## **Review Article**

DOI: https://dx.doi.org/10.18203/2394-6040.ijcmph20214303

# Biomimetic mechanical properties and its role in restorative dentistry

Thuraya Abdulrahim Basudan<sup>1\*</sup>, Wafa Mansour Alqahtani<sup>2</sup>, Fatimah Abdullah Almughalliq<sup>3</sup>, Atyaf Saeed Alshahrani<sup>4</sup>, Atheer Mubarak Aldawsari<sup>4</sup>, Atheer Ali Algouzi<sup>5</sup>, Anas Riyadh Hamdoon<sup>6</sup>, Abdulaziz Saleh Alkarim<sup>7</sup>, Amal Abdulrahman Al Shalwan<sup>4</sup>, Ghadah Hamid Alhuzili<sup>8</sup>, Nusaybah Hamzah Maghrabi<sup>3</sup>

**Received:** 12 October 2021 **Accepted:** 27 October 2021

### \*Correspondence:

Dr. Thuraya Abdulrahim Basudan, E-mail: tbasudan@moh.gov.sa

**Copyright:** © the author(s), publisher and licensee Medip Academy. This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License, which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

## **ABSTRACT**

The main aim of introducing biomimetic materials is to achieve successful remineralization using biocompatible and optimally functioning materials that can be used to manage diseased and defective tissues in a minimally invasive process. Recently, evidence shows that many biomimetics was introduced with excellent advantages and favorable outcomes in the different fields of dentistry. A wide acceptance of biomimetics was reported in the field of dentistry as the modalities were efficaciously applied in the different endodontic and restorative procedures. In the present literature review, we have discussed the biomimetic mechanical characteristics of the different restoration materials that are currently used in the field of restorative dentistry. The current evidence supports the use and applications for biomimetics in the field of restorative dentistry based on the extensively reported evidence regarding the mechanical and functional characteristics of these modalities which mimic the functions of normal teeth. Accordingly, these modalities can be used to solve the underlying clinical challenges that are routinely faced in the settings of restoration. Furthermore, different materials were introduced and evaluated for their efficacies, and the clinical decision of these materials is based on many factors and should be taken based on dentist-and-patient interaction.

Keywords: Restoration, Biomemetics, Biocompatability, Dentistry, Dental resin composites, Glass-ionomer cermics

## INTRODUCTION

Biomimetics was successfully introduced within the different fields, including the field of dentistry. The main aim of introducing these materials is to achieve successful remineralization using biocompatible and optimally functioning materials that can be used to manage diseased and defective tissues in a minimally invasive process.

Recently, evidence showed that many biomimetics was introduced with excellent advantages and favorable outcomes in the different fields of dentistry.

Among these, bioactive glasses, casein phosphate, mineral trioxide, tricalcium phosphate, nano-and microhydroxyapatite were introduced as effective remineralization, biocompatibility, bioactivity, and biomimicry potentials.<sup>1,2</sup>

<sup>&</sup>lt;sup>1</sup>Department of Restorative Dentistry, East Jeddah Hospital, Jeddah, Saudi Arabia

<sup>&</sup>lt;sup>2</sup>General Dentist, Minsitry of Health, Abha, Saudi Arabia

<sup>&</sup>lt;sup>3</sup>College of Dentistry, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia

<sup>&</sup>lt;sup>4</sup>College of Dentistry, King Khalid University, Abha, Saudi Arabia

<sup>&</sup>lt;sup>5</sup>General Dentist, Garden Clinics, Abha, Saudi Arabia

<sup>&</sup>lt;sup>6</sup>College of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia

<sup>&</sup>lt;sup>7</sup>General Dentist, King Abdulaziz University Hospital, Jeddah, Saudi Arabia

<sup>&</sup>lt;sup>8</sup>College of Dentistry, Umm Al-Qura University, Mecca, Saudi Arabia

A wide acceptance of biomimetics was reported in the field of dentistry as the modalities were efficaciously applied in the different endodontic and restorative procedures.<sup>3,4</sup> Many previous investigations have validated the efficacy of these modalities and compared them to the naturally occurring dental tissues to adequately provide more understanding of their abilities and roles in the different settings, including restorative dentistry.<sup>5-7</sup> In the present study, we aim to provide evidence regarding the biomimetic mechanical properties of the different restoration materials.

#### **METHODS**

This literature review was based on an extensive literature search in Medline, Cochrane, and EMBASE databases on which was performed 2<sup>nd</sup> October 2021 using the medical subject headings (MeSH) or a combination of all possible related terms, according to the database. To avoid missing poetential studies, a further manual search for papers was done through Google Scholar, while the reference lists of the initially included papers. Studies discussing the biomimetic mechanical properties of restoration materials were screened for useful information, with no limitations posed on date, language, age of participants, or publication type.

#### DISCUSSION

In the field of dentistry, particularly within the settings of dentistry and endodontics, restorative biomimetic mechanical properties has been an area of interest to researchers within this field which, accordingly, has continuously generated updated evidence regarding the different perspectives of these modalities. In the field of restorative dentistry, biomimetic approaches were mainly conducted to processing the different restoration properties using the different materials by making them similar to the naturally-occurring oral environment and function at a similar efficacy. At the molecular level, evidence also shows that these modalities were efficaciously applied for hard-and other purposes, including soft-tissue regeneration, and wound healing augmentation.<sup>8,9</sup> Accordingly, evidence demonstrates that different biomimetic restorative materials can be used in the different restorative dentistry approaches, including the aesthetic, structural, and biomechanical compatibility of these materials within a macrostructural level. In this context, it has been demonstrated in the various relevant investigations in the literature that natural teeth are generally used for manufacturing and validation of biomimetics to obtain materials that function at the same efficacy as the normal human teeth with well-adapted properties.

Based on the various advances in the field of developing biomimetic restorative materials, many innovative approaches were introduced to the literature to maintain more teeth preservation and conservation. Adequate respect should also be given to the different proposed biomimetic principles to maintain favorable outcomes regarding restoration. Some of these factors include the position of the targeted tooth within the arch, anatomy, and mechanics of the different intra-coronal relevant structures, shades, and hues.<sup>10</sup>

Based on the aesthetic requirements and severity of the underlying damage, it has been demonstrated that glassionomer cement, dental ceramics, and resin dental composites can be used to achieve such restoration outcomes. Evidence shows that most of these materials can adequately replace significant tooth damage and mimic the naturally occurring dentin and enamel. Moreover, the authors also indicate that resin dental composites can be used to restore moderate damage. In this context, the pulp is usually minimally prepared, which has been reported with many advantages regarding the less frequent teeth fractures due to the reduced pulp involvement. A low configuration factor was also reported for these materials in the context of maintaining and strengthening the remaining tooth structures. In

In another context, bonded porcelain restorations are recommended in cases of severe teeth damage.11 High compressive strength, good wear behavior, and fracture resistance were also reported for the use of alumina ceramics in the field of dentistry. It has been furtherly reported that using nano-hydroxyapatite can also achieve favorable restoration outcomes because it has great biocompatibility similar to the natural components of the bones and teeth. Many characteristics were also reported for using glass-ionomer cement, being efficaciously bactericidal, in addition to having similar satisfying characteristics to dentin, and therefore, they have been reported to be efficacious biomimetics. These materials have been reported to be widely used across the different restoration approaches. However, they are not generally approached in the field of load-bearing posterior dentition as a result of the underlying poor tensile strength.<sup>13</sup>

Many investigations have aimed to predict the clinical performance of the different biomimetic materials by evaluating the surface hardness and elastic modulus of these materials. 14-20 Evidence shows that the latter perspective is used to properly evaluate the stiffness of the different restoration materials, as it gives a clear picture of the intrinsic features of the approached materials. Studies also show that the elastic modulus of the different restoration materials might significantly mismatch with the characteristics of the natural dentin and tooth structure. However, further investigations also demonstrated that some restoration materials can survive for up to 12 years, according to previous clinical investigations.<sup>21,22</sup> Compared to dental resin composites, dentin, and enamel, glass-ionomer ceramic materials usually exhibit a reduced elastic modulus. Accordingly, it has been demonstrated that the clinical performance of the glass-ionomer ceramic materials is not likely to be longer than the aforementioned modalities due to of the

poor mechanical properties when restoring load-bearing areas, like the subsequent surface wear and brittleness. On the other hand, other advantages were reported for using glass-ionomer ceramic materials across the different studies in the literature. Some of these include the well-established chemical bonding with teeth, the anti-coagulant properties, and being able to release fluoride adequately. Accordingly, it has been indicated that these materials are mainly used for the restoration of small cavities, being used as luting modalities for cementing bridges and crowns, in addition to being used as cavity liners, particularly in the settings of deciduous dentition.

Evidence also shows that the recent advances in indirect restoration materials show that the different characteristics of these materials, including thermal expansion, hardness, and elastic modulus are similar to the characteristics of enamel. Accordingly, it has been evidenced that ceramic veneers can successfully be used in the settings of anterior teeth restoration approaches due to of the potential uniform disruption of the underlying stressors on these materials. It has been furtherly demonstrated that ceramic laminates can be additionally applied with favorable outcomes as a result of their aesthetic perspectives, in addition to fulfilling the different mechanical considerations. Another advantage for the biomimetic materials that were reported among the studies in the literature includes the relevancy of the different surface features to the real environmental dental ones, and to the previously discussed intrinsic properties. In this context, it has been demonstrated that the different restoration materials should be assessed using surface hardness, which can be used to evaluate the resistance of these materials to the prognostic surface indentation. This can furtherly be used in the settings of predicting polishing abilities, and abrasion resistance of the different restoration materials when applied within the oral environment.26

It has been recommended that the surface hardness of the restoration materials and the hardness of the enamel surfaces should be closely similar to each other to obtain better outcomes. This has been suggested because the external surfaces of the used restoration materials are extensively exposed to the moist atmosphere and masticatory forces. Accordingly, studies show that estimated low surface hardness of the approached restoration materials might be an indicator for the development of abrasions, which might subsequently lead to porosity and surface wear formation, in addition to restoration failure. 27-29 The estimated surface hardness for the dentin and enamel was reported to range between 0.71 to 0.92 and 2.23 to 7.18 GPa, indicating that the enamel is composed of extensive hard tissue.<sup>30</sup> On the other hand, when the different restoration materials were compared to the dentin and enamel in terms of surface hardness, it has been demonstrated that the estimated concept for the direct resin composite and glass-ionomer cement materials are remarkably lower than the naturally occurring concepts of the dentin and enamel of the normal teeth. Accordingly, it has been demonstrated that restoration failure and denture wear are more frequently observed with these materials. On the other hand, evidence also shows that the limits of surface hardness for dental ceramics and natural dentin are comparable. Previous studies also showed that failure of restoration might also develop secondary to the development of dental caries which result from plaque accumulation on the rough surfaces of the approached restoration materials. Another proposed cause for restoration failure following the application of dental resin composite materials is the abundant presence of porosities on the surface of these materials, which can significantly lead to cracks propagation over the surfaces of these materials. 34

The aforementioned evidence suggests that using dental ceramic restorations might offer better outcomes than the use of the glass-ionomer ceramic restorations and the direct resin composite materials. However, the outcomes of the restoration processes are not always determined by the long-standing functionality of the applied restoration materials, and favoring a material over the other should be determined according to a discussion between the patient and the dentist. For instance, many factors should be considered in this context, including psychomotor skills, clinicians' knowledge and experience, magnitude and rate of masticatory forces, tooth location, restoration size, and Caries index.<sup>35</sup> In a previous investigation by Opdam et al the authors demonstrated that among 1955 dental resin composites, that were included in this study to be reviewed for their 10 years restoration survival abilities, 82.2% of these materials had successful restoration frequencies.<sup>36</sup> Another investigation in Canada also demonstrated that the estimated 12 years survival rate among 1695 two-surface direct resin composite materials was 86%. For glass-ionomer ceramic restoration, it has been estimated that the survival rate was 28% in a 15-years follow-up investigation.<sup>37</sup> In another context, ceramic veneer restorations were reported with higher survival rates, which were 94.4% and 93% at 12 and 10-11 years, respectively, following placement among these restoration materials as reported in these investigations.<sup>38,39</sup> Stoll et al furtherly demonstrated that a survival rate of 97% at 10 years from the installation was estimated for a total of 1588 inlay restoration or ceramic inlay materials that were evaluated in this investigation.<sup>40</sup> Accordingly, it can be concluded that the different ceramics and dental resin composite restoration materials have promising biomimetic efficacies being able to function at similar effectiveness to the natural teeth. Other considerations that should be taken care of when studying biomimetic materials are the aesthetic and biocompatibility perspectives of these materials.

Evidence indicates that different restorative materials have dealt with the various esthetic issues that were previously reported among the different settings following restoration approaches. For instance, reduced discoloration, misaligned teeth and diastema, and pegshaped lateral incisors were reported following restorations with dental resin composite materials. This has been indicated among various investigations. Greengler et al estimated that 93% of the used dental resin composite material restorations were associated with satisfactory coloring matches with the adjacent teeth when followed up at 10 years.<sup>41</sup>

A similar rate of 94% was also reported at 17 years of follow-up for the same materials in a previous investigation by Wilder et al.<sup>42</sup> On the other hand, glassionomer ceramic restorations are associated with nonfavorable esthetic outcomes, and therefore, these materials are not recommended for anterior teeth restoration.<sup>7,43</sup> Biocompatibility of the restoration materials was also adequately investigated and the evidence confirms that direct resin composite materials are associated with the least frequency of toxicity that was also observed to reduce following their installation. Therefore, dentists should choose the best material based on the severity and area of tooth damage, in addition to taking adequate care of the patient's concerns.7,44,45

### **CONCLUSION**

The current evidence supports the use and applications for biomimetics in the field of restorative dentistry based on the extensively reported evidence regarding the mechanical and functional characteristics of these modalities which mimic the functions of normal teeth. Accordingly, these modalities can be used to solve the underlying clinical challenges that are routinely faced in the settings of restoration. Furthermore, different materials were introduced and evaluated for their efficacies and the clinical decision of these materials is based on many factors and should be taken based on dentist-and-patient interaction.

Funding: No funding sources Conflict of interest: None declared Ethical approval: Not required

## REFERENCES

- 1. Donnermeyer D, Bürklein S, Dammaschke T, Schäfer E. Endodontic sealers based on calcium silicates: a systematic review. Odontology. 2019;107(4):421-36.
- 2. Sanz JL, Lozano FJ, Llena C, Sauro S, Forner L. Bioactivity of Bioceramic Materials Used in the Dentin-Pulp Complex Therapy: A Systematic Review. Materials (Basel). 2019;12(7):1015.
- 3. Bazos P, Magne P. Bio-emulation: biomimetically emulating nature utilizing a histo-anatomic approach; structural analysis. Eur J Esthet Dent. 2011;6(1):8-19.
- 4. Tirlet G, Crescenzo H, Crescenzo D, Bazos P. Ceramic adhesive restorations and biomimetic

- dentistry: tissue preservation and adhesion. Int J Esthet Dent. 2014;9(3):354-69.
- 5. Murray PE, Godoy F, Hargreaves KM. Regenerative endodontics: a review of current status and a call for action. J Endod. 2007;33(4):377-90.
- 6. Bottino MC, Kamocki K, Yassen GH, Platt JA, Vail MM, Ehrlich Y, et al. Bioactive nanofibrous scaffolds for regenerative endodontics. J Dent Res. 2013;92(11):963-9.
- 7. Zafar MS, Amin F, Fareed MA, Ghabbani H, Riaz S, Khurshid Z, Kumar N. Biomimetic Aspects of Restorative Dentistry Biomaterials. Biomimetics (Basel). 2020;5(3):34.
- 8. Mann S. The biomimetics of enamel: a paradigm for organized biomaterials synthesis. Ciba Foundation symposium. 1997;205:261-9.
- 9. Slavkin HC. Biomimetics: replacing body parts is no longer science fiction. J Am Dent Assoc. 1996;127(8):1254-7.
- 10. Magne P, Belser U. Bonded porcelain restorations in the anterior dentition: a biomimetic approach. London: Quintessence publishing company; 2002.
- 11. Magne P. Composite resins and bonded porcelain: the postamalgam era?. J California Dent Assoc. 2006;34(2):135-47.
- 12. Morin D, DeLong R, Douglas WH. Cusp reinforcement by the acid-etch technique. J Dent Res. 1984;63(8):1075-8.
- 13. Mount GJ. An atlas of glass-ionomer cements: a clinician's guide. India: CRC Press; 2001.
- 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.
- 15. Chung SM, Yap AU, Tsai KT, Yap FL. Elastic modulus of resin-based dental restorative materials: a microindentation approach. J Biomed Mater Res B Appl Biomater. 2005;72(2):246-53.
- 16. Boaro LC, Gonçalves F, Guimarães TC, Ferracane JL, Versluis A, Braga RR. Polymerization stress, shrinkage and elastic modulus of current low-shrinkage restorative composites. Dent Mater. 2010;26(12):1144-50.
- 17. Trindade FZ, Valandro LF, Jager N, Bottino MA, Kleverlaan CJ. Elastic Properties of Lithium Disilicate Versus Feldspathic Inlays: Effect on the Bonding by 3D Finite Element Analysis. J Prosthodont. 2018;27(8):741-7.
- 18. Keogh P, Ray NJ, Lynch CD, Burke FM, Hannigan A. Surface microhardness of a resin composite exposed to a "first-generation" LED curing lamp, in vitro. Eur J Prosthodont Restor Dent. 2004;12(4):177-80.
- Bala O, Arisu HD, Yikilgan I, Arslan S, Gullu A. Evaluation of surface roughness and hardness of different glass ionomer cements. Eur J Dent. 2012;6(1):79-86.
- 20. Abed Y, Sabry H, Alrobeigy N. Degree of conversion and surface hardness of bulk-fill

- composite versus incremental-fill composite. Tanta Dent J. 2015;12(2):71-80.
- 21. Zafar MS. A comparison of dental restorative materials and mineralized dental tissues for surface nanomechanical properties. Life Sci J. 2014;11(10):19-24.
- 22. Jones DW, Rizkalla AS. Characterization of experimental composite biomaterials. J Biomed Mater Res. 1996;33(2):89-100.
- 23. Ilie N, Hickel R, Valceanu AS, Huth KC. Fracture toughness of dental restorative materials. Clin Oral Investig. 2012;16(2):489-98.
- 24. Mount GJ. Buonocore Memorial Lecture. Glassionomer cements: past, present and future. Oper Dent. 1994;19(3):82-90.
- 25. Naasan MA, Watson TF. Conventional glass ionomers as posterior restorations. A status report for the American Journal of Dentistry. Am J Dent. 1998;11(1):36-45.
- 26. Pereira LC, Nunes MC, Dibb RG, Powers JM, Roulet JF, Navarro MF. Mechanical properties and bond strength of glass-ionomer cements. J Adhes Dent. 2002;4(1):73-80.
- 27. Bonifácio CC, Kleverlaan CJ, Raggio DP, Werner A, Carvalho RC, Amerongen WE. Physical-mechanical properties of glass ionomer cements indicated for atraumatic restorative treatment. Aust Dent J. 2009;54(3):233-7.
- 28. Zimehl R, Hannig M. Non-metallic restorative materials based on glass ionomer cements—recent trends and developments. Colloids Surf A: Physicochem Eng Aspec. 2000;163(1):55-62.
- 29. McCabe JF, Walls AW. Applied dental materials. 9th ed. John Wiley and Sons; 2013.
- 30. Mahoney E, Holt A, Swain M, Kilpatrick N. The hardness and modulus of elasticity of primary molar teeth: an ultra-micro-indentation study. J Dent. 2000;28(8):589-94.
- 31. Beyth N, Bahir R, Matalon S, Domb AJ, Weiss EI. Streptococcus mutans biofilm changes surface-topography of resin composites. Dent Mater. 2008;24(6):732-6.
- 32. Svanberg M, Mjör IA, Orstavik D. Mutans streptococci in plaque from margins of amalgam, composite, and glass-ionomer restorations. J Dent Res. 1990;69(3):861-4.
- 33. Pedrini D, Jardim Júnior E, Vasconcelos AC. Retention of oral microorganisms on conventional and resin-modified glass-ionomer cements. Pesqui Odontol Bras. 2001;15(3):196-200.
- 34. Baran G, Boberick K, McCool J. Fatigue of restorative materials. Crit Rev Oral Biol Med. 2001;12(4):350-60.

- 35. Alamoush RA, Silikas N, Salim NA, Nasrawi S, Satterthwaite JD. Effect of the Composition of CAD/CAM Composite Blocks on Mechanical Properties. Biomed Res Int. 2018;2018;4893143.
- 36. Opdam NJ, Bronkhorst EM, Roeters JM, Loomans BA. A retrospective clinical study on longevity of posterior composite and amalgam restorations. Dent Mater. 2007;23(1):2-8.
- 37. Burke FJT, Lucarotti PSK. The ultimate guide to restoration longevity in England and Wales. Part 3: Glass ionomer restorations time to next intervention and to extraction of the restored tooth. Br Dent J. 2018;224(11):865-74.
- 38. Layton D, Walton T. An up to 16-year prospective study of 304 porcelain veneers. Int J Prosthodont. 2007;20(4):389-96.
- 39. Fradeani M, Redemagni M, Corrado M. Porcelain laminate veneers: 6- to 12-year clinical evaluation--a retrospective study. Int J Periodontics Restorative Dent. 2005;25(1):9-17.
- Stoll R, Cappel I, Momeni A, Pieper K, Stachniss V. Survival of inlays and partial crowns made of IPS empress after a 10-year observation period and in relation to various treatment parameters. Oper Dent. 2007;32(6):556-63.
- 41. Gaengler P, Hoyer I, Montag R. Clinical evaluation of posterior composite restorations: the 10-year report. J Adhes Dent. 2001;3(2):185-94.
- 42. Wilder AD, May KN, Bayne SC, Taylor DF, Leinfelder KF. Seventeen-year clinical study of ultraviolet-cured posterior composite Class I and II restorations. J Esthet Dent. 1999;11(3):135-42.
- 43. Piotrowski BT, Gillette WB, Hancock EB. Examining the prevalence and characteristics of abfractionlike cervical lesions in a population of U.S. veterans. J Am Dent Assoc. 2001;132(12):1694-701.
- 44. Mohanty M, Govind S, Behera R. Biomimetic Materials in Restorative Dentistry and Endodontics—A Review. Indian J Forensic Med Toxicol. 2021;15(2).
- 45. Basheer N, Madhubala M, Sekar M. Future Perspectives of Biomimetics in Restorative Dentistry. J Pharmaceut Res Int. 2020;19-28.

Cite this article as: Basudan TA, Alqahtani WM, Almughalliq FA, Alshahrani AS, Aldawsari AM, Algouzi AA, et al. Biomimetic mechanical properties and its role in restorative dentistry. Int J Community Med Public Health 2021;8:5598-602.