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Biomimetic materials in pediatric dentistry: A review article

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Abstract

In today's era, the human race is blindly running behind aesthetically pleasing procedures for the sake of acceptance in society wherein they lose their authenticity. Similar is the case with dentistry in which the biggest contradiction of modern restorative dentistry is that many of such artful procedures require the removal of existing dental tissue before a final prosthesis can be placed.

In order to save a tooth, existing dental archetypes demand that a portion of the target tooth must be defaced. Hence, we are forced to think that if the goal of modern dentistry is to save and salvage as much of a patient's natural dentition as possible, how does it make sense to rely on procedures that require the sabotage of the very thing you are trying to save? That's where biomimetic dentistry comes in. Upholding the natural teeth and dental conservancy at the heart is Biomimetic dentistry. This new approach is all about being on the lookout for the synthesis of modern dental technologies and low-impact tooth conservation. Instead of relying on dental replacements, biomimetic dentistry is about perpetuating as much of a natural tooth as possible. Instead of housing over dental blemishes, it is about repairing and restoring existing dental surfaces. Instead of relying on dental techniques that remove or destroy parts of an existing tooth, such as dental extractions, crowns, and root canals, biomimetic techniques strive to cut back on the removal of natural dental material. It's all about safeguarding what's there as much as possible and making it stronger and more resilient. Thus, the purpose of this article is to review various methods that not only result in a tooth that is more natural, but also more aesthetic, stronger, and longer lasting.

Keywords: Biomimetic Dentistry; Pediatric Dentistry; Child Response; Enamel; Dentin; Tissue engineering

1. Introduction

The perfect material does not exist in dentistry. There are numerous materials that can enhance clinical practice, smooth work, and enhance doctor-patient satisfaction.

As a multidisciplinary field, biomimetics is currently leading to the fabrication of novel materials with excellent mechanical properties [1]. This is a perspective on organic systems, their capabilities and artificial pathways emerging from the intersection of mobile biology, molecular biology, fabric sciences, dentistry and medicine. The Greek words bio and mimesis, which mean lifestyle and imitation, are derived from the same root. Depending on the specialised subject of the investigation, perceptions of the scope of biomimetics appear to differ widely. In biomimetics, we create artificial pathways to imitate organic processes by interpreting our understanding of organic systems and capabilities.

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2. Discussion

2.1. History

During the Fifties the American biophysicist and polymath Otto Schmitt advanced the idea of "Biomimetics" which was brought about with the aid of analysing the nerves in squid, trying to engineer a tool that replicated the organic machine of nerve propagation. He persisted to awareness on gadgets that mimic herbal structures and with the aid of using 1957 he had perceived a speak to the popular view of biophysics at that point and he referred to it as biomimetics [2]. In 1960 Jack E. Steele coined a similar term, bionics. Steele described bionics as "the technology of structures that have a few features copied from nature [3], or which constitute traits of herbal structures or their analogues. Schmitt used the term —biomimetic —in the name of certainly considered one among his papers, and with the aid of 1974 it had found its manner into Webster's Dictionary. Biomimicry was popularised with the aid of using scientist and creator Janine Benyus in her 1997 eBook Biomimicry: Innovation Inspired with the aid of using Nature [4,5].

The term biomimetics is recreation of one or more natural phenomena within the body biological conditions for producing biocompatible materials.

Biomimetics is an interdisciplinary approach inspired by innovations found in nature in the Biomimetic Dentistry, Materials can replace lost teeth structure, but requires more research to create enamel, dentin and even regenerative materials cellulose. The future will be wonderful.

The mid-20th century was an important history of biomimetic medicine with the ingenious invention of the cardiac pacemaker, heart valve prosthesis and knee replacement surgery or the contribution of painless injection needles combining biomimetics and bioengineering improving medical practice. Biocompatible short living medical bandages to detect the signal, helps monitor heart attack and myocardial infarction, anything that cannot be monitored or detected by electric medical equipment [6].

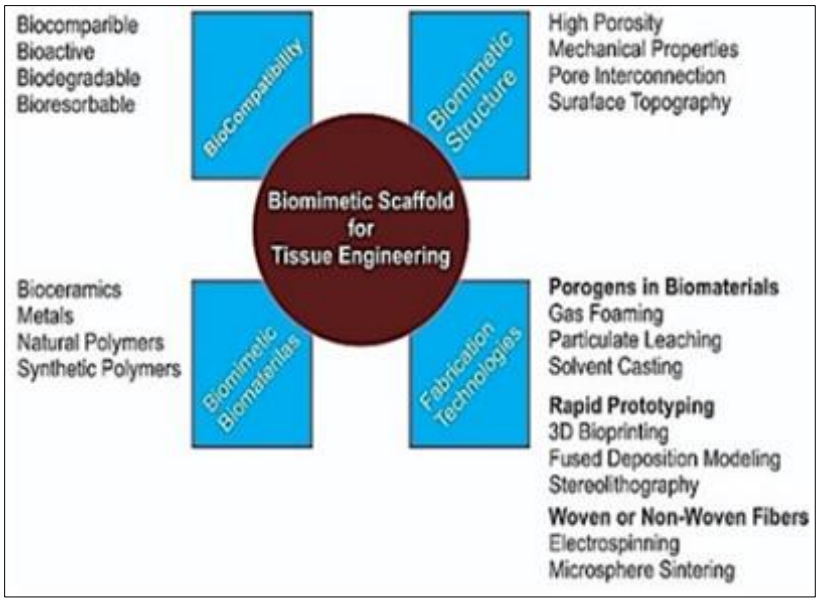

Figure 1 Scaffolding in Biomimetic Materials [7]

Mimicry in science entails recreating or imitating a reference or model. Dentists must agree on the proper reference if we are to restore what has been lost. Success that is ageless and unchangeable must be the standard reference point for the entire profession. The current tooth structure may experience additional issues as a result of wear, disease, and conventional restorations. Biomimetic concepts should be applied to artificially restore teeth to their natural functions and beauty because teeth lack a natural means of restoration.

2.2. Response of a child towards the Biomimetic materials used-

For a pediatric dentist, the most challenging and the rewarding act is to make a child actively responsive towards the treatment, enhancing social skills and recognition towards the materials we use during our procedure.

"Your natural teeth are the best teeth you will ever have. While man-made prosthetics can get close, no artificial replacement can beat your natural teeth. Biomimetic dentistry strives to conserve and preserve your natural teeth as opposed to replacing them." --- DR. MAMALY RESHAD, DDS

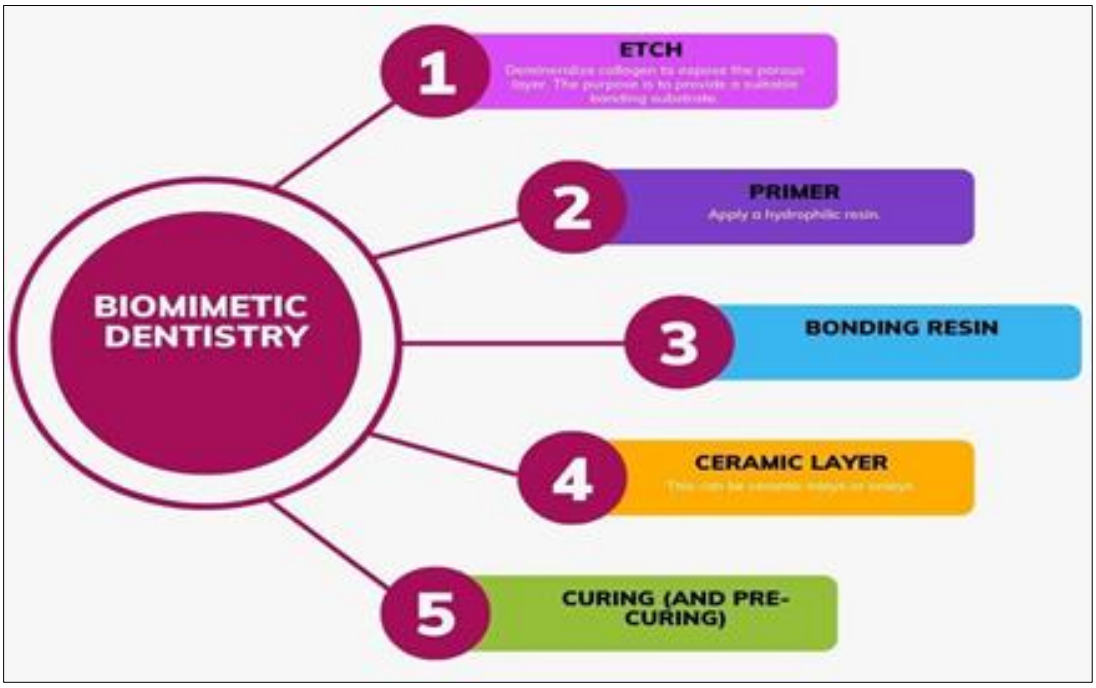

Figure 2 Biomimetic Dental Process

Biomimetics are particularly well suited to facilitate scientific and technical knowledge and thinking, to the children as they are peculiar and exponentially more curious to know about the dental materials, hence, the usage of biomimetic does not only demonstrate better results but is more accurate and less time consuming.

They emphasize more on tissue restoration, not replacement. The growth is not damaged and the child can have a sound and safe restorative treatment.

2.3. Why do pediatric dentists need to implement biomimetic materials more generally than in specific cases?

- Enhances tooth remineralization
- used pulp capping material
- For permanent restorations
- In apexification procedure
- It acts as scaffold and helps in regeneration of bone tissue [8]

As the search for the “ideal restorative material” continues, a new generation of material is introduced. These are called "smart" because these materials support the rest. These are hard enough to allow more conservative caries formation. Materials are subject to stress, temperature, humidity, pH, electric or magnetic field. Some of these are "biomimetic" in nature in that their properties mimic. Natural tooth substances such as enamel and dentin [9].

Materials traditionally for long-term use is believed that in this case the mouth survives longer. It is "passive" and has no interaction with the environment. Materials such as amalgam, composites and cement are often judged by ability to survive without reacting in the oral environment. Today the most promising Technologies for Life Efficiency and Reliability Improvement includes the use of “bioactive” smart materials.

3. Biomimetic concept of dentistry

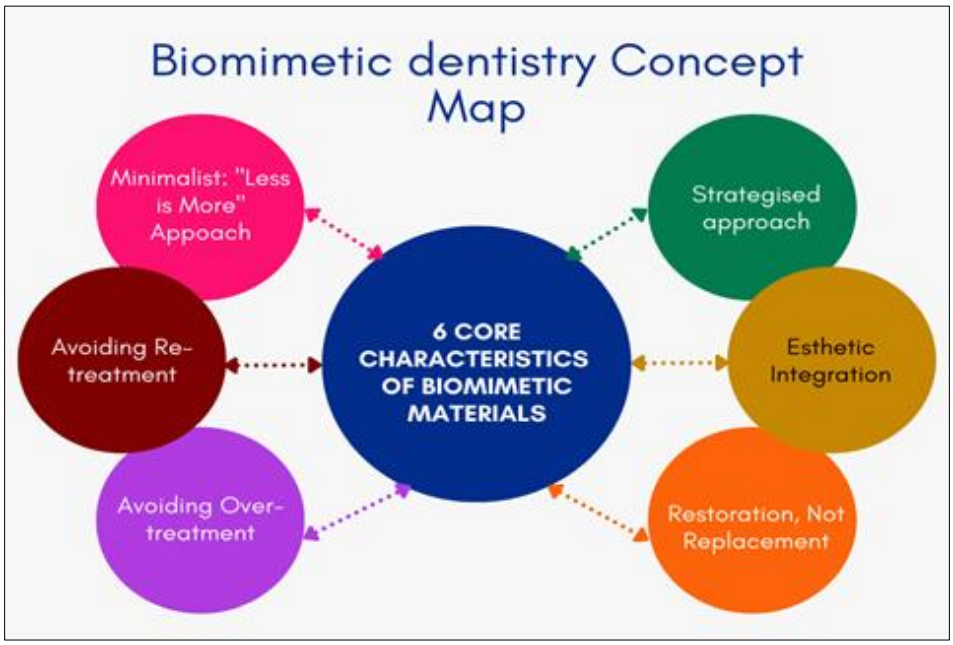

Figure 3 Core characteristics of biomimetic materials

3.1. Properties of smart materials

Smart materials sense changes in the environment around them and react in predictable ways [10].

In general, these properties are:

- Piezoelectric [11]- When there is a mechanical stress, an electric current is generated.
- Shape memory [12]- After being deformed, these materials can remember their original shape and return to that shape when heated.
- Thermo chromic - These materials change colour according to changes in temperature.
- Photochromic - These materials change colour according to changes in lighting conditions.
- Magnetic rheology - These are liquid materials that become solid when placed in a magnetic field.
- PH Sensitive - Material inflates/deflates when the pH of the ambient changes [13].
- Biofilm formation- The presence of biofilm on the surface of a material changes the interaction of the surface with the environment [14].

3.2. Distinguished property of Biomimetic Materials

Ever since the recent advancements and newer technologies in existence, biocompatibility and functional proliferative property (odontogenic/osteogenic) can also be determined. During a research study, when contacted with MTA (mineral trioxide aggregate), BD (Biodentine), and EMD (enamel matrix derivative), the stem cells demonstrated the efficient generation of dental hard tissues exhibiting similar morphological and functional characteristics as that of the normal one [15].

The many applications of smart materials have revolutionised in many areas of dentistry and it is certain that “smart materials” hold great promise for the future. These innovations in materials science marked the beginning of the era of bio-intelligent dentistry, a step into the future! So, it's time to think "smart" and apply bio-smart dentistry in our daily clinical practice.

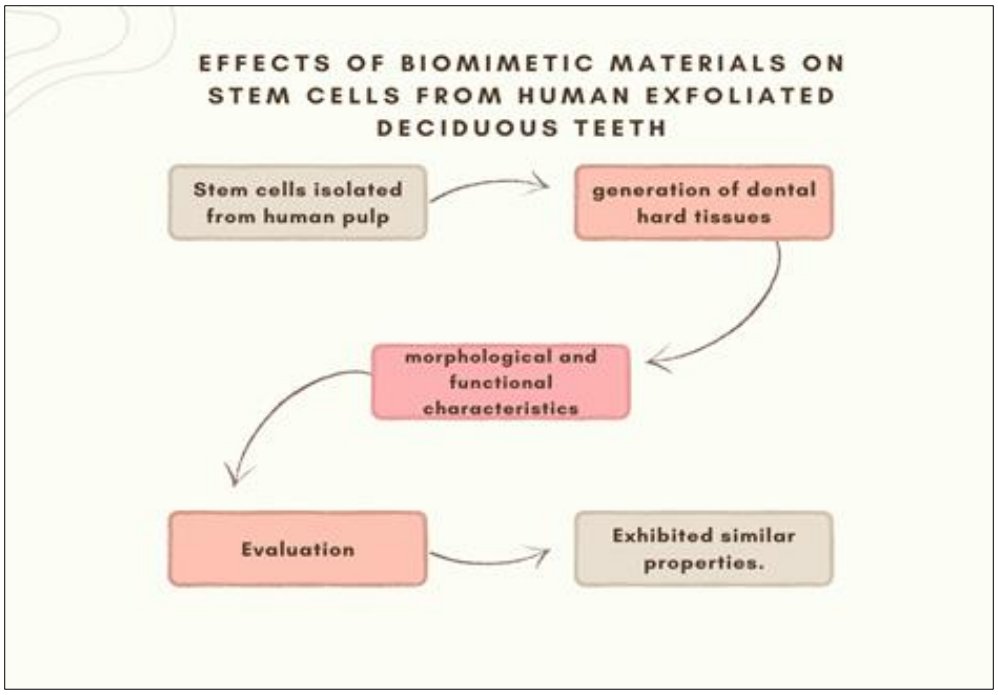

Figure 4 Effects of Biomimetic materials on Stem Cells from Human Exfoliated Deciduous teeth (SHED)

3.3. How do we define a Biomimetic Approach?

This involves reproducing a tooth's natural biomechanical function and aesthetics after it has been damaged or decayed. When restorative treatments are necessary, we act conservatively, removing only the damaged portions of the tooth. Restorations based on biomimicry include stress-reduced direct composites, porcelain inlays and onlays, and dental crowns [16].

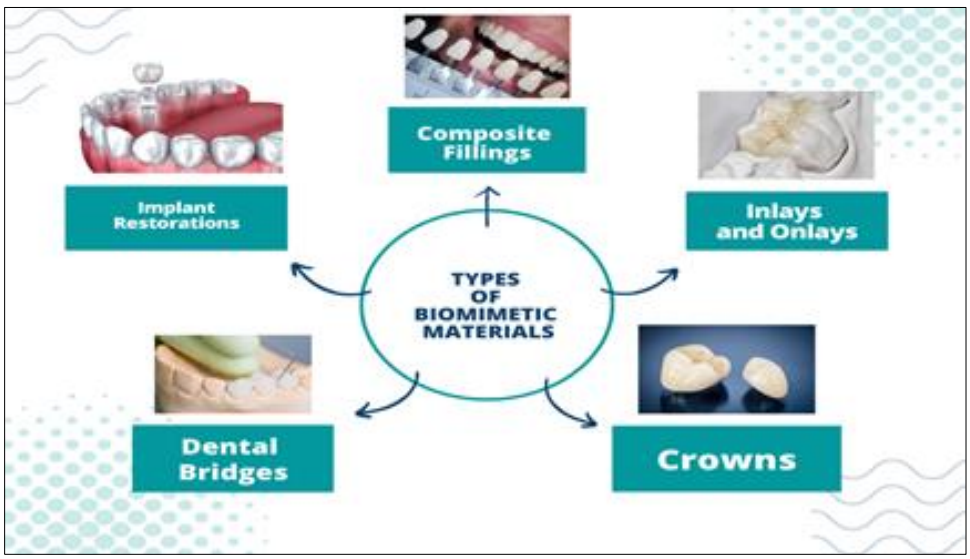

Figure 5 Various dental procedures using biomimetic materials

3.3.1. Composite fillings

To restore teeth with cavities and maintain a natural appearance, composite fillings use tooth-colored material. An amalgam filling is applied to the tooth after the decay is removed, and the material is cured with a specialised light to harden it. One visit is all that is required to complete a composite filling [16].

3.3.2. Inlays and Onlays

If there is not enough tooth structure left to support a filling but enough to support a partial crown, an inlay or onlay can be placed. A porcelain or gold inlay or onlay replaces the missing tooth structure aesthetically and functionally [16].

3.3.3. Crowns

The purpose of dental crowns is to restore the health, function, and appearance of a tooth that has been cracked, broken, worn down, or severely decayed. In order to get a crown, you must take digital impressions, remove all decay and damage from your tooth, and then bond the crown to the prepared tooth [16].

3.3.4. Dental bridges

Bridges are used to replace one or more missing teeth. The two teeth next to the missing teeth are given crowns as part of a standard dental bridge, and these crowned teeth support a span of replacement teeth, commonly referred to as pontics. Cantilever bridges, Maryland bridges, and implant-supported bridges are further bridge possibilities [16].

3.3.5. Implant Restorations

Dental implants are made up of three parts: a small titanium screw, an abutment that joins the screw and the final restoration, and the final restoration itself. A firm basis for fixed or removable replacement teeth is provided by the screw, which is inserted into the jawbone and replaces the tooth root. Over the course of a few months, the screw starts to merge with the bone [16].

3.4. Most commonly used biomimetic materials in pediatric dentistry [17]:

Table 1 Most commonly used biomimetic materials in pediatric dentistry

Calcium Hydroxide	•Cavity liner • Indirect pulp capping. • Direct pulp capping. • Pulpotomy. • Dressing of the root canal. • Long term temporary dressing. • Treatment of infected root canals and periapical lesions. • Apical closure. • Prevention of root resorption. • Repair of iatrogenic perforations. • Treatment of horizontal fracture. • Constituent of root canal sealer.
Mineral trioxide aggregate (MTA)	• Pulp capping. • Pulpotomy. • Root canal filling. • Furcation perforation repair. • Resorption repair [17].
Biodentine	• It is used as a dentine substitute under a permanent restoration, and can be categorised as Indirect pulp capping material. • Used as a direct pulp capping material • Partial pulpotomy. • Pulpotomy in primary molars • Apexification. • Repair of perforated root canals and/or pulp chamber/floor. • Root end filling material [18]
MTYA1 Ca-filler	Good direct pulp capping material [19]

TTCP	Biomedical purpose. Reduces inflammation and allergic effect resulting from acidic substances [20]
Sol-gel derived Ag-BG	The development of a cement-like behaviour of dental ceramics
Calcium Phosphate	Endodontic therapy because they are biocompatible, nontoxic and can induce mineralized tissue formation [21]

3.5. Broad Classification-

- Osteoproductive Materials- Osteogenic stem cells have colonised the area, which causes both an intracellular and an extracellular reaction at the contact.
- Osteoconductive Materials- When a substance at its interface merely causes an extracellular response, it provides a biocompatible interface along which bone can migrate [22].

Dental biomimetic is an alternative method in dentistry for the management of tooth decay. It has the potential beneficial properties of maintaining, mimicking and replacing natural tooth tissues (enamel and dentin) in the mouth without the use of toxic restorative materials.

Ultra-conservative treatment is recommended for the treatment of indented dentinal lesions. Therefore, the lesion restoration treatment is the most common technique used by dentists around the world today. It is used to prevent tooth decay and prevent its long-term progression.

It is well known that the traditional dental procedures for the removal of serious injuries depend on preparatory designs (cavity preparation) suitable for restorative materials.

It is well known that remineralization is a process that restores and replaces missing minerals (Hydroxyapatite = HA; Ca5 (PO) 3OH,

Fluorapatite = FA; Ca5 (PO) 3F or Strontium Fluorapatite = SrFA; Ca/Sr5 (PO) 3F) from the tooth surface to obtain a balancing mechanism [23].

The biomimetic method (especially the ATR technique) must be validated by Libyan dentists to achieve the remineralization of lost and damaged tooth tissues and essentially to alter the protocol. Knowledge on drill restorative treatment and fillers for fillings and cures [24].

Biomimicry describes a brand new technological know-how that research nature‘s exceptional thoughts and imitates those designs and methods to offer modern and sustainable answers for enterprise and studies improvement. It mimics consulting life‘s genius as nature to create new products, methods, and regulations to create new methods of residing which might be properly tailored to earth. It is a generation that is primarily based totally now no longer on what we are able to extract from nature, however on what we are able to examine from nature.

3.5.1. Or a clinician to have a really Biomimetic restorative materials-pushed practice, it implies the subsequent tenets:

Being obsessed with and in love with herbal dentition, and concerning intact unrestored enamel and their herbal layout because the absolute version to in addition the rumination and information of biology, morphology, mechanics, and function.

Striving for only removal of the diseased tissues and absolute upkeep of healthful tissues, in contrast to conventional prosthetic procedures that advocate massive sacrifices of healthful enamel, dentin, or even the pulp in a few instances, withinside the call of retention and resistance shape.

Becoming an expert “endodontist,” the use of verified adhesive protocols, and forsaking all principles primarily based totally on retention- and resistance-shape concepts due to the fact that much less is more. In different words, the use of direct, semi (in)direct, and oblique adhesive restorations in aggregate with composite resins, fibre-strengthened materials, and etchable ceramics, relying on the scale of the restorations and the complexity of the given case.

Making use of all up to date armamentaria, materials, products, and techniques that prefer minimally invasive procedures: visible aids, magnification, electric powered and oscillating handpieces, gold well-known dentin bonding agents, additive contours, instant dentin sealing, deep margin elevation, thermo-changed luting, etc.

4. Conclusion

The science and technology of the 21st century is largely based on the development of new materials, which are expected to be able to respond to environmental changes and perform their own functions under different conditions. Smart materials meet this requirement for environmentally friendly and responsive materials. Smart materials are a new generation of materials with great promise for the future in the field of "bio-smart dentistry". They are in the early stages of development and significant research is needed in this area of materials science. Pediatric dentists should be aware of these innovative materials so that they can use and utilise their optimal properties in their daily practice to provide effective and quality comprehensive treatment. Biomimetic Dentistry is primarily based totally at the philosophy that the intact teeth in its best colours and shades and, more importantly, its intracoronal anatomy, mechanics, and area in the arch, is the manual to reconstruction and the determinant [20]. In Biomimetic Dentistry there are aspects where the lost or missing dental tissue is restored, mainly to the overall go back of feature and aesthetics to the teeth or the fabric used can regenerate, mirror or mimic the misplaced dental tissue. This article will try and offer a higher knowledge of the relative function of the Biomimetic substances withinside the context of beyond and gift Dental substances.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

All the authors declare that there is no conflict of interest.

Statement of ethical approval

The study was approved by Institutional and Review Board, Kothiwal Dental College and Research Centre, Moradabad, Uttar Pradesh, India.

References

[1] Barthelat F. Biomimetics for next generation materials. Philos Trans A Math Phys Eng Sci. 2007 Dec 15;365(1861):2907-19.

[2] Chandran D, Chandran A. Scholars Journal of Dental Sciences. Nature. 2020;2:3.

[3] Vincent JFV. Biomimetics — a review. Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine. 2009;223(8):919-939.

[4] Bar-Cohen Y. (Ed.). Biomimetics: Mimicking and being Inspired by Biology. CRC Press, to be published in 2005.

[5] Bello OS, Adegoke KA, Oyewole RO. Biomimetic materials in our world: A review. J. Appl. Chem. 2013;5:22-35.

[6] Zhang G. Biomimicry in biomedical research. Organogenesis. 2012;8(4):101-102.

[7] Roseti, L.; Parisi, V.; Petretta, M.; Cavallo, C.; Desando, G.; Bartolotti, I.; Grigolo, B. Scaffolds for bone tissue engineering: State of the art and new perspectives. Mater. Sci. Eng. C 2017, 78, 1246–1262.

[8] Singh, D. A. P. S. (2021). Bioactive Material in Pediatric Dentistry. UNIVERSITYJOURNALOF DENTALSCIENCES, 7(2).: 117-123.

[9] Gupta V. Smart materials in dentistry: A review. International Journal for Advance Research and Development. 2018;3(6):89-96.

[10] Smart materials and systems. Postnote 2008;299:1-4.

[11] Allameh SM, Akogwu O, Collinson M, Thomas J, Soboyejo WO. Piezoelectric generators for biomedical and dental applications: Eff ects of cyclic loading. J Mater Sci Mater Med 2007;18:39-45.

[12] Gil FJ, Planell JA. Shape memory alloys for medical applications. Proc Inst Mech Eng H 1998;212:473-88.

[13] Stayton PS, El-Sayed ME, Murthy N, Bulmus V, Lackey C, Cheung C, et al. 'Smart' delivery systems for biomolecular therapeutics. Orthod Craniofac Res 2005;8:219-25.

[14] Rolland SL, McCabe JF, Robinson C, Walls AW. In vitro biofilm formation on the surface of resin-based dentine adhesives. Eur J Oral Sci 2006;114:243-9.

[15] Dahake PT, Kale YJ, Dadpe MV, Kendre SB. Effects of Biomimetic Materials on Stem Cells from Human Exfoliated Deciduous Teeth. Regenerative Engineering and Translational Medicine. 2022 Mar 30:1-8.

[16] https://www.aesthetics-in-dentistry.com/services/restorative-dental-services/

[17] Zafar M.S., Amin F., Fareed M.A., Ghabbani H., Riaz S., Khurshid Z. and Kumar N. (2020) Biomimetic aspects of restorative dentistry biomaterials. Biomimetics, 5(3).

[18] Dr. Vipin Arora et al. Bioactive dentin replacement. Journal of Dental and Medical Sciences 2013;12(4):51- 57.

[19] Niinuma et al, A. Newly developed resinous direct pulp capping agent containing calcium hydroxide (MTYA1-Ca). Int Endod J. 1999;32(6):475-83.

[20] Goswami S. Biomiometic Dentistry. J Oral Res Rev. 2018;10:28-32.

[21] Chatzistavrou X et al. Development of new sol-gel derived Ag-doped biomaterials for dental applications. Materials Research Society 2012; 1417: 39 – 46.

[22] Asthana G, Bhargava S. Bioactive materials: a comprehensive review. Sch. J. App. Med. Sci. 2014;2(6E):3231-7.

[23] Ten Cate J.M. and Van Duinen R.N.B. (1995) Hypermineralization of dentinal lesions adjacent to glass-ionomer cement restorations. Journal of Dental Research, 74(6), 1266-1271.

[24] Albeshti R. Biomimetic Dentistry: Less Drilling More Healing.

Author's short biography

Dr. Shruti Verma was born in Dehradun, city of Uttarakhand, state of India on 29th November, 1996. She was brought up in the heart of the city and completed her high school education at St. Joseph's Academy, Dehradun in 2014. She earned her Bachelor's degree in Dental Surgery from Seema Dental College and Hospital, Rishikesh, India in 2020. She started pursuing her Master's in Dental Surgery (Department of Pediatric and Preventive Dentistry) in 2021 from Kothiwal Dental College and Research Centre, Moradabad, India. She was awarded by the Indian Society of Pedodontics and Preventive Dentistry for her write-up on "Biomimetic Materials in Pediatric Dentistry: From Past to Future in 2022. The current article is a part of the same composition.