

Recent advances in dental materials

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Citation of this Article: Saaransh Handa, Dr Vasanthi Swami, “Recent advances in dental materials”, IJDSIR- June - 2021, Vol. – 4, Issue - 3, P. No. 469 – 476.

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Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Optimal oral health care has two distinct outcomes: good oral health care outcomes and a reduced environmental impact. Today's innovative CAD 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 aesthetics 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 over time. 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.

Keywords: Dental materials, Nanotechnology, CAD-CAM, restorative materials, composites, ceramics.

Introduction

Dental materials play an essential position with inside the rehabilitation of enamel systems and regeneration of oral tissues. In the remaining years, technological improvement performed a key position with inside 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]. The fact that the world's population is living longer is also important,

raising 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 prediction of long-term results. Traditional dental materials have been acquisitive for a long time, which means 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 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 crystallisation 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. [6] 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 (OCT) to test the surface structure differences introduced by temperature changes in crystallised or sintered ceramics used in dental laboratories.

Recent Advances in Dental Composites

1) Condensable composites or packable composites or polymer rigid Inorganic matrix material (PRIMM)

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. Aluminium oxide, silicon oxide glass particles, barium Aluminium 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. The resin will eventually polymerize and repair the crack as a result of this.

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, aesthetics, control over polymerization shrinkage, and marginal adsorption have been introduced [13].

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 2-3nm particle in these molecular hybrids. On a molecular scale, these nanoparticles are dispersed [14]. 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 [15].

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 minimise 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 [16].

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 [17, 18].

6) Self-adhering composites

Compo-bonds are another name for self-adhering composites. In a single product, self-adhering flowable composite blends the benefits of both dental adhesives and restorative materials technologies (8th generation) [19]. Self-etching dentin bonding agents and nano-filled resins are advantages of compo-bonds. They do away with the need for a preparatory bonding stage to adhere the resin to the tooth substrate, lowering the risk of postoperative sensitivity. Due to the fact that compo-bonds 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 [20].



Figure 1: Recent advances in composite dentistry

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 [21]. Alginate impression materials, on the

other hand, contain fine diatomaceous earth filler particles [table 1]. Owing 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 [22]. 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 setting 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 fibres with dimensions of 3-20 μm and more possible carcinogens are used as fillers. During use, these fibres will rise to the surface as dust, and inhaling them can cause respiratory problems [21]. Dedusting agents such as glycerin, glycol, polyethylene glycol, and polypropylene glycol have been used to try to improve the density of siliceous fibres [23]. Sepiolite (natural mineral fibre containing magnesium silicate -20 percent) 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 [24].

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 colour indicators were applied to the alginate impression materials.

These colour indicators change the colour of the alginate mix as the pH changes, causing the setting reaction to occur [25]. The alginate mix's colour changes, making it easier to determine the perfect consistency for loading it into the tray and making accurate impressions.

3) Extended pour alginates

It is unable 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 colour change content can be stored for up to 100 hours and can be used to prolong a pour.

content can be stored for up to 100 hours and can be used to prolong a pour [26].

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 stabiliser in the form of magnesium hydroxide [27].

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 stabilising agent, such as 0.01- 0.25 weight percent polyacrylamide (molecular weight 200,000 to 6,000,000), to traditional alginates improved mixing characteristics and the creation of smooth alginates [28].

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 [29].

1) The Low Viscosity/Flowable GIC

A new fluoride-releasing material 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 in order 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 [30]. Pit and fissure sealants, padding, endodontic sealers, and sealing of hypersensitive cervical areas are all examples of applications [31].

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 [32]. Ormocers are made up of three different

parts: organic, inorganic, and polysiloxanes. 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 [33].

3) Nano composite

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 [34]. 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's strength and aesthetic properties enable it to be used for both anterior and posterior restorations [35].

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 [36].

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 [37]. Epoxyresin 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 [38].

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 [Figure2].

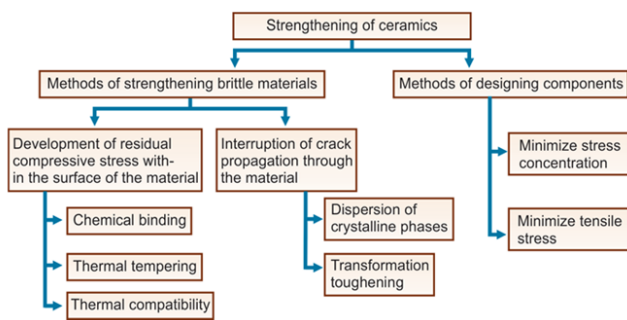


Figure 2- Methods of strengthening dental ceramics

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 [40].

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 [41].

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 [42]. 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 [43]. 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 poly crystals with higher fracture resistance than traditional ceramics. The Lava system digitises data using a laser optical system [44]. To compensate for shrinkage, the Lava CAD programme 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 have sufficient experience to use and operate the system [45].

Since most dental zirconia ceramics are opaque, copings must be veneered to achieve a high level of aesthetics. Appropriate shade selection is also critical in determining the aesthetic properties of the final product [46]. Bona et al compared the colour 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 are well-established and widely used techniques. These surgical and prosthetic techniques minimise the time and expense of implant-prosthetic care, which patients appreciate; however, they can pose a risk, especially when adequate primary stabilisation of the implant is not possible due to inadequate bone quantity or quality [47]. 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 minimise the risks associated with implant placement in post-extraction sockets and immediate prosthetic loading [48]. Simultaneously, the influence of emerging technology is transforming the field of implant dentistry. Intraoral scanners (IOS) and cone beam computed tomography (CBCT), applications for guided implant placement and computer-assisted design/computer-assisted manufacturing (CAD/ CAM), modern cosmetic materials (zirconia, lithium disilicate, ceramics), milling devices, and 3D printers are all revolutionising the surgeon and prosthodontist's 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 [49]. 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.

Conclusions

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 aesthetically 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 utilising 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, 442–449.

2. Li, R.W.K.; Chow, T.W.; Matinlinna, J.P. Ceramic dental biomaterials and CAD/CAM technology: State of the art. *J. Prosthodont.Res.* 2014, 58, 208–216.
3. [https://www.cell.com/trends/biotechnology/fulltext/S0167-7799\(15\)00191-2](https://www.cell.com/trends/biotechnology/fulltext/S0167-7799(15)00191-2)
4. <https://www.lidsen.com/journals/rpm/rpm-special-issues/advanced-dental-materials>
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, V.F.; 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, Havaladar SC, Shetye SA. Recent advances in composite resins – A review. *Paripex-Ind J Res.* 2018;7(8): 93-94.
8. Prachi Singh, Nitesh Kumar, Richa Singh, Kamini Kiran, Shailesh Kumar. Overview and recent advances in composite resin: A review. *Int J Sci Stud.* 2015; 3(9): 169-172.
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.