dental composites under static and dynamic compression. Clin Oral Investig. 26: 1491–1504.

Ilie, N., Bucuta, S., Draenert, M. 2013. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Oper Dent. 38(6): 618–25.

Jafarpour, D., Ferooz, R., Ferooz, M. 2022. Physical and mechanical properties of bulk fill and flowable resin composites stored dry and wet. Int J Dent.5:1–12.

Jang, J.H., Park, S.H., Hwang, I.N. 2015. Polymerization shrinkage and depth of cure of bulk-fill resin composites and highly filled flowable resin. Oper Dent. 40(2): 172–80.

Jun, S.K., Kim, D.A., Goo, H.J., Lee, H.H. 2013. Investigation of the correlation between the different mechanical properties of resin composites. Dent Mater J. 32(1): 48–57.

Kaisarly, D., Meierhofer, D., El Gezawi, M., Rösch, P., Kunzelmann, K.H. 2021. Effects of flowable liners on the shrinkage vectors of bulk-fill composites. Clin Oral Investig. 25: 4927–40.

Kermanshah, H., Ahmadi, E., Rafeie, N., Rafizadeh, S., Omrani, L.R. 2022. Vickers micro-hardness study of the effects of fluoride mouthwash on two types of CAD/CAM ceramic materials erosion. BMC Oral Health. 22: 1–8.

Kilic, V. 2020. Academic Studies in health Sciences – II Polymerization and Light Curing Units in Restorative Dentistry: 472–6. Kayseri: Gece.

Lima, R.B.W., Troconis, C.C.M., Moreno, M.B.P., Murillo-Gomes, F., De Goes, M.F. 2018. Depth of cure of bulk fill resin composites: a systematic review. J Esthet Res Dent. 30(6): 492–501.

Pedrosa M da, S., Nogueira, F.N., Balbo, V. De. O., Medeiros, I.S. 2021. Changes in color and contrast ratio of resin composites after curing and storage in water. Saudi Dent J. 33: 1160–5.

Powers, J.M., Wataha, J.C. 2017. Dental Materials : Foundations and Applications.11th ed: 46–52. St. Louis, Missouri: Elsevier.

Sidiqa, A.N., Soerachmann, B., Putri, M.Y. 2018. Evaluasi nilai kekerasan resin komposit bulkfill dengan variasi waktu penyinaran sinar LED (Evaluation of bulkfill composite resin hardness value with LED light curing time variation). JMKG. 7(2): 6–10.

Yudistian, I. 2021. Bulk Fill Composite Resin Restoration Techniques Replace Incremental Techniques. Interdental: Jurnal Kedokteran Gigi. 17(1): 9–14.

Zakiyah, D., Effendy, R., P. Prasetyo, E.A. 2018. The effect of glycerin on the surface hardness and roughness of nanofill composite. Conservative Dentistry Journal. 8(2): 104–11.

Zhang, J., Gao, P., Wei, Q., Yan, M., Xhao, Q., Xu, T., Zhu, S. 2019. Influence of water aging on surface hardness of low-shrinkage light-cured composite resins. J Oral Sci. 61(1): 89–94.

Microhardness of a flowable bulk-fill resin composite in immediate and 24-hour storage

ORIGINALITY REPORT

18%	13%	15%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.tmj.eg.net Internet Source	2%
2	guaiaca.ufpel.edu.br:8080 Internet Source	2%
3	Sunbul, Hanan Al, Nick Silikas, and David C. Watts. "Surface and bulk properties of dental resin- composites after solvent storage", Dental Materials, 2016. Publication	1%
4	Haridas, Hasna. "An In-Vitro Comparative Evaluation of Effect of Light Curing Exposure Time, Shade and Thickness on the Depth of Cure of Two Bulk Fill Composites and a Nanohybrid Composite", Rajiv Gandhi University of Health Sciences (India), 2023 Publication	1%
5	nsuworks.nova.edu Internet Source	1%

6	Marlus da Silva Pedrosa, Fernando Neves Nogueira, Vitor de Oliveira Baldo, Igor Studart Medeiros. "Changes in color and contrast ratio of resin composites after curing and storage in water", The Saudi Dental Journal, 2021 Publication	1 %
7	etheses.whiterose.ac.uk Internet Source	1 %
8	www.auctoresonline.org Internet Source	1 %
9	www.pubfacts.com Internet Source	1 %
10	Submitted to TechKnowledge Student Paper	1 %
11	www.karyailmiah.trisakti.ac.id Internet Source	1 %
12	S Shibasaki, T Takamizawa, K Nojiri, A Imai, A Tsujimoto, H Endo, S Suzuki, S Suda, WW Barkmeier, MA Latta, M Miyazaki. "Polymerization Behavior and Mechanical Properties of High-Viscosity Bulk Fill and Low Shrinkage Resin Composites", Operative Dentistry, 2017 Publication	1 %
13	theses.ncl.ac.uk	

Internet Source

1 %

14	onlinelibrary.wiley.com Internet Source	1 %
15	"Free Communication Sessions 01-20 and Poster Sessions 01-16", International Dental Journal, 2015. Publication	1 %
16	Kim, Eun-Ha, Kyoung-Hwa Jung, Sung-Ae Son, Bock Hur, Yong-Hoon Kwon, and Jeong-Kil Park. "Effect of resin thickness on the microhardness and optical properties of bulk-fill resin composites", Restorative Dentistry & Endodontics, 2015. Publication	1 %
17	Kyo-Han Kim, Joo L. Ong, Osamu Okuno. "The effect of filler loading and morphology on the mechanical properties of contemporary composites", The Journal of Prosthetic Dentistry, 2002 Publication	1 %
18	Submitted to University of the Western Cape Student Paper	1 %
19	doku.pub Internet Source	1 %

Exclude quotes	On	Exclude matches	< 15 words
Exclude bibliography	On		

Microhardness of a flowable bulk-fill resin composite in immediate and 24-hour storage

GRADEMARK REPORT

FINAL GRADE

/100

GENERAL COMMENTS

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6