ORIGINAL ARTICLE

Biomedica - Official Journal of University of Health Sciences, Lahore, Pakistan
Volume 39(4):156-160
https://doi.org/10.24911/BioMedica/5-1002

Biodentine achieves better Vickers microhardness and diametral tensile strength when compared to glass ionomer cement - an experimental study

Aneela Qaisar[1*], Nauman Ahmed Noor[2], Muhammad Amber Fareed[3]

ABSTRACT

Background and Objective: Replacing lost dentin with an appropriate substitute has been challenging in recent years. Biodentine and conventional glass ionomers are used as dentin replacement materials. This study aimed to compare the Vickers microhardness (VHN), diametral tensile strength (DTS), and setting time of Biodentine and glass ionomer cement (GIC).

Methods: This experimental study was conducted in the Department of Science of Dental Materials at Fatima Memorial College of Dentistry, Lahore, in collaboration with the Interdisciplinary Research Centre of Biomedical Materials, COMSATS Lahore from December 2022 to March 2023. A total of fifty disc-shaped samples (4 × 2 mm) of Biodentine and GIC Gold Label 2 were fabricated to assess the VHN, DTS, and setting time after immersion in distilled water for 1 hour and after 3 days. Data were analyzed by applying the paired and independent *t*-tests using Statistical Package for Social Sciences 26.0.

Results: The mean VHN value of Biodentine and GIC Gold Label 2 cement was 23.4 ± 1.5 and 17.5 ± 1.27 after 1 hour and 31.9 ± 1.66 and 29.6 ± 1.58 after 3 days, respectively. DTS of Biodentine [7.0 ± 0.91 mega pascal (MPa)] was significantly greater than GIC Gold label 2 (5.5 ± 0.68 MPa) after 1 hour ($p < 0.05$). However, after 3 days, there was a slight increase in the DTS of Biodentine (9.3 ± 1.53 MPa) while compared to GIC Gold label 2 (8.2 ± 1.0 MPa) and this difference was not statistically significant ($p > 0.05$). Biodentine had a higher setting time than GIC Gold label 2, with an initial setting time of 6.7 minutes compared to 2.9 minutes.

Conclusion: GIC Gold label 2 has a shorter setting time than the but Biodentine which, however, showed higher Vicker's microhardness and DTS. Therefore, Biodentine may be a more suitable substitute for dentine replacement than the GIC Gold label 2.

Keywords: Vickers microhardness, diametral tensile strength, setting time, glass ionomer cement, Biodentin.

Received: 09 July 2023 **Revised date:** 21 August 2023 **Accepted:** 18 September 2023

Correspondence to: Aneela Qaisar
*Associate Professor, Department of Science of Dental Materials, Fatima Memorial College of Medicine & Dentistry, Lahore, Pakistan.
Email: draneelaqaiser@gmail.com
Full list of author information is available at the end of the article.

Introduction

The integrity of tooth structure is significantly compromised by the loss of dentin due to caries or tooth preparation. Replacing lost dentin with an appropriate substitute has been challenging in recent years. The advent of new materials promises better mechanical and physical properties than those of their predecessors. Glass ionomer cement (GIC) has been the staple for dentin replacement over the years. However, its high initial solubility, low initial strength, and inability to stimulate reparative dentin formation limit its use under certain conditions.[1] An ideal dentin substitute should have dentin-like mechanical properties, excellent biocompatibility, low solubility, and the ability to induce hard-tissue regeneration. The materials used for this purpose include calcium hydroxide, GIC, and mineral trioxide aggregates. Newer bioactive materials, such as Biodentine, bioglass, and bioceramics, are also used to improve overall properties.[1] In recent years, Biodentine has gained popularity owing to its superior strength, stability, and ability to form secondary dentin.[2]

Biodentine is a calcium silicate-based material that exhibits physical and chemical properties similar to those of certain Portland cement.[3] It is biocompatible and can form reactionary and reparative dentin by stimulating odontoblasts and cell differentiation.[4] Conventional GICs are used in many applications in dentistry because of their excellent physical properties. Therefore, they are extensively used for dentin replacement in the coronal region.[5] However, the bond strength of Biodentine with the tooth is better than that of the other materials with good marginal adaptation and superior surface properties. The Vickers microhardness (VHN) values and compressive strength of Biodentine are greater than those of conventional and resin-modified GIC.[6]

There are limited data on GIC and Biodentine in the Pakistani population; therefore, this experimental study was designed to compare the diametral tensile strength (DTS), VHN, and setting time of Biodentine and GIC to determine a better substitute for dentine replacement.

Methods

This experimental study was conducted in the Department of Science of Dental Materials at Fatima Memorial College of Dentistry Lahore, Pakistan, in collaboration with the Interdisciplinary Research Centre of Biomedical Materials (IRCBM), COMSATS Lahore from December 2022 to March 2023 after taking institutional review board approval. Ten disc-shaped specimens of conventional GIC Gold label 2 (GC Corporation, Tokyo, Japan) and calcium silicate-based dentine substitute material Biodentine, Septodont (St. Maur-des-Fossés, France) were prepared and tested for VHN and DTS after immersion in distilled water at the time intervals of 1 hour and 3 days. Five samples were prepared for each material to record the setting time measurement after 1 hour as mentioned in Table 1.

Materials Preparation

Biodentine™ (Septodont (St. Maur-des-Fossés, France) and GC-Gold labels were mixed according to the manufacturer's instructions. Five drops of Biodentine liquid were added to the capsule. It was closed and vibrated for 30 seconds in an amalgamator (HAID Semedent, China) at 3,000 rpm. The mixed material was collected by using a spatula provided by the manufacturer.

The GC Gold label was mixed on a mixing pad using a spatula with a p/l ratio of 1:2. The specimens were manufactured at a room temperature of 23°C ± 2°C and relative air humidity of 50% ± 10%, as recommended by the American Dental Association specification No. 66. After mixing, the materials were inserted into a Teflon mold with a diameter of 4 mm and length of 2 mm. Both materials were filled into molds and covered with polyester strips (Proben, Catanduva, Brazil). It was pressed for 20 seconds to remove the excess material. The specimens were carefully inspected and trimmed using silicon carbide paper (600 grit). The samples were immediately transferred to glass containers containing distilled water, and sealed with paraffin wax.[7]

Measurement of VHN

It was calculated using a Digital Microhardness tester (Siowon HV-1000, Germany) with a diamond indenter. One polished cement surface of each sample was loaded with a diamond indenter (Siowon, Wetzlar, Germany) weighing 100 g for 30 seconds. This produced a stamped mark in the homogeneous region of the cement surface. The impression of the diamond indenter with two orthogonal diagonals of equal length was measured after release, and the hardness values were calculated accordingly.[8]

Measurement of DTS

DTS was measured by placing specimens on a computer-controlled materials testing machine (Instron, USA) under 5 KN compression and data was recorded using computer software. The specimens were compressed at a crosshead speed of 0.5 mm/minute to introduce tensile stress into the material in the plane of the force applied during the test.[9]

Measurement of setting time

A 453.6 ± 0.1 g Gilmore needle was used to measure the setting time at the interval of every 5 seconds. The needle created an indentation when it was placed on the cement surface. The time was measured when the indenter needle hardly left a mark on the cement surface.[10]

Statistical analysis

Statistical Package for Social Sciences software (SPSS Inc., version 23, Chicago, IL) was used for data processing and analysis. Mean ± S.D was calculated for descriptive statistics. A paired *t*-test was performed to compare the properties of the Biodentine and GIC after each storage period. An independent *t*-test was used to compare the mean values of the individual groups of Biodentine and GC Gold label 2 after different storage periods.

Table 1. *Experimental materials and tests at different time intervals.*

Test	Material	1 hour (*n*)	3 day (*n*)
VHN	Biodentine	5	5
	GC Gold label 2	5	5
DTS	Biodentine	5	5
	GC Gold label 2	5	5
Setting time	Biodentine	5	
	GC Gold label 2	5	-

Results

The mean VHN value of Biodentine and GC Gold Label 2 cement was 23.4 ± 1.5 and 17.5 ± 1.27 HV after 1 hour and 31.9 ± 1.66 and 29.6 ± 1.5 HV after 3 days, respectively. The increase in mean VHN value for both Biodentine and GC Gold Label 2 cement after 1 hour and 3 days was statistically significant as shown in Table 2. The mean VHN value of Biodentine after 1 hour and 3 days was greater than that of GC Gold label 2 and this difference was statistically significant ($p < 0.05$).

DTS of Biodentine was 7.0 ± 0.91 and 9.3 ± 1.53 mega pascal (MPa) at the first hour and after 3 days, respectively. While it was 5.5 ± 0.68 MPa for GC after the first hour and 8.2 ± 1.0 MPa after 3 days. Statistically, there was a significant increase in DTS after 1 hour to 3 days for both materials as described in Table 2. Also, DTS of Biodentine (7.0 ± 0.91 MPa) was significantly greater than GC Gold label 2 (5.5 ± 0.68 MPa) after 1 hour. However, on day 3, there was a slight increase in the DTS of Biodentine (9.3 ± 1.53 MPa) while compared to GC Gold label 2 (8.2 ± 1.0 MPa) and this difference was not statistically significant ($p > 0.05$) (Table 2). The initial setting time for Biodentine was 6.7 ± 0.2 and 2.9 ±0.1 minutes for GC Gold label 2 cement and the difference was statistically significant ($p < 0.05$) (Table 2).

Discussion

VHN and DTS are essential parameters to determine the mechanical properties of the material used as a dentine substitute.[11] The VHN determines the resistance of a material to plastic deformation after penetration or indentation. The microhardness values for sound dentine range from 50 to 70 HV.[12] DTS is a key performance indicator because many failures of dental restorations are often caused by tensile stress.[13]

The present study found a greater mean VHN value of Biodentine than that of GC Gold label 2 after 1 hour and 3 days of immersion in distilled water. Similar findings were observed in a study by Anu and Thomus[14] in which the physical properties of Biodentine were compared with those of a conventional GIC (Fuji IX) and a resin-modified glass ionomer (Vitrebond). They also reported higher surface microhardness of Biodentine while comparing it with other materials. Another study conducted by Arnez et al.[15] found higher microhardness values exhibited by Biodentine than glassionomer cement after immersion in mouthwash.

Biodentine, a frequent tricalcium silicate-based material, has been evaluated for different aspects such as replacing or repairing the dentine since its launching in 2009. Despite the variable results, different investigations showed the superior physical and clinical properties of Biodentine making it suitable for clinical dental procedures because of biocompatiblity and easily handled product with a short setting time.[16] A shorter setting time allows for immediate restoration of the teeth. It is recommended to use as a dentin substitute in composite restorations, endodontic materials, and temporary restorative materials for the posterior teeth.[17] Biodentine exhibits greater microhardness than Fuji IX GIC at different time intervals.[18] Manual mixing of the Biodentine liquid decreases the setting time and increases the microhardness.[19] Different physiochemical aspects of Biodentine have been analyzed which favor its versatility, stability, and higher compressive and flexural strengths. Apart from these properties it is easy to handle and is a low-cost material.[20]

The physical, chemical, and mechanical features and surface topography of the material are affected by adding the liquid to the powder.[21] A study reports the reduction in VHN of Biodentine from 130 HV to approximately 90 HV after etching

Table 2. *VHN, DTS, and setting time of Biodentine and GC Gold label 2.*

Procedure	Material	1 hour Mean ± S.D *n* = 10	3 day Mean ± S. D *n* = 10	*p*-value*
Vickers hardness (VHN)	Biodentine	23.4 ± 0.58	31.9 ± 1.66	0.021*
	GC Gold label2	17.5 ± 1.27	29.6 ± 1.58	0.042*
p-value		<0.05**	<0.05**	
DTS (MPa)	Biodentine	7.0 ± 0.91	9.3 ± 1.53	0.011*
	GC Gold label 2	5.5 ± 0.68	8.2 ± 1.0	0.014*
p-value		<0.05	0.063	
Setting time (Minutes) *n* = 5	Materials	Mean ± SD	---	0.023
	Biodentine	6.7 ± 0.2	---	
	GC Gold label 2	2.9 ± 0.1	---	

Statistical significance was considered at an α level of 0.05. Paired *t*-test compared the means of Biodentine and GIC after 1 hour and 3 days.* Independent *t*-test compared the means of Biodentine and GC Gold label 2 after 1 hour and 3 days and setting time.**

with 35% phosphoric acid for 1 minute. [22] Elsayed[9] evaluated the effects of the addition of strontium fluoride and fluoride only on the compressive and DTSs of Biodentine. He found higher DTS for Biodentine alone than other modified groups; however, the difference was not statistically significant ($p > 0.05$). The reason for the increase in tensile strength of Biodentine may be due to the low water/powder ratio which increases the good working of cement. As it incorporates hydro soluble polymer in the liquid component of cement apart from water-soluble polycarboxylate in the cement's powder.[23]

Setting time, a clinically relevant feature of restorative materials refers to the length of time required for a material to get hard from a liquid form. The set material retains its shape, withstands stress, and counteracts the dislocation. This also affects the sealing ability and ingress of microorganisms. An adequate setting time is also important for ensuring proper handling characteristics.[24]

In the current study, the initial setting time of Biodentine was recorded as 6.7 ± 2 minutes. Earlier studies by Rajasekharan et al.[25] and Kaup et al.[26] reported an initial setting time of Bidentine as 13.1, and 85.66 ± 6.03 minutes, respectively. Nevertheless, in both studies, the setting time for Biodentine varied significantly compared with the time given in the manufacturer's instructions. In contrast, the setting time of GIC Gold label 2 was 2.9 ± 0.1 minutes which was significantly lesser than the Biodentine and is easier for clinicians to use. The overall mechanical properties and setting time of Biodentine make it a good choice for use as a dentine substitute material.

Conclusion

Based on the results of the study, it is concluded that the Biodentine makes a good choice for dental procedures as it achieved a higher VHN and DTS but longer setting time when compared to the GIC Gold label 2. These findings can be used to explore further the physical properties and longevity of dentine in future clinical studies.

Limitations of the study

Various properties of Biodentine and GIC materials were studied after being stored for a short period of time not exceeding 3 days. Long-term studies may further validate the results significantly as surface abrasions due to wear in a natural environment might influence these properties.

Acknowledgement

The authors would like to thank all the technical staff at IRCBM, COMSATS, Institute of Technology Lahore, Pakistan, for their assistance in performing different tests using a Universal testing machine.

List of Abbreviations

DTS	Diametral tensile strength
GIC	Glass ionomer cement
HV	Vickers microhardness
IRCBM	Interdisciplinary Research Centre of Biomedical Materials
MPa	Mega pascal
SPSS	Statistical Package for Social Sciences
SD	standard deviation
VHN	Vickers hardness number

Conflict of interest

None to declare.

Grant support and financial disclosure

None to disclose.

Ethical approval

Ethical approval was granted by the Institutional Review Board of Fatima Memorial College of Medicine and Dentistry, Lahore, Pakistan, vide Letter No. FMH-25/ 10/2022-IRB-1122, dated 01-12-2022.

Authors' contributions

AQ: Conception and design of the study, drafting of the manuscript with critical intellectual input.
NAN: Acquisition and analysis of data, drafting of the manuscript.
MAF: Conception and design of the study, critical intellectual input.
ALL AUTHORS: Approval of the final version of the manuscript to be published.

Authors ' Details

Aneela Qaisar[1], Nauman Ahmed Noor[2], Muhammad Amber Fareed[3,4]

1. Associate Professor, Department of Science of Dental Materials, Fatima Memorial College of Medicine & Dentistry, Lahore, Pakistan
2. Assistant Professor, Department of Science of Dental Materials, Fatima Memorial College of Medicine and Dentistry, Lahore, Pakistan
3. Professor, College of Dentistry, Centre of Medical and Bio-Allied Health Sciences Research, Ajman University, Ajman, UAE.
4. Visiting Faculty at Interdisciplinary Research Centre of Biomedical Materials (IRCBM), COMSATS, Lahore, Pakistan

References

1. Mocquot C, Attik N, Pradelle-Plasse N, Grosgogeat B, Brigitte G, Pierre C. Bioactivity assessment of bioactive glasses for dental applications: a critical review. Dent Mater. 2020;36(9):1116–43. doi.org/10.1016/j.dental.2020.03.020
2. Zaidi SJ. Biodentineis an ideal biomimetic material for minimally invasive dentistry. Pak J Med Dent. 2021;10(04):63–9. Available from: http://ojs.zu.edu.pk/ojs/index.php/pjmd/article/view/1547
3. Zafar K, Jamal S, Ghafoor R. Bio-active cements-mineral trioxide aggregate based calcium silicate materials: a narrative review. J Pak Med Assoc. 2020;70(3):497–504. Available from: https://ecommons.aku.edu/pakistan_fhs_mc_surg_dent_oral_maxillofac/155.
4. Widbiller M, Jeanneau C, Galler KM, Laurent P, About I. Biocompatibility and bioactive properties of BiodentineTM.

Biodentine™: properties and clinical applications. New York, NY: Springer International Publishing; 2022. 31–50 pp. https://doi.org/10.1007/978-3-030-80932-4_3

5. Makanjuola J, Deb S. Chemically activated glass-ionomer cements as bioactive materials in dentistry: a review. Prosthesis. 2023;5(1):327–45. https://doi.org/10.3390/prosthesis5010024.
6. Bansal R, Bansal M, Matta M, Walia S, Kaur B, Sahrma N. Evaluation of marginal adaptation of MTA, Biodentine, and MTA plus as root-end filling materials - an SEM study. Dent J Adv Stud. 2019;07(01):006–11. https://doi.org/10.1055/s-0039-1684154
7. Abo-Eldahab G, Kamel M, Nour K. The effect of different polishing methods on the surface roughness of resin composites (An *in-vitro* study). Egypt Dent J. 2022;68(4):4039–51. https://doi.org/10.21608/EDJ.2022.156850.2220
8. Schiavi A, Origlia C, Germak A, Prato A, Genta G. Indentation modulus, indentation work and creep of metals and alloys at the macro-scale level: experimental insights into the use of a primary Vickers hardness standard machine. Materials. 2021;14(11):2912. https://doi.org/10.3390/ma14112912
9. Elsayed HM. Effect of incorporating strontium fluoride and fluoride on compressive and diametral tensile strengths of Biodentine. Al-Azhar J Dent Sci. 2020;23(4):363–8. doi 10.21608/AJDSM.2020.25643.1024
10. Ravindran V, Jeevanandan G. Comparative evaluation of the physical and antimicrobial properties of mineral trioxide aggregate, biodentine, and a modified fast-setting mineral trioxide aggregate without tricalcium aluminate: an *in vitro* study. Cureus. 2023;15(8):1–13. https://doi.org/10.7759/cureus.42856
11. Kopecskó K, Baranyi A. Comparative study of setting time and heat of hydration development of Portland cement according to EN 196–3. In: Armenta JLR, Flores-Hernández CG, editors. Applications of calorimetry. London, UK: Intech Open; 2022. https://doi.org/10.5772/intechopen.101912
12. Haralur SB, Alqahtani MM, Alqahtani RA, Shabab RM, Hummadi KA. Effect of dentin-disinfection chemicals on shear bond strength and microhardness of resin-infiltrated human dentin in different adhesive protocols. Medicina. 2022;58(9):1244. https://doi.org/10.3390/medicina58091244
13. Choudhury WR, Nekkanti S. Mechanical properties of SDR™ and Biodentine™ as dentin replacement materials: an *in vitro* study. J Contemp Dent Pract. 2022;23(1):43–8. Available from: https://pubmed.ncbi.nlm.nih.gov/35656656/
14. Anu J, Thomas A. A comparative evaluation of the microhardness of glass ionomer cements modified with chitosan and chlorhexidine: a 1-year *in vitro* study. J Int Oral Health. 2019;11(6):376–83. Available from: https://www.jioh.org/text.asp?2019/11/6/376/271784
15. Arnez MM, Castelo R, Ugarte D, Almeida LPA, Catirse AB. Microhardness and surface roughness of Biodentine exposed to mouthwashes. J Conserv Dent. 2021;24(4):379–83. https://doi.org/10.4103/jcd.jcd_113_21
16. Kadali NS, Alla RK, Ramaraju AV, Sajjan SMC, Mantena SR, Raju RV. An overview of composition, properties, and applications of Biodentine. Int J Dent Mater. 2021;3(4):120–6. https://doi.org/10.37983/IJDM.2021.3404
17. Varghese NS, Gurunathan D. Review of literature on the properties and studies done on Biodentineas a pulp rehabilitating agent. J Popul Ther Clin Pharmacol. 2023;30(16):171–8. https://doi.org/10.47750/jptcp.2023.30.16.021’
18. Bolhari B, Meraji N, Khazaee P, Ghabraei S, Valizadeh S. Do different time intervals in placement of restorative materials over calcium silicate cements, affect interface microhardness of different restorative materials? Dentistry 3000. 2021;9(1):85–94. https://doi.org/10.5195/d3000.2021.159
19. Pires MD, Cordeiro J, Vasconcelos I, Alves M, Quaresma SA, Ginjeira A, et al. Effect of different manipulations on the physical, chemical and microstructural characteristics of Biodentine. Dent Mater. 2021;37(7):e399–406. https://doi.org/10.1016/j.dental.2021.03.021
20. Docimo R, Carrante VF, Costacurta M. The physical-mechanical properties and biocompatibility of Biodentine: a review. J Osseointegr. 2021;13(1):47–50. https://doi.org/10.23805/J0.2021.13.01.08
21. Domingos Pires M, Cordeiro J, Vasconcelos I, Alves M, Quaresma SA, Ginjeira A. Effect of different manipulations on the physical, chemical and microstructural characteristics of Biodentine. Dent Mater. 2021;37(7):e399–406. https://doi.org/10.1016/j.dental.2021.03.021
22. Camilleri J. Investigation of Biodentineas dentine replacement material. J Dent. 2013 Jul 1;41(7):600–10. https://doi: 10.1016/j.jdent.2013.05.003
23. Lucas CD, Viapiana R, Bosso-Martelo R, Guerreiro-Tanomaru JM, Camilleri J, Tanomaru-Filho M. Physicochemical properties and dentin bond strength of a tricalcium silicate-based retrograde material. Braz Dental J. 2017;28:51–6. https://doi.org/10.1590/0103-6440201701135
24. Singla MG, Wahi P. Comparative evaluation of shear bond strength of Biodentine, Endocem mineral trioxide aggregate, and theracal LC to resin composite using a universal adhesive: an: *in vitro*: study. Endodontology. 2020;32(1):14–9. https://doi.org/10.4103/endo.endo_7_19
25. Rajasekharan S, Martens LC, Cauwels RGEC, Anthonappa RP. Biodentine™ material characteristics and clinical applications: a 3year literature review and update. Eur Arch Paediatr Dent. 2018;19(1):1–22. https://doi.org/10.1007/s40368-018-0328-x
26. S.Kaup M, Schäfer E, Dammaschke T. An *in vitro* study of different material properties of Biodentinecompared to ProRoot MTA. Head Face Med. 2015;11(1):1–8. https://doi.org/10.1186/s13005-015-0074-9