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Nano Glass Ionomer Cement- A Review

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KEYWORDS

Nanodentistry, Dental restorative materials, Nano glass ionomer cements, Biocompatibility, Glass ionomer cements.

ABSTRACT:

Glass ionomer cements are tooth coloured materials that bond chemically to dental hard tissues. It has aesthetic qualities along with specific adhesion to enamel and dentin. Incorporation of nanoparticles into glass powder of glass ionomers led to wider particle size distribution which resulted in higher mechanical values. Its bonding mechanism should be attributed to micro-mechanical locking provided by the surface roughness. Enhancing mechanical properties adds to serviceability and shelf-life of restorative materials. The bioactive hydroxyapatite and fluorapatite were incorporated into resin composites and glass ionomers. Cumulative F-release decreases when the microgranular glass particles with fluoride are replaced by nanogranular glass particles with fluoride. It is important to remove all the remnants of the linings of the pathological lesion or will be very careful in inspecting its margins after removing it. Addition of chlorhexidine along with nano GIC is done due to antibacterial properties. The review article concludes that nano-glass ionomer cement has properties that were deficient in glass ionomer cement.

INTRODUCTION

Dental caries provide a link or adhesive between a restoration and prepared tooth, bonding them together through some form of surface attachment (1). The cementing agent's primary requirement is to hold a restoration in place for an indefinite period of time and maintain a seal between restoration and tooth (2). Dental cements are brittle materials when hardened and are often formed by mixing powder and liquid together. They can be resin-based or acid-based cements. The ideal requirements of a cement that is yet to be discovered are not harmful to tooth or surrounding tissue, allows sufficient working time to place the restoration, fluid enough to allow complete seating of restoration, intact restoration (3). Glass ionomer cement was invented by wilson and kent in 1970 (4). They are water based cements known as polyalkenoate cements (4). Its generic name is based on the reactions between silicate glass and polyacrylic acid and also the formation arises from an acid-base reaction between the components (5). The extensive use of glass ionomer cements as a filling material in stress bearing areas is limited by their poor mechanical properties (6). Due to their ability to modify the physical properties by changing the powder liquid ratio or their chemical formulation they could be used in a wide range of clinical applications (7). In the posterior dental region they are mostly used as a temporary filling material (8). Nanotechnology is manipulating matter on molecular and atomic levels which has potential for enormous changes in the field of medicine and dentistry. The concept of nanotechnology was first elaborated in 1959 by Richard feynmann. Nanomaterials are materials with components less than 100nm in at least one dimension (9). Nanotechnology has application in many fields like medicine, diagnostics, drug delivery, tissue engineering, dentistry (10). With the growing research on nanotechnology and its use in day to day life, a day may come where nanodentistry will succeed in maintaining perfect oral health (11). The incorporation of nanoparticles' average particle size of glass ionomers led to wider particle distribution, which resulted in higher mechanical values. They can occupy the empty spaces between glass ionomer particles and act as reinforcing material in composition of glass ionomer cements (12). The nanofiller components of nano ionomer cements enhance physical properties of hardened restoration (13). Nano light curing glass ionomer restorative blends nanotechnology. The most important advantages of glass ionomer cement is excellent aesthetics, superb

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polish and improved wear resistance. Appropriate treatment can prevent long-term damage to the internal structures and save the teeth (14) and also the efficiency of the diagnostic aids plays an important role in the treatment plan (15).

Glass Ionomer Cements and its types

Glass ionomer cements are tooth coloured materials bound chemically to dental hard tissues (16). It prevents secondary caries due to its prolonged fluoride release (17). The important property of glass ionomer cements is margin adaptation and leakage. It has specific adhesion to enamel and dentin coupled with aesthetic qualities (18). Glass ionomer cements are self-hardening cements (19). Bacteria play a major role in the formation and progression of pulpal and periapical diseases so Glass ionomer cements are more preferred in clinical dentistry due to their ability to release fluoride and prevent secondary caries, biocompatibility, chemical adhesion to dentin and enamel, coefficient of thermal expansion is similar to that of tooth structure and versatility (20)(21). Glass ionomer cements components, when mixed together, undergo a setting reaction involving neutralization of the acid groups by the powdered solid glass base (22). Glass composition of glass ionomer cements contains silica, alumina, fluoride and liquid composition of glass ionomer cements contains polyacrylic acid, itaconic acid, maleic acid and tartaric acid. The setting time of glass ionomer cement is 3-5 minutes and the manipulation of glass ionomer cement is done using plastic spatula along with a paper pad (23). Powder liquid ratio is 1.5:1 and mixing time is 45 seconds. Types of glass ionomer cements are
Type I- luting
Type II- restoration
Type III- base/ liner
Type IV- filling pits and fissure sealants
Type V- luting orthodontic purposes
Type VI- core buildup purposes
Type VII- High fluoride releasing command set
Type VIII- ART (atraumatic restorative treatment)
Type IX- pediatric glass ionomer cement

The clinical indications are primary restorations, transition restorations, small class I restorations, sandwich restorations, class III and IV restorations and also core build up (24). Recent studies have suggested that incorporation of nanosized particles or clusters can improve the mechanical properties of dental restorative materials (25). In reference to (23), the results show that increased resistance to fracture and improved reliability in strength irrespective of environmental conditions. GIC requires a conservative preparation with a sound remaining dentin thickness (26). Conventional glass ionomer cements can be used to seal the calcified tooth (27).

Nanotechnology

It is defined as the science and engineering involved in design and synthesis characteristics and application of materials and devices whose smallest functional organization in at least one dimension is on the nanometer scale or one billionth of a meter (28). Nanotechnology gives rise to better dental materials and improved oral health related diagnostic materials. Nanotechnology has inherent excellent potential to give newer era materials and techniques but public acceptance, human safety and legal regulations must be adequately tackled before it flourish its advantages in dental care.

Nano glass ionomer cements

Nanosized particles or nanodusters improve mechanical properties of dental restorative material such as glass ionomer cements or resin composites. Production of nanosized particles for incorporation to glass ionomer cements mainly carried through nanofabrication of bulk materials such as apatite silicate glasses and some metal oxide (29). Conventional glass ionomer cements with nano sized glass particles decrease setting time and enhance the compression strength and elastic modulus (30). The main advantages are decreasing the setting time and enhanced ease of handling and manipulation. Enhancing mechanical properties adds to serviceability and shelf-life of restorative materials as they are able to withstand masticatory and occlusal forces more efficiently (31). In reference to (31), the results show that the introduction of nano-sized apatites, have not only improved the mechanical properties of conventional GICs, but have also enhanced fluoride release in vitro by increasing the crystallinity of the set matrix, apatite crystals can make the set cement more stable and improve the bond strength with tooth structure and increased fluoride content can reduce secondary caries in restorations. Powder modified glass ionomer cements which involves doping powder glass ionomer cement with nanoparticles which decreases setting time and enhances compression strength and elastic modulus (32). In reference to (32), HA/ZrO2-

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filled glass ionomer cement composites were found to have improved biocompatibility and bioactivity.

Nanohydroxyapatite and glass ionomers cements

Various studies have investigated the mechanical character, microleakage and mineralizing potential of nano-hydroxyapatite (nano-HAP)-added glass ionomer cement (33)(34)The bioactive hydroxyapatite and fluorapatite was incorporated into resin composites and glass ionomers (35). The addition of nano-HAp (nHAp) and nano-FAp (nFAp) to the GIC powder resulted in significantly improved flexural, tensile, and compressive strengths of GIC. 8% nano-HAP incorporated into GIC as composite, and pure GIC as control. It was achieved that 8% nano-HAP-added GIC tightly fills the tooth, has mineralizing potential and can be used as liner or filling material for prevention.Micro-hydroxyapatite and nano-hydroxyapatite were added to self cured resin modified glass ionomer cement and modified glass ionomer cement. The difference in resistance to demineralization and bonding strength was evaluated. RelyX is used as the base glass ionomer cement material and also used for control groups. The results indicate that nano-hydroxyapatite added to glass ionomer cement exhibited increased resistance to demineralization when compared to glass ionomer cement composed of macro-hydroxyapatite (36). Dental avulsions lead to complete displacement of the tooth from its socket in the alveolar bone but it could be fixed using nano hydroxyapatite due to its mineralization potential property (37) but the interaction between chlorhexidine (CHX) and sodium hypochlorite (NaOCl) yields a thick precipitate capable of occluding dentinal tubules (38).

Antimicrobial Activity of Nano Glass Ionomer Cement

In dentistry, antimicrobial activity of a wide range of cements with different applications is relevant. Antibacterial activity of dental luting cements is a very important property for applying dental crowns, bridges, inlays, onlays, or veneers (39) because bacteria is present on the walls of preparation and gain access to the cavity due to microleakage after cementation**.** Among the dental restorative materials, glass ionomer cements (GICs) are found to be cariostatic and antibacterial due to release of fluoride (40). In Reference (41), antibacterial activity of three dental cements modified by nanosilver was evaluated : Sealapex, RelyX ARC, and Vitrebond. The cement was incorporated with 0.05mL of silver nanoparticles solution.It is imperative to assess the nanosilver for potential teratogenic effects on humans. There can be loss of tooth structure due to bacterial damage (42). It is important to remove all the remnants of the linings of the pathological lesion or will be very careful in inspecting its margins after removing it (43). Addition of chlorhexidine along with nano GIC may enhance the antibacterial properties (44).

Powder-based nano modification of glass ionomer cements

The size of glass powder is altered to change the mechanical and physical properties of GICs. In study, it demonstrated the effect of introducing nanosized glass powder on the setting characteristics and mechanical properties of GIC. Addition of nanosized fluoroaluminosilicate glass decreased the setting time and also improved the mechanical properties of the GIC. There are a number of procedures used to replicate the detrimental effect of oral environment on the restorative materials. It is observed that thermocycling has a more negative impact on the mechanical properties of nanomodified materials than those of conventional ionomers. Over the past few years there have been several modifications aimed to increase the mechanical, physical, biological, and optical properties of GICs. Nanomodification of GICs mainly involves the incorporation of nanosized fillers to the powder component. In a study by De Caluwe, it was observed that combining nano granular glass and macro granular glass with different compositions of glass ionomer cement improved the mechanical and physical properties of glass ionomer cement.The results showed that the setting time of GIC decreases when macro granular glass particles were replaced by nano granular glass particles.The compressive strength and Young's modulus measured after 24hours of setting was increased. The effect is more pronounced when the nanogranular glass particles contain fluoride. After thermocycling, it was observed that the compressive strength decreased for many formulations and most of the effect was pronounced for cements containing nanogranular glass particles. Hence, the strength of the GIC seems mainly determined by the microgranular glass particles. Cumulative Fluoride release decreases when the microgranular glass particles with fluoride are replaced by nanogranular glass particles without fluoride (25).

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Glass ionomer cements modified with other nanoparticles

Zirconia (zirconium oxide, ZrO_2) is a ceramic which has been used in dentistry for the production of crowns (45), dentures, and dental implants (46). A study by Gu (32) evaluated the effect on the mechanical properties of incorporating nanosized HAp and zirconia (nZrO_2) to conventional GIC. In the study, it was observed that the addition of nHAp and nZrO_2 at a concentration of 4% by volume resulted in significant improvement in the mechanical properties of the cement. Nevertheless, in the same study, when scanning electron micrographs of conventional set GIC and set nHAp/nZrO_2- modified GIC were compared, more cracks were observed in the latter (27). This could have a detrimental effect on the long-term viability of these modified cements, because the cracks may lead to marginal failure and subsequent failure of the restorations. Other nanosized particles, such as calcium fluoride (CaF_2) and titania (titanium oxide; TiO_2), have also been used to modify GICs (47). Addition of CaF_2 to resin-modified GICs (RMGICs) may prolong the longevity of these cements by improving the mechanical properties, but it may also have an adverse effect on fluoride release from the cement. Although nano-TiO_2 (nTiO_2) has been observed to improve the mechanical properties and enhance the antibacterial attributes of GICs, more studies are required to determine the safety of these modified restorations, because titania is known to be cytotoxic (48). Nanoparticles of chitosan, a deacylated form of chitin, a polysaccharide found in shells of crustaceans, have been observed to improve the flexural strength of GICs significantly due to increased interaction between the chitosan chains and the GIC matrix

Nanomodified resin-modified glass ionomer cements

To improve the mechanical properties of GICs, they may be combined with a self-curing or light-activated resin polymer. These RMGICs are less susceptible to flexural fractures and expansion due to water sorption and have better esthetics (49). However, RMGICs still have some disadvantages. First, they have inferior mechanical properties when compared to resin composites (50). Moreover, they have higher creep and lower fluoride release when compared to conventional GICs. Nanoclusters of silica have been incorporated to powder formulation of RMGICs to improve the mechanical properties and fluoride release from the set cement (51). RMGICs are supplied with a primer which aids in bonding of tooth structure. RMGICs bond to the tooth structure through a combination of micromechanical interactions due to the infiltration of resins into the etched tooth surface and ionic bonding between the HAp crystals present in the tooth and the acids RMGICs. The nanofillers for RMGICs increase the infiltration of resin into the pores in the etched tooth surface and enhance the binding. However, studies indicate that there is no significant difference between the tensile bond strength of nanoRMGICs and conventional GIC (51). Abrasion produced by toothbrush stimulates less surface roughness on the surface of nano-RMGICs when compared to conventional RMGICs (52).

Comparative studies on properties of Nano Glass Ionomer Cement

Most of the restorations maintained good quality during the observation period, which was considered a short material may be used with confidence in Class V carious lesions. A longer evaluation period may be recommended to decide the use of restorative material safely in Class V cavities. In reference (53), Sayyedan proved that higher mechanical properties could be achieved by addition of forsterite (Mg_2SiO_4) nanoparticles to ceramic parts of GIC. In reference to (35), moshaverinia aimed to enhance the mechanical strength of glass ionomer cements, while preserving their unique clinical properties by characterising, synthesizing and incorporation into a formulation of Fuji II commercial GIC a N-vinylpyrrolidone (NVP) containing polymer, nano-hydroxy and fluorapatite (nano-HA and FA). The mechanical properties of the resulting cements were evaluated and it was shown that these materials are promising additives for glass-ionomer restorative dental materials. This study showed that addition of NVP, nano-HA and FA into glass-ionomer cements had the ability to enhance the mechanical strength compared to the unmodified cement. The effect of nanoparticles on mechanical properties of GIC was more impressive than addition of NVP modified polyacrylic acid to GIC. Some bioactive restorative material can cause postoperative sensitivity or pain (54–63)

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CONCLUSION

Advances in nanotechnology are paving the future of healthcare management and dental restorations.

Therefore it can be concluded that nano glass ionomer cements fulfills almost all deficient properties of glass ionomer cement. Nano glass ionomer cement must be preferably used in dentistry. There are very few studies focusing on the nano-modification of GIC that concentrate on effects they have on the pulpal cells. Hence, more mechanical, biological studies, and eventually, clinical trials are needed and essential to ascertain the status of nano-modified GICs in clinical practice.

REFERENCES

1. Wingo K. A Review of Dental Cements. J Vet Dent [Internet]. 2018 Mar 1;35(1):18–27. Available from: https://doi.org/10.1177/0898756418755339
2. Hill EE. Dental cements for definitive luting: a review and practical clinical considerations. Dent Clin North Am [Internet]. 2007 Jul;51(3):643–58, vi. Available from: http://dx.doi.org/10.1016/j.cden.2007.04.002
3. Craig RG. Craig's Restorative Dental Materials [Internet]. Mosby Elsevier; 2006. 632 p. Available from: https://play.google.com/store/books/details?id=EDFqAAAAMAAJ
4. Crisp S, Ferner AJ, Lewis BG, Wilson AD. Properties of improved glass-ionomer cement formulations. J Dent [Internet]. 1975 May;3(3):125–30. Available from: http://dx.doi.org/10.1016/0300-5712(75)90063-9
5. Yip HK, Tay FR, Ngo HC, Smales RJ, Pashley DH. Bonding of contemporary glass ionomer cements to dentin [Internet]. Vol. 17, Dental Materials. 2001. p. 456–70. Available from: http://dx.doi.org/10.1016/s0109-5641(01)00007-0
6. Xie D, Brantley WA, Culbertson BM, Wang G. Mechanical properties and microstructures of glass-ionomer cements. Dent Mater [Internet]. 2000 Mar;16(2):129–38. Available from: http://dx.doi.org/10.1016/s0109-5641(99)00093-7
7. Pelka M, Ebert J, Schneider H. Comparison of two-and three-body wear of glass-ionomers and composites. European journal of [Internet]. 1996; Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1600-0722.1996.tb00057.x
8. Hickel R, Manhart J, García-Godoy F. Clinical results and new developments of direct posterior restorations. Am J Dent [Internet]. 2000 Nov;13(Spec No):41D – 54D. Available from: https://www.ncbi.nlm.nih.gov/pubmed/11763918
9. Sharma S, Bansal A, Sachdev P. Nanotechnology-the Era Of Molecular Dentistry. Indian journal of [Internet]. 2011; Available from: http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=09764003&asa=Y&AN=69719188&h=QLIPVUYzULC9NIkikcQY0EIbRAvMgp1xlOhNQrJNyL7sXzQGbUvOibR9JevL9nFoMT6btdHECaZ9ZF2M5Lxjsw%3D%3D&crl=c
10. Kanaparthy R, Kanaparthy A. The changing face of dentistry: nanotechnology. Int J Nanomedicine [Internet]. 2011 Nov 9;6:2799–804. Available from: http://dx.doi.org/10.2147/IJN.S24353
11. Bhardwaj A, Bhardwaj A, Misuriya A, Maroli S, Manjula S, Singh AK. Nanotechnology in dentistry: Present and future. J Int Oral Health [Internet]. 2014 Feb;6(1):121–6. Available from: https://www.ncbi.nlm.nih.gov/pubmed/24653616
12. Moshaverinia A, Ansari S. Movasaghi z, Billington RW, Darr JA, Rehman Iu. Modification of conventional glass-ionomer cements with N-vinylpyrrolidone containing polyacids, nano-hydroxy and fluoroapatite to improve mechanical properties. Dent Mater J. 2008;24:1381–90.
13. Lyapina MG, Tzekova M, Dencheva M, Krasteva A, Yaneva-Deliverska M, Kisselova A. Nano-glass-ionomer cements in modern restorative dentistry. Journal of IMAB--Annual Proceeding Scientific Papers [Internet]. 2016;22(2):1160–5. Available from: https://www.journal-imab-bg.org/issues-2016/issue2/vol22issue2p1160-1165.html
14. Jose J, Subbaiyan H. Different Treatment Modalities followed by Dental Practitioners for Ellis Class 2 Fracture–A Questionnaire-based Survey. Open Dent J [Internet]. 2020; Available from: https://opendentistryjournal.com/VOLUME/14/PAGE/59/FULLTEXT/
15. Janani K, Palanivelu A, Sandhya R. Diagnostic accuracy of dental pulse oximeter with customized sensor holder, thermal test and electric pulp test for the evaluation of pulp vitality - An in vivo study [Internet]. Vol. 23, Brazilian Dental Science. 2020. Available from: http://dx.doi.org/10.14295/bds.2020.v23i1.1805
16. Cho SY, Cheng AC. A review of glass ionomer restorations in the primary dentition. J Can Dent Assoc [Internet]. 1999 Oct;65(9):491–5. Available from: https://www.ncbi.nlm.nih.gov/pubmed/10560209
17. Sarrett DC. Clinical challenges and the relevance of materials testing for posterior composite restorations. Dent Mater [Internet]. 2005 Jan;21(1):9–20. Available from: http://dx.doi.org/10.1016/j.dental.2004.10.001
18. Yip HK, Lam WT, Smales RJ. Fluoride release,

weight loss and erosive wear of modern aesthetic restoratives. Br Dent J [Internet]. 1999 Sep 11;187(5):265–70. Available from: http://dx.doi.org/10.1038/sj.bdj.4800256
19. Nicholson JW, Croll TP. Glass-ionomer cements in restorative dentistry. Quintessence Int [Internet]. 1997 Nov;28(11):705–14. Available from: https://www.ncbi.nlm.nih.gov/pubmed/9573860
20. Croll TP, Nicholson JW. Glass ionomer cements in pediatric dentistry: review of the literature. Pediatr Dent [Internet]. 2002 Sep;24(5):423–9. Available from: https://www.ncbi.nlm.nih.gov/pubmed/12412956
21. Manohar M, Sharma S. A survey of the knowledge, attitude, and awareness about the principal choice of intracanal medicaments among the general dental practitioners and nonendodontic specialists [Internet]. Vol. 29, Indian Journal of Dental Research. 2018. p. 716. Available from: http://dx.doi.org/10.4103/ijdr.ijdr_716_16
22. Berg MC, Benetti AR, Bordallo HN. Glass ionomer cements: Liquid dynamics in confinement [Internet]. Vol. 32, Dental Materials. 2016. p. e70. Available from: http://dx.doi.org/10.1016/j.dental.2016.08.146
23. Billington RW, Pearson GJ, Williams JA. Uptake of fluoride ions by the glass component of glass ionomer cement. J Dent [Internet]. 2007 May;35(5):452–5. Available from: http://dx.doi.org/10.1016/j.jdent.2006.11.008
24. Chandki R, Kala M, N. KK, Brigit B, Banthia P, Banthia R. NANODENTISTRY: Exploring the beauty of miniature [Internet]. Journal of Clinical and Experimental Dentistry. 2012. p. e119–24. Available from: http://dx.doi.org/10.4317/jced.50720
25. Curtis AR, Palin WM, Fleming GJP, Shortall ACC, Marquis PM. The mechanical properties of nanofilled resin-based composites: the impact of dry and wet cyclic pre-loading on bi-axial flexure strength. Dent Mater [Internet]. 2009 Feb;25(2):188–97. Available from: http://dx.doi.org/10.1016/j.dental.2008.06.003
26. Ramanathan S, Solete P. Cone-beam Computed Tomography Evaluation of Root Canal Preparation using Various Rotary Instruments: An in vitro Study [Internet]. Vol. 16, The Journal of Contemporary Dental Practice. 2015. p. 869–72. Available from: http://dx.doi.org/10.5005/jp-journals-10024-1773
27. Kumar D, Delphine Priscilla Antony S. Calcified Canal and Negotiation-A Review [Internet]. Vol. 11, Research Journal of Pharmacy and Technology. 2018. p. 3727. Available from: http://dx.doi.org/10.5958/0974-360x.2018.00683.2
28. Verma S, Chevvuri R, Sharma H. Nanotechnology in dentistry: Unleashing the hidden gems. J Indian Soc Periodontol [Internet]. 2018 May;22(3):196–200. Available from: http://dx.doi.org/10.4103/jisp.jisp_35_18
29. Khoroushi M, Keshani F. A review of glass-ionomers: From conventional glass-ionomer to bioactive glass-ionomer. Dent Res J [Internet]. 2013 Jul;10(4):411–20. Available from: https://www.ncbi.nlm.nih.gov/pubmed/24130573
30. Caluwé TD, De Caluwé T, Vercruysse CWJ, Fraeyman S, Verbeeck RMH. The influence of particle size and fluorine content of aluminosilicate glass on the glass ionomer cement properties [Internet]. Vol. 30, Dental Materials. 2014. p. 1029–38. Available from: http://dx.doi.org/10.1016/j.dental.2014.06.003
31. Najeeb S, Khurshid Z, Zafar MS, Khan AS, Zohaib S, Martí JMN, et al. Modifications in Glass Ionomer Cements: Nano-Sized Fillers and Bioactive Nanoceramics. Int J Mol Sci [Internet]. 2016 Jul 14;17(7). Available from: http://dx.doi.org/10.3390/ijms17071134
32. Gu YW, Yap AUJ, Cheang P, Khor KA. Effects of incorporation of HA/ZrO(2) into glass ionomer cement (GIC). Biomaterials [Internet]. 2005 Mar;26(7):713–20. Available from: http://dx.doi.org/10.1016/j.biomaterials.2004.03.019
33. Mu YB, Zang GX, Sun HC, Wang CK. Effect of nano-hydroxyapatite to glass ionomer cement. Hua Xi Kou Qiang Yi Xue Za Zhi [Internet]. 2007; Available from: https://europepmc.org/abstract/med/18306621
34. Rajendran R, Kunjusankaran RN, Sandhya R, Anilkumar A, Santhosh R, Patil SR. Comparative Evaluation of Remineralizing Potential of a Paste Containing Bioactive Glass and a Topical Cream Containing Casein Phosphopeptide-Amorphous Calcium Phosphate: An in Vitro Study. Pesqui Bras Odontopediatria Clin Integr [Internet]. 2019;19. Available from: http://www.scielo.br/scielo.php?pid=S1983-46322019000100364&script=sci_arttext
35. Moshaverinia A, Ansari S, Moshaverinia M, Roohpour N, Darr JA, Rehman I. Effects of incorporation of hydroxyapatite and fluoroapatite nanobioceramics into conventional glass ionomer cements (GIC) [Internet]. Vol. 4, Acta Biomaterialia. 2008. p. 432–40. Available from: http://dx.doi.org/10.1016/j.actbio.2007.07.011
36. Lee JJ, Lee YK, Choi BJ, Lee JH, Choi HJ, Son HK, et al. Physical Properties of Resin-Reinforced Glass Ionomer Cement Modified with Micro and Nano-Hydroxyapatite [Internet]. Vol. 10, Journal

of Nanoscience and Nanotechnology. 2010. p. 5270–6. Available from: http://dx.doi.org/10.1166/jnn.2010.2422
37. R R, Rajakeerthi R, Ms N. Natural Product as the Storage medium for an avulsed tooth – A Systematic Review [Internet]. Vol. 22, Cumhuriyet Dental Journal. 2019. p. 249–56. Available from: http://dx.doi.org/10.7126/cumudj.525182
38. Siddique R, Sureshbabu NM, Somasundaram J, Jacob B, Selvam D. Qualitative and quantitative analysis of precipitate formation following interaction of chlorhexidine with sodium hypochlorite, neem, and tulsi. J Conserv Dent [Internet]. 2019 Jan;22(1):40–7. Available from: http://dx.doi.org/10.4103/JCD.JCD_284_18
39. Ravinthar K, Others. Recent Advancements in Laminates and Veneers in Dentistry. Research Journal of Pharmacy and Technology [Internet]. 2018;11(2):785–7. Available from: http://www.indianjournals.com/ijor.aspx?target=ijor:rjpt&volume=11&issue=2&article=070
40. Teja KV, Ramesh S, Priya V. Regulation of matrix metalloproteinase-3 gene expression in inflammation: A molecular study. J Conserv Dent [Internet]. 2018 Nov;21(6):592–6. Available from: http://dx.doi.org/10.4103/JCD.JCD_154_18
41. Magalhães APR, Santos LB, Lopes LG, de Araújo Estrela CR, Estrela C, Torres ÉM, et al. Nanosilver Application in Dental Cements [Internet]. Vol. 2012, ISRN Nanotechnology. 2012. p. 1–6. Available from: http://dx.doi.org/10.5402/2012/365438
42. Nandakumar M, Nasim I. Comparative evaluation of grape seed and cranberry extracts in preventing enamel erosion: An optical emission spectrometric analysis. J Conserv Dent [Internet]. 2018 Sep;21(5):516–20. Available from: http://dx.doi.org/10.4103/JCD.JCD_110_18
43. Teja KV, Ramesh S. Shape optimal and clean more. Saudi Endodontic Journal [Internet]. 2019 Sep 1 [cited 2020 Jun 10];9(3):235. Available from: http://www.saudiendodj.com/article.asp?issn=1658-5984;year=2019;volume=9;issue=3;spage=235;epage=236;aulast=Teja
44. Noor SSSE, S Syed Shihaab, Pradeep. Chlorhexidine: Its properties and effects [Internet]. Vol. 9, Research Journal of Pharmacy and Technology. 2016. p. 1755. Available from: http://dx.doi.org/10.5958/0974-360x.2016.00353.x
45. Kolbeck C, Behr M, Rosentritt M. Fracture force of tooth–tooth-and implant–tooth-supported all-ceramic fixed partial dentures using titanium vs. customised zirconia implant abutments. Clin Oral Implants Res [Internet]. 2008; Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1600-0501.2008.01551.x
46. Calvo-Guirado JL, Aguilar Salvatierra A, Gargallo-Albiol J, Delgado-Ruiz RA, Maté Sanchez JE, Satorres-Nieto M. Zirconia with laser-modified microgrooved surface vs. titanium implants covered with melatonin stimulates bone formation. Experimental study in tibia rabbits. Clin Oral Implants Res [Internet]. 2015;26(12):1421–9. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/clr.12472
47. Elsaka SE, Hamouda IM, Swain MV. Titanium dioxide nanoparticles addition to a conventional glass-ionomer restorative: influence on physical and antibacterial properties. J Dent [Internet]. 2011 Sep;39(9):589–98. Available from: http://dx.doi.org/10.1016/j.jdent.2011.05.006
48. Hall S, Bradley T, Moore JT, Kuykindall T, Minella L. Acute and chronic toxicity of nano-scale TiO2particles to freshwater fish, cladocerans, and green algae, and effects of organic and inorganic substrate on TiO2toxicity [Internet]. Vol. 3, Nanotoxicology. 2009. p. 91–7. Available from: http://dx.doi.org/10.1080/17435390902788078
49. McCabe JF. Resin-modified glass-ionomers. Biomaterials [Internet]. 1998 Mar;19(6):521–7. Available from: http://dx.doi.org/10.1016/s0142-9612(98)00132-x
50. McCabe JF, Walls AWG. Resin based filling materials. Applied dental materials. 2008;9:195–224.
51. Coutinho E, Cardoso MV, De Munck J, Neves AA, Van Landuyt KL, Poitevin A, et al. Bonding effectiveness and interfacial characterization of a nano-filled resin-modified glass-ionomer. Dent Mater [Internet]. 2009 Nov;25(11):1347–57. Available from: http://dx.doi.org/10.1016/j.dental.2009.06.004
52. Hussainy SN, Nasim I, Thomas T, Ranjan M. Clinical performance of resin-modified glass ionomer cement, flowable composite, and polyacid-modified resin composite in noncarious cervical lesions: One-year follow-up. J Conserv Dent [Internet]. 2018 Sep;21(5):510–5. Available from: http://dx.doi.org/10.4103/JCD.JCD_51_18
53. Sayyedan FS, Fathi M, Edris H, Doostmohammadi A, Mortazavi V, Shirani F. Fluoride release and bioactivity evaluation of glass ionomer: Forsterite nanocomposite. Dent Res J [Internet]. 2013 Jul;10(4):452–9. Available from: https://www.ncbi.nlm.nih.gov/pubmed/24130579
54. Ramesh Kumar KR, Shanta Sundari KK,

Journal of Chemical Health Risks

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Venkatesan A, Chandrasekar S. Depth of resin penetration into enamel with 3 types of enamel conditioning methods: a confocal microscopic study. Am J Orthod Dentofacial Orthop [Internet]. 2011 Oct;140(4):479–85. Available from: http://dx.doi.org/10.1016/j.ajodo.2010.10.022

55. Johnson J, Lakshmanan G, M B, R M V, Kalimuthu K, Sekar D. Computational identification of MiRNA-7110 from pulmonary arterial hypertension (PAH) ESTs: a new microRNA that links diabetes and PAH. Hypertens Res [Internet]. 2020 Apr;43(4):360–2. Available from: http://dx.doi.org/10.1038/s41440-019-0369-5
56. Azeem RA, Sureshbabu NM. Clinical performance of direct versus indirect composite restorations in posterior teeth: A systematic review. J Conserv Dent [Internet]. 2018 Jan;21(1):2–9. Available from: http://dx.doi.org/10.4103/JCD.JCD_213_16
57. Mp SK. Relationship between dental anxiety and pain experience during dental extractions. Asian Journal of Pharmaceutical and Clinical Research. 2017;458–61.
58. Jain RK, Kumar SP, Manjula WS. Comparison of intrusion effects on maxillary incisors among mini implant anchorage, j-hook headgear and utility arch. J Clin Diagn Res [Internet]. 2014 Jul;8(7):ZC21–4. Available from: http://dx.doi.org/10.7860/JCDR/2014/8339.4554
59. Felicita AS. Quantification of intrusive/retraction force and moment generated during en-masse retraction of maxillary anterior teeth using mini-implants: A conceptual approach. Dental Press J Orthod [Internet]. 2017 Sep;22(5):47–55. Available from: http://dx.doi.org/10.1590/2177-6709.22.5.047-055.oar
60. Krishnan S. Effect of Bisphosphonates on Orthodontic Tooth Movement—An Update [Internet]. JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH. 2015. Available from: http://dx.doi.org/10.7860/jcdr/2015/11162.5769
61. Neelakantan P, Subbarao C, Subbarao CV, De-Deus G, Zehnder M. The impact of root dentine conditioning on sealing ability and push-out bond strength of an epoxy resin root canal sealer. Int Endod J [Internet]. 2011 Jun;44(6):491–8. Available from: http://dx.doi.org/10.1111/j.1365-2591.2010.01848.x
62. Kumar S. The emerging role of botulinum toxin in the treatment of orofacial disorders: Literature update. Asian J Pharm Clin Res [Internet]. 2017 Sep 1;10(9):21. Available from: https://innovareacademics.in/journals/index.php/ajpcr/article/view/16914
63. Mohanavel V, Ashraff Ali KS, Prasath S, Sathish T, Ravichandran M. Microstructural and tribological characteristics of AA6351/Si3N4 composites manufactured by stir casting. Journal of Materials Research and Technology [Internet]. 2020 Nov 1;9(6):14662–72. Available from: https://www.sciencedirect.com/science/article/pii/S2238785420318548