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Reviewing dental materials: Progresses for oral health and restoration

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Abstract. The field of density has made great progress in the modern era, especially in the aspects of developing a variety of novel materials that are used to repair teeth. Compared to traditional c, novel dental restorative materials are devoted to combining practicality and aesthetics, which are under the full consideration of the demands of patients. The emphasis of this review lies in the comparison of different novel dental restorative materials by providing their principles, benefits, disadvantages, and applications. The main advanced materials in this area that are chosen to be researched in this review are Ultra-High Molecular Weight Polyethylene Nanocomposites, Zirconia-based Composites, Activa Bioactive Restorative, Hydroxyapatite Restoration Materials, Bioprinting Materials, as well as Biomimetic and Tooth Surface Regeneration Materials. Researchers need to innovate in dental restorative materials with continuous pursuit. As these novel materials rapidly develop and are taken actions into application, they have a positive influence on dentistry. Our work involving studies of novel dental restorative materials provides patients with more practical and aesthetic therapy suggestions.

Keywords: Dentistry, Materials, Restoration.

1. Introduction

In the field of dentistry, one of the core and fundamental factors is the evolution of tooth replacement materials. These techniques and biological materials have already changed the dental practice and patient experience. Dentists and researchers have explored, refined, and introduced materials. So, some of the materials have experienced an optimization of functions, even integrated with natural teeth. This article will explain the roles, principles, and applications of Ultra-High Molecular Weight Polyethylene Nanocomposites [1-5], Zirconia-based Composites [6-8], Activa Bioactive Restorative [9], Hydroxyapatite Restoration Materials [10-12], Bioprinting Materials [13,14], as well as Biomimetic and Tooth Surface Regeneration Materials [15,16]. It will also compare these materials with historical dental restoration materials. This article illustrates the magnificent progress in oral rehabilitation through constant research on dental restorative materials. Not only do these materials make great contributions to fixing teeth, but they also help the development of aesthetic medicine. The researchers realize the

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combination of Academic wisdom, clinical techniques, and the patients' feelings, as well as display determination of continuous research and innovation to benefit human beings.

2. Ultra-High Molecular Weight Polyethylene (UHMWPE) Nanocomposites

In dentistry, Ultra-High Molecular Weight Polyethylene (UHMWPE) is renowned for biocompatibility and strength. Yet, graphene-based materials (GES) show promise as nanofillers to elevate dental restorative materials.

Increased Structural Order: The chemical modification and sonic exfoliation processes have resulted in a more ordered structure within the material. This enhanced structural order could improve the mechanical performance and stability of dental restorative materials, making them suitable for applications under high loads, such as chewing [1].

Crystallinity Index (CI): It has been observed that GES exhibits a higher Crystallinity Index (CI). This suggests a more ordered structure within the material, crucial for maintaining stability and reliability in dental restorations [2].

Size and Morphology: High-resolution SEM and AFM images have demonstrated that GES has nanometric dimensions and a specific morphology [3]. This could potentially influence the appearance and integration of the material within dental tissues, aiding in better adaptation [4].

Dynamic Mechanical Properties: The analysis indicates that adding GES can enhance the dynamic mechanical properties of the material, increasing its stiffness. This could facilitate easier shaping and adaptation during tooth restoration while maintaining adequate stiffness [5].

3. Zirconia-based Composites

Optical Properties: The appearance of dental restorations relies on optical properties, particularly translucency. Nanostructured ceramics, specifically zirconia-based ones, can improve translucency by reducing grain sizes to the nanoscale. This is crucial for creating realistic and aesthetically pleasing dental restorations [6].

Mechanical Properties: Zirconia-based ceramics have exceptional mechanical properties, including high flexural strength and fracture toughness. Nanostructured versions of these ceramics often exhibit even better mechanical properties than their micrometric counterparts due to fine grain sizes and improved microstructural homogeneity [7].

Commercial Nanostructured Zirconia-Based Ceramics: There are two commercial nanostructured zirconia-based ceramics for dental applications mentioned in the text: ZrHP-nano® and NANOZR®. These products have specific characteristics and can be used for dental restorations, such as single crowns, bridges, and implant-supported prostheses [8].

Clinical Trials and Indications: Clinical trials for nanostructured zirconia-based ceramics in dentistry are limited but show promising results. These ceramics have been used successfully in dental restorations with high survival rates. Recommendations include specific design considerations and cementation protocols for these restorations.

4. Activa Bioactive Restorative

Characteristics: Activa Bioactive Restorative with adhesive contains phosphate acid groups with antimicrobial properties, potentially enhancing its interaction with tooth structure [9].

Filtek Z350 XT/Z350 is a nanocomposite material with excellent shear bond strength.

Activa Bioactive Restorative with adhesive could be used when strong bonding and bioactive characteristics are desired, although its self-adhesive property should not be relied upon.

Fluoride Release: The mean fluoride concentration released by Activa Bioactive Restorative was 19.720 ppm on Day 1 and decreased to 0.032 ppm on Day 15.

The mean fluoride concentration released by Equia Forte glass ionomer cement (GIC) was 37,739 ppm on Day 1 and decreased to 9,703 ppm on Day 15.

Advantages: Equia Forte GIC exhibits high fluoride release, which can help prevent caries in the restoration and the surrounding tooth structure.

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Activa Bioactive Restorative releases a significant amount of fluoride on the first day, potentially providing initial caries prevention in the restoration vicinity.

Disadvantages: Activa Bioactive Restorative releases fluoride at a lower rate and may not offer sufficient caries protection in the long term.

Characteristics: Equia Forte is a GIC known for its high fluoride ion release, making it suitable for situations where caries prevention is crucial.

Activa Bioactive Restorative releases fluoride but at a slower rate, which may be suitable for cases not requiring high fluoride ion release.

Applications: Equia Forte is appropriate for cases where substantial fluoride release is needed to prevent caries [9].

5. Hydroxyapatite Restoration Materials

Hydroxyapatite restoration materials have been widely used to fix teeth in dentistry in the modern era. This material can repair tissue and be antibacterial by leaching calcium and hydroxyl ions into the surroundings. On the one hand, hydroxyapatite restoration materials have plenty of advantages. First of all, the principle of hydroxyapatite restoration is that it can form calcific bridges when applied to exposed pulpal tissue, and it will release calcium ions during ionic dissociation if it touches water as well [10]. Moreover, Hydroxyapatite restoration materials are effective in antibiosis. Increasing the hydroxyl ions and raising the pondus hydrogenii value is beneficial to prevent the regrowth of residual bacteria and restrict bacterial re-entry into the root canal system [11]. On the other hand, there are some disadvantages in hydroxyapatite restoration materials, too. In view that this material, when used as calcium hydroxide liners, cannot adhere to dentine or resin-based restorative materials, it will lead to a poor seal [12].

6. Bioprinting Materials

Bioprinting material is used in fixing complicated dental structures through customization, which can achieve a better effect on fixing teeth and shed new light on repairing. It makes excellent progress in replicating the natural regenerative processes [13]. It helps dental tissue repair by building an appropriate microenvironment that can support cell adhesion, proliferation, and differentiation with the consideration factors of biocompatible scaffolds, growth factors, and stem cells. In the modern era, the emergence of 3D bioprinting has improved the fabrication of complex scaffolds for dental tissue engineering. This technology can control scaffold architecture, porosity, and spatial distribution accurately. By adapting the design software on the computer, the patient-specific product will be created layer-by-layer with tailored mechanical and biological properties. However, this technology is under colossal challenge. The biomaterials which are chosen to be the 3D printing materials are restricted. They should fully consider the suitable rheological properties, biocompatibility, bioactivity, and mechanical strength. The complexity is how to maintain its structural integrity prosperously when it is used for printing and supporting cell viability. Moreover, another problem is that the bioprinting material lacks vascularization in the dental environment, which has a bad influence on the survival of tissue, nutrition, and integration of regenerated tissues [14].

7. Biomimetic and Tooth Surface Regeneration Materials

Biomimetic and tooth surface regeneration materials are generally employed in dentistry, which means to copy or mimic [15]. To create new synthetic materials and organs, the interdisciplinary field of “biomimicry” imitates the best biological approaches and strategies found in nature by applying concepts from physics, mathematics, chemistry, and engineering. Biomimetic dentistry is a method to repair damaged teeth under the consideration of the combination of art and science. Besides, appearance, function, and strength are the main requirements of biomimicry. To achieve this goal, scientists have created plenty of materials, and glass ionomer (Man-made dentin), dental resin, and ceramics are most widely used within them. There are several reasons for this. First and foremost, glass ionomer greatly benefits repairing teeth, which can constantly release fluoride and bond to enamel and dentin adhesively. As is all known, fluoride is good for the stiffness of teeth and makes teeth more stable. Besides, dental

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composite resin is an excellent material for restoring diseased and defective teeth due to its brilliant aesthetics, great biocompatibility, and ease of use [16]. Therefore, biomimetic and tooth surface regeneration materials benefit dental restoration.

8. Conclusion

Dental materials play a crucial role in oral health and restoration. Ultra-high molecular Weight Polyethylene (UHMWPE) nanocomposites, enhanced with graphene-based nanofillers, offer biocompatibility and strength for dental restorations. Nanostructured zirconia-based composites improve translucency and mechanical strength. Activa Bioactive Restorative provides strong bonding and bioactivity, releasing fluoride for initial caries prevention. Hydroxyapatite restoration materials have antibacterial properties but may lack adhesion in certain applications. Bioprinting materials, enabled by 3D technology, promise precise dental structures but face challenges like material selection and vascularization. Biomimetic materials like glass ionomer and dental resin offer aesthetics and fluoride release. These materials continue to advance oral care, benefitting patients' dental health.

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References

[1] Chevalier, J., Olagnon, C., & Fantozzi, G. (1999). Crack propagation and fatigue in zirconia-based composites. Composites Part A-applied Science and Manufacturing, 30(4), 525–530. https://doi.org/10.1016/s1359-835x(98)00145-6

[2] Arena, A., Prete, F., Rambaldi, E., Bignozzi, M. C., Monaco, C., Di Fiore, A., & Chevalier, J. (2019). Nanostructured Zirconia-Based Ceramics and Composites in Dentistry: A State-of-the-Art Review. Nanomaterials, 9(10), 1393. https://www.mdpi.com/2079-4991/9/10/1393

[3] Aliyu, I. K., Samad, M. A., & Al-Qutub, A. M. (2021). Friction and Wear Behavior of Ultra-high Molecular Weight Polyethylene/Graphene Nanoplatelets Nanocomposite Coatings at Elevated Temperatures. Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology, 135065012110537. https://doi.org/10.1177/13506501211053744

[4] Mutar, M. A., & Mahdi, M. S. (2019). Synthesis and characterization of novel nanocomposites with nanofillers particles and their applications as dental materials. Periodicals of Engineering and Natural Sciences (PEN), 7(3), 1512. https://doi.org/10.21533/pen.v7i3.815

[5] de Oliveira Aguiar, V., Roget Rodriguez Pita, V. J., de Fatima Vieira Marques, M., Soares, I. T., Martins Ferreira, E. H., Oliveira, M. S., & Monteiro, S. N. (2021). Ultra-high molecular weight polyethylene nanocomposites reinforced with novel surface chemically modified sonic-exfoliated graphene. Journal of Materials Research and Technology, 11, 1932-1941. https://doi.org/10.1016/j.jmrt.2021.02.027

[6] Torrisi, A., Torrisi, L., Cutroneo, M., Michalcova, A., D'Angelo, M., & Silipigni, L. (2023). Ultra-High Molecular Weight Polyethylene Modifications Produced by Carbon Nanotubes and Fe2O3 Nanoparticles. Polymers, 15(5), 1169. https://www.mdpi.com/2073-4360/15/5/1169

[7] Palmero, P., Fornabaio, M., Montanaro, L., Reveron, H., Esnouf, C., & Chevalier, J. (2015). Towards long-lasting zirconia-based composites for dental implants. Part I: Innovative synthesis, microstructural characterization, and in vitro stability. Biomaterials, 50, 38–46. https://doi.org/10.1016/j.biomaterials.2015.01.018

[8] Duarte, D. G. (n.d.). Synthesis and ceramic processing of alumina and zirconia-based composites infiltrated with glass phase for dental applications. Retrieved from https://inis.iaea.org/search/search.aspx?orig_q=RN:43130698

[9] Rifai, H., Qasim, S. S. B., Mahdi, S., Lambert, M., Zarazir, R., Amenta, F., . . . Zogheib, C. M. (2022). In-vitro evaluation of the shear bond strength and fluoride release of a new bioactive

DOI: 10.54254/2755-2721/84/20240882

dental composite material. Journal of Clinical and Experimental Dentistry, e55–e63. https://doi.org/10.4317/jced.58966

[10] Desai, S., & Chandler, N. (2009). Calcium Hydroxide–Based Root Canal Sealers: A Review. Journal of Endodontics, 35(4), 475-480. doi:10.1016/j.joen.2008.11.026

[11] Kim, S., Hwangbo, H., Chae, S., & Lee, H. (2023). Biopolymers and Their Application in Bioprinting Processes for Dental Tissue Engineering. Pharmaceutics, 15(8), 2118. Retrieved from https://www.mdpi.com/1999-4923/15/8/2118

[12] Arandi, N. (2017). Calcium hydroxide liners: a literature review. Clinical, Cosmetic and Investigational Dentistry, Volume 9, 67-72. doi:10.2147/ccidec81

[13] Ostrovidov, S., Ramalingam, M., Bae, H., Orive, G., Fujie, T., Shi, X., & Kaji, H. (2023). Bioprinting and biomaterials for dental alveolar tissue regeneration. Front Bioeng Biotechnol, 11, 991821. https://doi.org/10.3389/fbioe.2023.991821

[14] Kim, S., Hwangbo, H., Chae, S., & Lee, H. (2023). Biopolymers and Their Application in Bioprinting Processes for Dental Tissue Engineering. Pharmaceutics, 15(8), 2118. Retrieved from https://www.mdpi.com/1999-4923/15/8/2118

[15] Zafar, M. S., Amin, F., Fareed, M. A., Ghabbani, H., Riaz, S., Khurshid, Z., & Kumar, N. (2020). Biomimetic Aspects of Restorative Dentistry Biomaterials. Biomimetics, 5(3), 34. https://www.mdpi.com/2313-7673/5/3/34

[16] Singer, L., Fouda, A., & Bourauel, C. (2023). Biomimetic approaches and materials in restorative and regenerative dentistry: review article. BMC Oral Health, 23(1), 105. doi:10.1186/s12903-023-02808-3