REVIEW ARTICLE

Recent Advances in Dental Materials

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ABSTRACT

Optimal oral health care has two distinct outcomes: Good oral health-care outcomes and a reduced environmental impact. Today's innovative computer-assisted design technologies, combined with advanced milling equipment and material options, provide a significant competitive advantage to the forward-thinking dental laboratory. These modern materials produce extremely natural, lifelike esthetics while necessitating less post-processing and handling than was previously required. The global acceptance of zirconia in dentistry has been nothing short of revolutionary. This is due in part to the fact that tooth preparation requirements are limited, allowing dentists to use preparation techniques that they have become accustomed to overtime. Nanotechnology has resulted in the development of novel and cost-effective dental materials. Silver nanoparticles, zinc oxide-based nanoparticles, and copper-based nanoparticles are examples of antimicrobial dental nanomaterials. The acceptance of digital technology is driving demand for more material options. In the present review, recent advances in dental materials are discussed.

Key words: Dental materials, nanotechnology, computer-assisted design/computer-assisted manufacturing, restorative materials, composites, ceramics

INTRODUCTION

Dental materials play an essential position within side of the rehabilitation of enamel systems and regeneration of oral tissues. In the remaining years, technological improvement performed a key position within side the field of dental substances, introducing the engineered substances. These substances showing a "smart behavior" generated a brand new generation that facilitates the dental substances to reply to stimuli through changing one or greater in their homes without compromising the safety of enamel and oral tissues.[1,2] Nanotechnology is currently driving the dental materials industry to substantial growth, thus reflecting on improvements in materials available for oral prevention and treatment. Striking recent advances in organic nanotechnology for dentistry have come from polymer-based nanomaterials including modified chitosan, polymeric nanogels, and dendrimers.[3] Fact that the world's population is living longer is also important raising the standards for biomaterials' durability and the dependability of oral cavity structures. The above is a powerful motivator to seek out new dental biomaterial solutions in terms of structure, properties, and technology. One example is research into active materials, which have a major role to play in regenerative processes. Resin composites, polymers, glass ionomers, ceramics, endodontic materials, graft materials, bioactive glasses, graphene, titanium, zirconium, and silicate cement are among the materials currently under development. Additive methods, nanomaterial technologies, and biomimetic coatings have all opened up new possibilities of dental care.[4]

Despite its widespread clinical use and low adhesive values in cementation, zirconia appears to be insufficient. As compared to the values obtained with glass ceramics, zirconia fails to have a sufficient etchable surface due to its chemical inertia. Primers containing 10-methacryloyloxydecyl dihydrogen phosphate (10 MDP) have been designed to overcome these limitations.[5] The 10 MDP was effective to improve the bond strength between resin-cement and zirconia. Clinically, this new generation of dental materials needs to be validated to enable

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prediction of long-term results. Traditional dental materials have been acquisitive for a long time, which means that they were produced elsewhere for various purposes and then adopted into clinical practice using the principles of "adopt, adapt, enhance," often with idiosyncratic and personal recipes of individual practitioners.

The rapid advancement and widespread adoption of emerging technology has resulted in the production of specialized materials for use in computer-assisted design/computer-assisted manufacturing (CAD/CAM) systems. These digitally oriented materials are more "advanced" than those used in analogue techniques. They are usually available in partially crystallized form for milling, after which they must undergo thermal treatment to achieve final crystallization at a specific temperature for a specific period, as specified by the manufacturer.[6] Crystallization is a critical phase in the laboratory that is carried out in an oven by a dental technician. In this regard, Duma *et al*. made an important contribution to the use of novel systems to monitor and develop oven calibration methods, focusing on the use of optical coherence tomography to test the surface structure differences introduced by temperature changes in crystallized or sintered ceramics used in dental laboratories.[6] In the present review, recent advances in dental materials are discussed.

RECENT ADVANCES IN DENTAL COMPOSITES

1. Condensable composites or packable composites or polymer rigid inorganic matrix material: Unlike traditional composites, the resin in this device is incorporated into the fibrous ceramic filler network, rather than the filler particles being used in the composite resin matrix. Aluminum oxide, silicon oxide glass particles, barium aluminum silicate, and strontium glasses are the most popular fillers.[7] Colloidal silica ultrafine particles are also used to monitor handling characteristics including viscosity, flow resistance, condensability, and reduced stickiness. This definition provides a foundation for fabricating packable or condensable posterior composite resin, which has the benefits of better occlusal anatomy reproduction, improved marginal adaptation, and ease of achieving a good contact point.[8] These materials have stronger physical and mechanical properties than hybrid composites and are closer to silver amalgam.[9] The clinical performance of these products, on the other hand, is similar to that of hybrid composites.[10]
2. Self-repairing composites: An epoxy-based structure of resin-filled microcapsules makes up the self-healing and self-repairing composite. When the epoxy resin crazes, these microcapsules can be broken, releasing the resin.[11] The resin then fills the gaps and reacts with Grubb's catalyst, which is spread in the epoxy composite. As a result, the resin will eventually polymerize and repair the crack.
3. Indirect composite resins: Indirect composites, such as inlay and onlay systems, were created in response to the major clinical issues with direct posterior composite resins. Since indirect composite resin restorations are fabricated on a die rather than directly in the cavity preparation, they have better marginal adaptation, contour, and proximal touch.[12] Indirect resin restorative systems with unusually good properties such as wear resistance, esthetics, control over polymerization shrinkage, and marginal adsorption have been introduced.[8]
4. Organically modified ceramic oligomers (ORMOCER): They are small hybrid structures made up of inorganic and organic copolymers that are molecule sized. Inorganic –SI-O-SI- network binds organic reactive monomers. Methacrylate-terminated strings, for example, are grafted on to a central cyclic polysiloxane 2–3 nm particle in these molecular hybrids. On a molecular scale, these nanoparticles are dispersed.[13] These crosslinking molecules have a high molecular weight, are flexible, and have a low viscosity. Curing causes a low-level polymerization due to the wide distance between crosslinks.[14]
5. Flowable composites: The primary goal of these composites was to enhance the handling properties of composite resins. Traditional hybrid composites of the same filler size have less filler material than these composites. To minimize the viscosity of the mixture, the resin matrix was increased. They lack the power to withstand high stresses because the filler content has been reduced.[15] These materials, on the other hand, wet the tooth surface more effectively and flow easily through all undercuts, forming thin layers and reducing the creation of air pockets at the tooth-restoration interface.[16,17]

6. Self-adhering composites: Compobonds are the another name for self-adhering composites. It is a single product where self-adhering flowable composite blends the benefits of both dental adhesives and restorative materials technologies (8th generation).[18] Self-etching dentin bonding agents and nano-filled resins are the advantages of compobonds. They do away with the need for a preparatory bonding stage to adhere the resin to the tooth substrate, lowering the risk of post-operative sensitivity. Due to the fact that compobonds serve as both a dentin adhesive and a resin restorative material, a longer curing time is needed to ensure that both constituents are completely polymerized.[19]

ADVANCES IN ALGINATE IMPRESSION MATERIALS

Alginate is commonly used for producing edentulous and partially edentulous impressions for the fabrication of full and removable partial dentures, though it is not ideal in every way. Alginate impression materials are simple to use, record fine data, and are less expensive than their elastic counterparts.[20] Alginate impression materials, on the other hand, contain fine diatomaceous earth filler particles [Table 1]. Due to their low density, these fillers rise to the surface as dust when the lid of the alginate storage container is opened. Since alginates are extremely hydrophilic, they absorb water and moisture, causing dimensional changes. Furthermore, their low viscosity can cause patients to experience a gag reflex.[21] Since these materials do not adhere well to impression trays, perforated trays must be used to render impressions.

Composition

Potassium or sodium alginate	dissolves in water and reacts with calcium ions
Calcium sulphate dihydrate	A reactor ,reacts with potassium alginate to form a dihydrate insoluble alginate gel
Zinc oxide	Filler particles, affects properties and setting time
Potassium titanium fluoride	Accelerator ,counteracts the inhibiting effect of the hydrocolloid on the setting of stone,ensures good quality surface of the cast
Diatomaceous earth	Filler particles, controls the consistency of the mix and the flexibility of the set alginate
Trisodium phosphate	Retarder,controls the settting time to produce either regular or fast set alginates
Coloring agents	
Flavoring agents	

Table 1: Composition of alginate impression material

1. Dust-free alginates: These materials were created to eliminate silicosis, which is caused by diatomaceous earth fillers in traditional alginate impression materials, which cause silicosis. Low-density siliceous fibers with dimensions of 3–20 μm and more possible carcinogens are used as fillers. During use, these fibers will rise to the surface as dust, and inhaling them can cause respiratory problems.[20] Dedusting agents such as glycerin, glycol, polyethylene glycol, and polypropylene glycol have been used to try to improve the density of siliceous fibers.[21,22] Sepiolite (natural mineral fiber containing magnesium silicate – 20%) was recently applied to alginate products to help keep alginate particles together and prevent dust particles from leaping. This reduced the amount of dust produced during the dispensing of alginate impression materials. Tetrafluoroethylene was also used by a number of manufacturers to prevent dust particles from rising by creating a cobweb during mixing.[23]
2. Chromatic alginates: The difficulty in determining the ideal consistency of alginate content during manipulation has been observed among some undergraduate students. To distinguish the different stages of manipulation, various color indicators were applied to the alginate impression materials. These color indicators change the color of the alginate mix as the pH changes, causing the setting reaction to occur.[24] The alginate mix's color changes, making it easier to determine the perfect consistency for loading it into the tray and making accurate impressions.
3. Extended pour alginates: It was not possible to store the alginate impression for a longer period of time due to syneresis and imbibition. Manufacturers' attempts to solve the issue resulted in the invention of two new alginate materials: CAVEX Color Change (Darby Dental Supply, USA) and Extend a Pour (Darby Dental Supply, USA) (Dux Dental Products). Cavex color change content can be stored for up to 100 h and can be used to prolong a pour.[25]
4. Alginate in the form of two-paste system: To avoid powder contamination and inconsistency in dispensing a specific amount of powder, alginates were produced in two-paste systems. It is made up of two components: Base paste and catalyst paste. The base paste is made up

of soluble alginate, water, and fillers, while the catalyst paste is made up of calcium salts, viscous liquids like liquid paraffin, and a pH stabilizer in the form of magnesium hydroxide.[26]

5. Alginate with polyacrylamide incorporation: Since water does not easily wet the powder, traditional alginates can appear to form a grainy mass with lumps of unmixed material when mixed with water. The addition of a thickening and stabilizing agent, such as 0.01–0.25 weight percent polyacrylamide (molecular weight 200,000–6,000,000), to traditional alginates improved mixing characteristics and the creation of smooth alginates.[27]

RECENT ADVANCES OF DENTAL RESTORATIVE MATERIALS

Material, equipment, and technique advances have changed both the art and science of restorative dentistry, and future advancements will undoubtedly continue this discipline's evolution. Dental amalgam has been used as a restorative material for over 150 years. Alternative filling products have become increasingly popular as people become more conscious of the harmful effects of mercury on the environment.[28]

1. The low viscosity/flowable GIC: This is a new fluoride-releasing material that has been designed to address the shortcomings of existing fluoride-releasing materials. The more fluoride a substance releases, the more open its structure becomes, resulting in low power. If these fluoride-containing materials are made more dense and solid to increase their strength, the effectiveness of F release is reduced. A sudden burst of fluoride release occurs shortly after placement, accompanied by a rapid decline in ion release rate.[29] Pit and fissure sealants, padding, endodontic sealers, and sealing of hypersensitive cervical areas are all examples of applications.[30]
2. Ormocers: Electronics, microsystem technology, plastic refinement, conservation and corrosion coatings, practical glass coatings, and anti-scratch protective coatings all use these products. Ormocers have both an inorganic and organic network.[31] Ormocers are made up of three different parts: Organic, inorganic, and polysiloxane. The proportions of these components may have an effect on the material's mechanical, thermal, and optical properties. Silane molecules, a multifunctional binding agent, bind the inorganic components to the organic polymers. The organic part of the methacrylate groups forms a three-dimensional structure after polymerization.[32]
3. Nanocomposite: Advanced methacrylate resins and curing methods were used to create nanocomposites. Two new forms of nanofiller particles have been discovered. Particles and nanoclusters that are nanomeric. Nanomeric silica nanoparticles are monodisperse, non-aggregated, and non-agglomerated.[33] The dental nanocomposite device exhibits high translucency, polish, and polish retention comparable to microfills while retaining physical properties and resistance comparable to other hybrid composites. The resin-based nanocomposite strength and esthetic properties enable it to be used for both anterior and posterior restorations.[34]
4. Antimicrobial composite: Antimicrobial properties of composites can be achieved by incorporating agents such as silver or one or more antibiotics into the material. The antimicrobial properties of silver and titanium particles were applied to improve the biocompatibility of the composites. Instead of leaching, the antibacterial properties were dependent on touch and lasted for at least a month.[35]
5. Self-healing composite: External static (creep) or dynamic (fatigue) forces, internal stress states, corrosion, breakdown, erosion, or biodegradation are all examples of physical, chemical, and biological stimuli that cause materials to degrade. This eventually causes the material structure to deteriorate, and the material to fail.[36] Epoxy resin composite was one of the first self-healing synthetic materials, and it resembles resin-based dental materials in appearance. When a crack appears in the epoxy composite material, some of the microcapsules near the crack are broken, allowing the resin to escape. Resin was used to fill the holes and then reacts with a Grubbs catalyst dispersed in the epoxy composite, resulting in polymerization.[37]

ADVANCES IN DENTAL CERAMICS

Several researchers have experimented with reinforcing ceramics with various crystalline phases, which has resulted in improved mechanical properties. The mechanisms of crystalline reinforced ceramic materials' strengthening have been discussed in the literature [Figure 1].

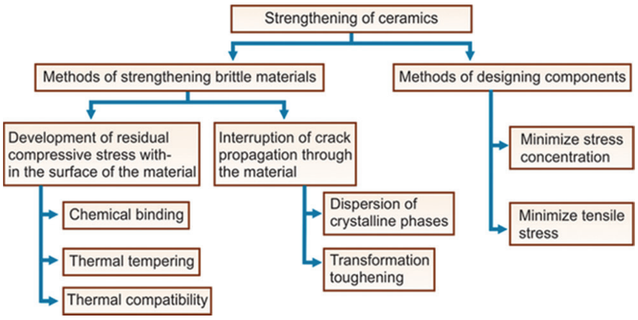

Figure 1: Methods of strengthening dental ceramics.

1. Sintered porcelains: Sintering is the method of bringing ceramic powder particles together by heating them to high temperatures, which causes atomic motion. Porcelain sintering facilitates physical-chemical reactions that determine the final properties of ceramic products. In the final stage of sintering, the volume of porosity decreases. The sintering temperature has the greatest impact on the amount of porosity.[38,39]
2. Slip-cast ceramics: The pouring of an aqueous porcelain slip on a refractory die is known as slip-casting. The porosity of the refractory die aids condensation by capillary action absorbing water from the slide. The refractory die is then shot at a high temperature. The refractory die shrinks more than the condensed slip during this heat treatment, making separation easier. Before veneering porcelain can be applied, the resulting ceramic must be either infiltrated with molten glass or completely sintered.[40]
3. Machinable ceramics: The invention of CAD-CAM technology for the production of machined inlays, onlays, and crowns contributed to the development of a new generation of machinable ceramics. The benefits of this method include the elimination of impressions, which saves time in the dentist chair and prevents cross-contamination between the patient and dentist operational fields.[41] The scanning of prepared tooth structure and digitization of the information into the machine are needed for the fabrication of ceramic prosthesis. In the computer, design the restoration and then activate the milling machine to cut the ceramic into the desired form. To increase fracture resistance, adhesive resin cements are widely recommended for luting these all-ceramic crowns.[42] The Lava CAD/CAM System (3M ESPE, St. Paul, Minnesota) was implemented more recently. It is used to make zirconia system for all ceramic restorations, using yttria-stabilized tetragonal zirconia polycrystals with higher fracture resistance than traditional ceramics. The Lava system digitizes data using a laser optical system.[43] To compensate for shrinkage, the Lava CAD program automatically finds the margin and recommends a pontic, while CAM creates an expanded structure. In a single consultation, the machinable ceramic prostheses can be administered to the patient. However, this system has many disadvantages, including the need for costly equipment and the requirement that the dentist/technician has sufficient experience to use and operate the system.[44] Since most dental zirconia ceramics are opaque, copings must be veneered to achieve a high level of esthetics. Appropriate shade selection is also critical in determining the esthetic properties of the final product.[45] Bona *et al*. compared the color variations between different CAD-CAM ceramic restorations and recommended that the final shade of CAD-CAM ceramic restorations be adjusted carefully to achieve a clinically appropriate shade match.

IMPLANT DENTISTRY – NEW MATERIALS AND TECHNOLOGIES

The field of implant dentistry is undergoing a significant transformation. Dental implant placement in post-extraction sockets and immediate prosthetic loading is well-established and widely used techniques. These surgical and prosthetic techniques minimize the time and expense of implant prosthetic care, which patients appreciate; however, they can pose a risk, especially when adequate primary stabilization of the implant is not possible due to inadequate bone quantity or quality.[46] Implant manufacturers have introduced fixtures with complex macrotopographies, designed to improve primary stability, and surfaces with peculiar micro- and nanotopographies, able to accelerate the processes of bone healing and prosthetic loading, into the market to minimize the risks associated with implant placement in post-extraction sockets and immediate prosthetic loading.[47] Simultaneously, the influence of emerging technology is transforming the field of implant dentistry. Intraoral scanners and cone-beam computed tomography, applications for guided implant placement and CAD/CAM, modern cosmetic materials (zirconia, lithium disilicate, and ceramics), milling devices, and 3D printers are all revolutionizing the surgeon and prosthodontist professions.

NANOTECHNOLOGY

Nanotechnology is currently propelling the dental materials industry to new heights, resulting in advancements in oral prevention and treatment materials. The current review focuses on new advances in nanotechnology applied to dentistry, with a focus on the use of nanomaterials to improve oral care quality, research perspectives in this field, and discussions on safety issues related to the use of dental nanomaterials.[48] The Cutting Edge Properties (morphological, antibacterial, mechanical, fluorescence, antitumoral, and remineralization and regeneration potential) of polymeric, metallic, and inorganic nano-based materials, as well as their use as nanocluster fillers, in nanocomposites, mouthwashes, drugs, and biomimetic dental materials, are all discussed in detail.

CONCLUSION

The development of sustainable materials enables dental practices to differentiate themselves from competitors, as generations such as the millennials seek more than just a generic family dentist, but one who serves the greater good of society. These material advancements are directly related to laboratory adoption of digital technology. The significance of accurate and esthetically pleasing dental materials in completing the digital link cannot be overstated. The number of options available has grown as a result of ongoing manufacturer research and development. By utilizing better workflow solutions, laboratories have been able to offer new and innovative products to their clinicians.

REFERENCES

1. Zhang Y, Mai Z, Barani A, Bush M, Lawn B. Fracture-resistant monolithic dental crowns. Dent Mater 2016;32:442-9.
2. Li RW, Chow TW, Matinlinna J.P. Ceramic dental biomaterials and CAD/CAM technology: State of the art. J Prosthodont Res 2014;58:208-16.
3. Available from: https://www.cell.com/trends/biotechnology/fulltext/S0167-7799(15)00191-2. [Last accessed on 2021 Mar 18].
4. Available from: https://www.lidsen.com/journals/rpm/rpm-special-issues/advanced-dental-materials. [Last accessed on 2021 Mar 18].
5. Valente F, Mavriqi L, Traini T. Effects of 10-MDP based primer on shear bond strength between zirconia and new experimental resin cement. Materials 2020;13:235.
6. Duma VF, Sinescu C, Bradu A, Podoleanu A. optical coherence tomography investigations and modeling of the sintering of ceramic crowns. Materials 2019;12:947.
7. Faras R, Pujar M, Lahiri A, Havaldar SC, Shetye SA. Recent advances in composite resins a review. Paripex Ind J Res 2018;7:93-4.
8. Singh P, Kumar N, Singh R, Kiran K, Kumar S. Overview and recent advances in composite resin: A review. Int J Sci Stud 2015;3:169-72.
9. Suzuki S. Does the wear resistance of packable composite equal that of dental amalgam? J Esthet Restor Dent 2004;16:355-65.
10. de Souza FB, Guimaraes RP, Silva CH. A clinical evaluation of packable and microhybrid resin composite restorations: One-year report. Quintessence Int 2005;36:41.
11. Badami V, Ahuja B. Biosmart materials: Breaking new ground in dentistry. Sci World J 2014;2014:986912.
12. Ravi RK, Alla RK, Shammas M, Devarhubli A. Dental composite a versatile restorative material: An overview. Ind J Dent Sci 2013;5:111-5.
13. Alla RK. Restorative materials: Composite resins. In: Dental Materials Science. New Delhi, India: Jaypee Brothers Medical Publishers (P) Ltd.; 2013. p. 130-48.
14. Sivakumar A, Valiathan A. Dental ceramics and ormocer technology navigating the future. Trends Biomater Artif Organs 2006;20:40-3.
15. Mohan M, Ramciya KV, Baby J. Comparison of fracture resistance of teeth restored with microhybrid, fiber reinforced and nanohybrid composite resins an *in-vitro* study. Int J Recent Sci Res 2019;10:34460-5.
16. Olmez A, Oztas N, Bodur H. The effect of flowable resin composite on microleakage and internal voids in class II composite restorations. Oper Dent 2004;29:713-9.
17. Gupta R, Tomer AK, Kumari A, Perle N, Chauhan P, Rana S. Recent advances in bulkfill flowable composite resins: A review. Int J App Dent Sci 2017;3:79-81.
18. Shaalan OO, Abou-Auf E, El Zoghby AF. Clinical evaluation of self-adhering flowable composite versus conventional flowable composite in conservative Class I cavities: Randomized controlled trial. J Cons Dent 2018;21:485.
19. D'Alpino PH, da Rocha Svizero N, Carrilho M. Self-adhering composites. In: Miletic V, editors. Dental Composite Materials for Direct Restorations. Cham: Springer; 2018.
20. Alla RK. Dental Materials science. In: Impression Materials. New Delhi, India: Jaypee Medical Publishers Pvt Ltd.; 2013. p. 182-190.
21. Anusavice KJ, Shen C, Rawls HR. Philips' Science of Dental Materials in Impression Materials. 12th ed. United States: Elsevier Science; 2013. p. 171-6.
22. Sakaguchi RL, Powers JM. Craig's Restorative Dental Materials in Replicating materials Impression and Casting. 13th ed. United States: Elsevier; 2012. p. 277-86.
23. Kaur G, Jain P, Uppal M, Sikka R. Alginate impression

material: From then till now. J Clin Dent 2012;5:2.

24. Craig RG. Review of dental impression materials. Adv Dent Res 1988;2:51-64.
25. Jamani KD. The effect of pouring time and storage condition on the accuracy of irreversible hydrocolloid impressions. Saudi Dent J 2002;14:126-30.
26. Pelico MA. Settable Alginate Compositions. US Patent, No. 4381947; 1984.
27. Pellico MA. Settable Alginate Compositions Containing Polyacrylamide. Los Angeles, CA: US Patent, No. 4468484; 1984.
28. Ambili C, Prasad BS. The era of future dentistry: Recent advances and future perspectives of restorative dentistry: A literature review. Int J Appl Dent Sci 2019;5:111-6.
29. Dhoot R, Bhondwe S, Mahajan V, Lonare S, Rana K. Advances in glass ionomer cement (GIC): A review. IOSR J Dent Med Sci 2016;15:124-6.
30. Care L, Davidson J. Advances in glass ionomer cement. J Minim Interv Dent 2009;2:3.
31. Antoniades HM, Kalinderis K, Pedulus L, Papadogiannis Y. The effect of pulse activation on microleakage of a packable composite resinand two ormocers. J Oral Rehabil 2004;31:1068-74.
32. Kournetas N, Chakmakchi M, Kakaboura A, Rahiotis C, Geis-Gerstorfer J. Marginal and internal adaptation of class II ormocer and hybrid resin composite restorations before and after load cycling. Clin Oral Investig 2004;8:123-9.
33. Turssi CP, Ferracane JL, Vogel K. Filler features and their effects on wear and degree of conversion of particulate dental resin composites. Biomater 2005;26:4932-37.
34. Terry DA. Applications of nanotechnology. Ed Comment 2004;16:417-22.
35. Saku S, Kotake H, Scougall-Vilchis RJ, Ohashi S, Hotta M, Horiuchi S, *et al*. Antibacterial activity of composite resin with glass ionomer filler particulates. Dent Mater 2010;29:193-8.
36. Jandt KD, Sigusch BW. Future perspectives of resin based dental materials. Dent Mater 2009;25:1001-6.
37. Lahari K, Jaidka S, Somani R, Revelli A, Kumar D, Jaidka R. Recent advances in composite restorations. Int J Adv Res 2019;7:761-79.
38. White SR, Sottos NR, Geubelle PH, Moore JS, Kessler MR, Sriram SR, *et al*. Autonomic healing of polymer composites. Nature 2001;409:794-7.
39. Cheung KC, Darvell BW, Sintering of dental porcelain: Effect of time and temperature on appearance and porosity. Dent Mater 2002;18:163-73.
40. Denry IL. Recent advances in ceramics for dentistry. Crit Rev Oral Biol Med 1996;7:134-43.
41. Taskonak B, Anusavice K, Mecholsky J. Role of investment interaction layer on strength and toughness of ceramic laminates. Dent Mater 2004;20:701-8.
42. Duret F, Preston JD. CAD/CAM imaging in dentistry. Curr Opin Dent 1991;1:150-4.
43. Mantri SS, Bhasin AS. CAD/CAM dental restorations: An overview. Ann Essences Dent 2010;2:123-8.
44. Bona AD, Pecho OE, Ghinea R, Cardona JC, Pérez MM. Colour parameters and shade correspondence of CAD-CAM ceramic systems. J Dent 2015;43:726-34.
45. Saracoglu A, Cura C, Cotert HS. Effect of various surface treatment methods on the bond strength of the heat-pressed ceramic samples. J Oral Rehabil 2004;31:790-7.
46. Available from: https://www.hindawi.com/journals/bmri/si/321095. [Last accessed on 2021 Mar 18].
47. Available from: https://www.researchgate.net/publication/315246419_biomaterials_for_dental_implants_an_overview. [Last accessed on 2021 Mar 18].
48. Ghadimi E, Eimar H, Song J, Marelli B, Ciobanu O, Abdallah MN, *et al*. Regulated fracture in tooth enamel: A nanotechnological strategy from nature. J Biomechnol 2014;47:2444-51.