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Article

Future Directions in Restorative and Aesthetic Dentistry: Innovations, Digital Advancements, and Biomimetic Approaches

Tay Hatem Kadhom Al-Taie

1. Department of University Healthcare - Al-Nahrain University
* Correspondence: tayhatim212@gmail.com, https://orcid.org/0000-0002-3752-6511

Abstract: Advancements in biomaterials, digital technology, and regenerative methods are resulting in a great transformation of restorative and aesthetic dentistry. Yet, the integration of biomimetic and AI based digital workflows as well as sustainability into clinical routines is not yet extensively explored. However, the article fills this gap by reviewing bioactive and nanotechnology enhanced materials, CAD/CAM, AI driven diagnostics and those that are regenerative such as stem cell therapies. The study synthesizes recent research and clinical advances to identify how modern materials increase mechanical strength, aesthetics and longevity while digital tools support precision of treatment and patient centered care. The findings indicate that biomimetic materials, minimally invasive approaches, and regenerative strategies, combined, can result in restorations that are functionally durable, visually natural and biologically compatible. This is the future where individualized therapies, sustainability and the industrial integration of restorative practice become the trends. Implications for a paradigm shift toward further more efficient and biocompatible, environmentally responsible dentistry, with potential improvement of patient outcomes and the establishment of a new Dental care standard in the worldwide.

Keywords: Bioactive Materials; Digital Dentistry; Minimally Invasive Techniques; Regenerative Dentistry; Nanotechnology in Dentistry; Aesthetic Restorations

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1. Introduction

For many years, restorative dentistry has been searching for materials and methods to repair damaged tooth structures. Numerous alternatives are offered as potential perfect replacements in the investigation of new product advances. Because of this, the industry has sometimes released restoratives that combine the best mechanical and natural-looking qualities. Furthermore, a large number of in vitro and in vivo investigations have examined materials and techniques to provide clinical and scientific justification for reliably producing restorations that mimic tooth tissues. Skilled ceramists use complex stacking procedures to create excellent outcomes that resemble biological tissues, as shown in Figure 1 [1].

Figure 1. Single unit ceramic crown on maxillary left central Incisor .

Clinicians have always been crucial in creating restorations that combine the properties of real tissues with synthetic ones in accordance with biomimetic principles. In the multidisciplinary area of biomimetics, materials, synthetic systems, or devices with functionalities that resemble biological processes are created using concepts from engineering, chemistry, and biology [2].

According to the biomimetic dental school of thinking, ceramics feldspathic porcelain, in particular, are the materials that most nearly resemble tooth structures in this case because they closely mimic the mechanical and visual properties of dental enamel. The calcium phosphate crystals (hydroxyapatite) and other component minerals of this acellular layer give enamel an anisotropic behavior and a light dispersion comparable to that seen in porcelain because enamel's high mineral composition makes it extremely similar to glass. The perfect synthetic alternative definition, however, can only be supported by more careful consideration. Compared to composite resins, porcelain is said to be more abrasive to opposing enamel. Furthermore, because of the longer and more expensive laboratory procedure, its production method necessitates more invasive tooth preparations as well as a more intricate and expensive workflow [3].

Recent advances in restorative and cosmetic dentistry combine science, technology, and art to improve dental health, function, and aesthetics. Restorative dentistry uses fillings, crowns, bridges, dentures, and dental implants to repair and replace teeth. Cosmetic dentistry, or aesthetic dentistry, employs teeth whitening, veneers, and composite bonding to improve the appearance of the teeth, gums, and smile. Modern minimally invasive treatments, biomimetic materials, and digital dentistry have transformed treatment methods, improving patient results, durability, and aesthetics. Restorative dentistry has advanced with biomimetic materials that imitate enamel and dentin. Modern composite resins and ceramics are strong, translucent, and wear-resistant, making restorations beautiful and enduring [4].

Nanotechnology has increased these materials' mechanical qualities, antimicrobial effects, and durability. Adhesive dentistry now uses stronger bonding chemicals to adhere to enamel and dentin, minimizing microleakage and secondary cavities. CAD/CAM technology transforms restorative procedures by creating precise, individualized restorations like crowns, veneers, inlays, and onlays in one dental visit. Intraoral scanners, digital impressions, and 3D printing improve treatment accuracy, efficiency, and patient comfort. AI in dentistry has improved diagnostic precision, treatment planning, and predictive analytics, enabling individualized and efficient patient care. Another innovative discipline, regenerative dentistry, uses stem cell therapy, platelet-rich plasma (PRP), and tissue engineering to rebuild tooth structures and periodontal tissues. Research on dental pulp stem cells (DPSCs) and mesenchymal stem cells (MSCs) has shown promise in rebuilding dentin, pulp, and periodontal tissues, enabling biological tooth repair and regeneration. In teeth whitening, veneer creation, and orthodontics, technology has improved aesthetic dentistry. Modern teeth whitening methods use light-activated gels and lasers for faster, more effective, and less sensitive outcomes. Thinner, more durable porcelain and composite veneers offer little preparation and outstanding aesthetics. Practitioners might use digital smile design (DSD) software to simulate treatment results to ensure patient satisfaction before starting therapy. Modern orthodontic treatments like clear aligners and lingual braces are more discreet and pleasant than metal braces, making them more appealing to adult patients. AI-driven orthodontic planning and 3D printing have increased aligner fabrication accuracy and efficiency, shortened treatment times and improved alignment [5].

Recent advances in soft tissue aesthetics, including gingival contouring, crown lengthening, and lip repositioning, improve smile harmony. Lasers increase soft tissue management precision, healing time, and patient comfort. Biomaterials having antimicrobial characteristics to prevent bacterial adhesion and biofilm formation are another restorative and aesthetic dentistry innovation [6]. Silver nanoparticles, bioactive glasses, and antimicrobial peptides are being studied to prolong restorations and prevent infections. Digital workflow integration in dental practices has simplified patient management from diagnosis to restoration. AR and VR in patient education and treatment simulations have increased patient involvement and treatment acceptability. Dental procedures using biodegradable materials, non-toxic sterilization, and digital processes are also becoming more environmentally friendly. Although impressive, assuring accessibility, affordability, and widespread deployment of cutting-edge dental treatments remains difficult. Future research may improve biomaterials, regeneration methods, and AI for diagnostics and treatment. As restorative and cosmetic dentistry evolves, interdisciplinary approaches, tailored treatment tactics, and patient-centered care will be crucial. New materials, digital advances, and regenerative procedures will revolutionize modern dentistry, enhancing patient quality of life worldwide [7].

2. Materials and Methods

The rehabilitative alternatives available to doctors have greatly evolved over the past 30 years. In 1981, young dentists had different material choices than they do today. Direct restorative materials included triturated amalgam capsules and composite materials (paste A and B) ready for simultaneous mixing before polymerization. In those days, the shade-picking and stacking process seemed too futuristic. In the past, dentists recommended a single shade for 75% of anterior fillings [8]. Patients had various expectations and definitions of esthetics at the time, as shown in Figure 2.

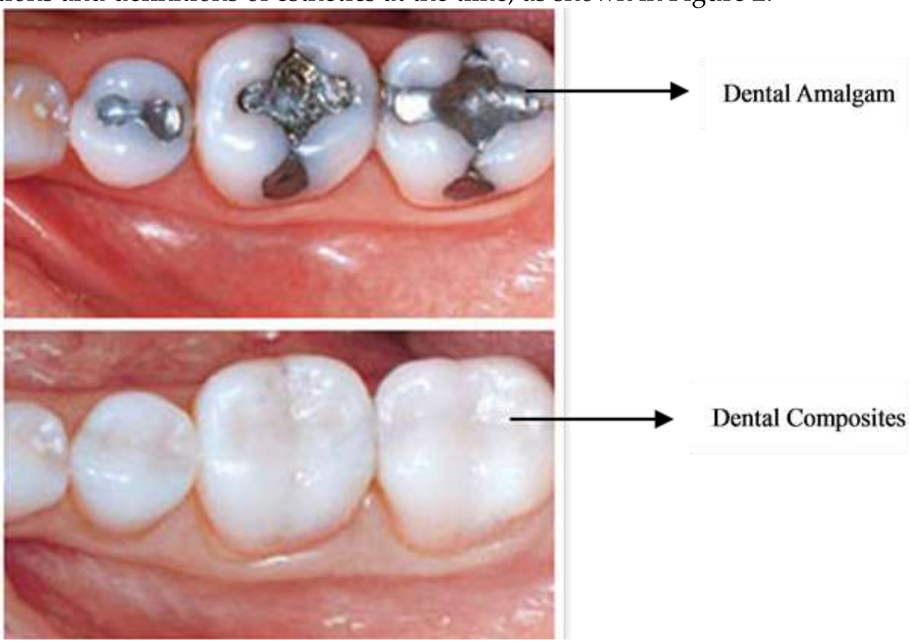

Figure 2. Dental composites .

Indirect Restorations

The indirect porcelain technique developed modestly. Beginning in the mid-1990s, a determined group of patients accelerated expansion as dental specialists sought a bioidentical repair that mimicked natural teeth's optical metamerisms [9]. Ceramics entered dentistry in the late 18th century when dentists discovered porcelain could be used to create denture teeth, which could be hollowed out and fitted to teeth for jacket crowns. While porcelain jacket crowns are attractive, their lack of strength (50 MPa) makes them readily chip off [10].

However, utilizing PFMs in the aesthetic zone has problems, such as limiting light properties like translucency and diffraction. In the 21st century, dentists must weigh the relative relevance of several variables, including strength, conservatism, and aesthetics, while making material decisions. Anterior aesthetics drives dentistry. There should be no "one size fits all" approach to diagnosing and treating people. Appropriate aesthetics need a commitment from lab technicians and clinicians to provide a restoration that not only looks good but also respects the underlying tooth structure [11].

Direct Restorations

In the latter half of the 20th century, silicate types of cement replaced acrylic resins as the only cosmetic material used in dentistry. Composites began to replace acrylic resin in the 1970s, and the first microfill composites were developed in the 1980s. Due to bonding technology and added features, the utilization of composites started to advance in the 1990s. Beginning with micro hybrids, information on the structure, size, load, and chemical makeup of the particles was generated. Diffraction capacity started to distinguish, and techniques for layering different composite materials to mimic the subtleties of tooth structure emerged [12].

In recent years, smart materials have drawn a lot of interest and attention in the dentistry field. The traditional glass ionomer has a number of uses. Glass ionomers have varying levels of translucency. The tissues of the tooth pulp are biocompatible with glass ionomers. It was first used as a biomaterial to restore the human body's missing skeletal tissues. Glass ionomers, which are primarily composed of glass and an organic acid, may be utilized to provide an attractive effect. However, they are not as beautiful as composites. In a London laboratory, Alan Wilson and his associates created GIC for the first time in the late 1960s [13].

In dentistry, acrylic resin first appeared in the middle of the 1950s. Since then, materials based on acrylic have been essential in the fields of restorative and prosthetics. Bowen's invention of bisphenol A glycidyl methacrylate, or BIS-GMA, in the early 1960s opened the door for a wider range of resin applications. The newer polymer has a better chance of having much larger applications, such as anterior and posterior composite cavities, indirect restorations, pit and fissure sealants, and more wear-resistant denture teeth. This composition had a higher molecular weight, which led to better mechanical properties and a decrease in polymerization shrinkage [14].

3. Results

Over time, dental materials have evolved to increase durability, aesthetics, biocompatibility, and usability. Bioactive materials like bioactive glass and calcium silicate-based cement, which rebuild teeth and encourage remineralization and healing, are revolutionary. These compounds release calcium, phosphate, and fluoride ions to prevent secondary cavities and prolong restorations. Composite resins, which are more attractive, wear-resistant, and durable than amalgam, have transformed restorative dentistry [15]. Nanoparticle-reinforced composites improve mechanical strength, polish ability, and color stability. Due to their robustness, natural look, and biocompatibility, zirconia, and lithium disilicate ceramic restorations have replaced metal-based ones. Crowns, bridges, and implant-supported prostheses made of these ceramics are metal-free and durable. 3D printing and CAD/CAM technologies have also transformed dental restorations by making crowns, bridges, dentures, and orthodontic aligners in a fraction of the time. Treatment time and visits are reduced with this computerized approach, improving accuracy and patient experience [16].

Smart materials like pH-responsive and antimicrobial coatings have expanded preventative dentistry. When required, these materials release antimicrobials to reduce bacterial colonization and prevent illnesses. Advanced adhesive dentistry has produced stronger, more dependable bonding chemicals that form a lasting contact between restorations and natural tooth structures, reducing microleakage and boosting lifetime. Biodegradable and regenerative materials, including stem-cell-infused scaffolds and hydrogels, are being investigated for tissue engineering to regenerate dentin, enamel, and pulp tissue. Laser-treated and nano-coated dental implants improve osseointegration and healing time. Modern polymer-based materials like flexible partial dentures and thermoplastic resins have enhanced patient comfort and adaption, minimizing allergies and mechanical failure. Glass ionomer cements with increased fluoride release have helped reduce cavities in childhood and geriatric dentistry. For environmental and health reasons, BPA-free composites and biodegradable impression materials have been developed in response to the green dental material trend. With biomimetic materials, artificial enamel, and self-healing resins in development, restorative and preventative dentistry will be transformed, improving patient outcomes and oral health globally [17], as shown in Figure 3.

Figure 3. Future Trends and Innovations in Dental [18].

Minimally invasive dentistry has transformed patient treatment by preserving dental structure, minimizing pain, and increasing long-term results. One of the biggest advances in cavity preparation is air abrasion and laser technology, which eliminates the need for drills and minimizes damage to good enamel and dentin. Laser dentistry uses erbium-doped lasers to cut hard and soft tissues precisely and painlessly, decreasing anesthetic and speeding recovery. Adhesive bonding allows cautious cavity preparations in restorative dentistry, removing just the afflicted tooth while preserving structural integrity [19].

Resin infiltration, especially for early-stage caries control, allows dentists to stop carious lesions without drilling, protecting tooth tissue and improving aesthetics. Bioactive compounds, including casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) and silver diamine fluoride (SDF), have also encouraged non-invasive caries prevention and arrest. Laser-assisted periodontal therapies, guided tissue regeneration, and enzyme-based biofilm removal have also reduced the requirement for surgery in periodontal therapy. Rotary nickel-titanium (NiTi) equipment and reciprocating file systems have made root canal operations more conservative, conserving dentin and minimizing tooth fracture risk. Regenerative endodontic methods, which use growth factors and stem cells to regenerate pulp-like tissue and extend tooth life, are also promising. Clear aligners and micro-osteoperforations expedite tooth movement and reduce patient pain compared to conventional braces in orthodontics [20].

Dynamic navigation technologies and computer-guided implant placement enable flapless surgery that lowers damage, discomfort, and recovery time. Implant placement and bone grafting are now more exact and less traumatic thanks to piezosurgery, which uses ultrasonic vibrations to cut bone. Non-prep or minimal-prep veneers are becoming more popular in cosmetic dentistry because they improve smiles while retaining most of the tooth structure. Digital dentistry, incorporating intraoral scanners and CAD/CAM technology, has improved accuracy and chair time and eliminated impressions, enabling less invasive procedures. AI in diagnoses and treatment planning has also enabled early dental disease identification and less intrusive therapies. Minimally invasive dentistry is moving away from harsh treatments and toward conservative, patient-friendly methods, increasing patient experience, treatment results, and long-term dental health. With biomaterials, nanotechnology, and regenerative therapy research, minimally invasive dentistry might change dental care by stressing preservation and prevention over significant intervention [21].

4. Discussion.

The Role of Digital Dentistry in Aesthetic Outcomes

Digital dentistry has revolutionized aesthetic outcomes by enhancing precision, efficiency, and predictability in dental treatments. Advanced technologies such as intraoral scanners, CAD/CAM systems, 3D printing, and digital smile design (DSD) allow for highly accurate planning and fabrication of restorations, ensuring superior aesthetics with minimal invasiveness. Intraoral scanners replace traditional impressions, providing detailed digital models that improve treatment accuracy while enhancing patient comfort. CAD/CAM technology enables the chairside fabrication of crowns, veneers, and bridges with precise fit, natural translucency, and optimal shade matching, reducing treatment time and eliminating errors associated with conventional lab work [22].

Digital smile design empowers clinicians and patients to collaboratively visualize and modify aesthetic goals before treatment, ensuring a more predictable and satisfying outcome. 3D printing has further transformed aesthetic dentistry by enabling the rapid production of customized aligners, temporary restorations, and surgical guides for more efficient and precise procedures. Additionally, artificial intelligence and machine learning are being integrated into digital workflows to refine aesthetic analysis and treatment planning, improving outcomes based on facial proportions and symmetry. The combination of these innovations ensures that restorations blend seamlessly with natural dentition, enhancing both function and appearance. Moreover, digital technology facilitates minimally invasive approaches by preserving more tooth structure while achieving optimal aesthetics. As digital dentistry continues to advance, the ability to create lifelike, customized, and long-lasting aesthetic solutions will further redefine patient expectations and treatment success, solidifying its essential role in modern cosmetic and restorative dentistry[23]

Biomimetic Approaches in Tooth Restoration

Biomimetic approaches in tooth restoration focus on replicating the structure, function, and properties of natural teeth to enhance durability, aesthetics, and long-term success. Unlike traditional restorative techniques that often sacrifice healthy tooth structure, biomimetic dentistry emphasizes minimally invasive procedures and materials that mimic the natural biomechanics of enamel and dentin. Advances in adhesive dentistry play a crucial role, with high-performance bonding agents and layered composite techniques ensuring restorations function harmoniously with natural tooth flexion and stress distribution. Bioactive materials, such as calcium silicate-based cement and bioactive glass, actively promote remineralization and strengthen the surrounding tooth structure, reducing the risk of secondary caries and restoration failure [24].

Additionally, nanotechnology has led to the development of nanoparticle-reinforced composites that improve mechanical strength, wear resistance, and longevity while maintaining the tooth's natural translucency. The use of smart materials, such as self-healing resins and pH-responsive composites, further enhances the restorative process by actively responding to changes in the oral environment. Digital workflows, including

CAD/CAM and 3D printing, have improved the precision of biomimetic restorations, allowing for the fabrication of highly customized, minimally invasive prosthetics that seamlessly integrate with natural dentition. As research progresses, regenerative techniques using stem cells and biomimetic scaffolds offer promising solutions for restoring lost tooth structure biologically. By prioritizing natural function and aesthetics, biomimetic dentistry is transforming restorative treatments, leading to longer-lasting, more natural-looking, and patient-friendly solutions that align with the principles of preservation and biological harmony [25].

Current Trends in Teeth Whitening Procedures

Innovative technology and formulas have improved teeth whitening efficacy, safety, and patient comfort. Professional in-office whitening treatments using high-concentration hydrogen peroxide or carbamide peroxide gels triggered by LED lights or lasers are a major trend. Because potassium nitrate and fluoride desensitize, these procedures provide quick results with low sensitivity. Patients now have more effective and easier at-home whitening alternatives with custom-fitted trays, whitening pens, and LED-activated kits. To soothe sensitive teeth, peroxide-free whitening products like PAP (phthalimidoperoxycaproic acid) are becoming more popular [26]. Nanotechnology also produces nano-hydroxyapatite-based whitening products that brighten teeth and remineralize enamel. Charcoal-based and natural whitening solutions are popular, although their long-term performance and safety are disputed. With AI-driven shade-matching technologies, digital dentistry can create more exact and individualized whitening regimens. For a complete smile makeover, combo treatments that combine whitening with veneers or composite bonding are becoming more popular. As consumer demand for whiter teeth rises, minimally invasive, long-lasting, and sensitivity-free teeth whitening technologies are changing the future, assuring safer and more effective treatments customized to specific patient requirements [27].

Restorative and aesthetic dentistry's future

Biomaterial, digital, and regenerative dentistry research is rapidly advancing restorative and cosmetic dentistry. These specialities aim to improve restorative lifespan, aesthetics, and usefulness while increasing patient comfort and decreasing invasiveness. Bioactive materials, digital workflows, AI, and regenerative dentistry are offering more individualized, precise, and physiologically harmonious dental treatment [28].

Progress in Biomaterials and Bioactive Restorations

Bioactive materials that rebuild tooth structure and encourage healing and remineralization have changed restorative dentistry. Bioactive glass, calcium silicate-based cement, and fluoride-releasing composites will be used in dental restorations. These materials actively interact with the oral environment to prevent secondary caries, prolong restorations, and strengthen tooth structures [29].

Additionally, nanotechnology is vital to biomaterial refinement. Nanoparticle-reinforced composites and ceramics outperform traditional materials in strength, wear resistance, and attractiveness. These nanomaterials better imitate enamel and dentin, creating durable, realistic restorations. Smart materials like self-healing resins and pH-responsive composites will revolutionize restorative dentistry by enabling restorations to adapt and mend tiny faults autonomously, minimizing replacement over time.

Integrating AI and Digital Dentistry

Digital technology is transforming restorative and cosmetic dentistry. The extensive use of CAD/CAM systems, intraoral scanners, and 3D printing has improved dental restoration efficiency and accuracy. As these technologies advance, restoration speed, accuracy, and personalization will increase, improving patient outcomes [30].

Digital dentistry using artificial intelligence (AI) is promising. AI-driven diagnosis and treatment planning software helps dentists discover cavities, fractures, and other dental disorders with unprecedented precision. AI systems can evaluate massive quantities of data to forecast treatment results, offer ideal restorative procedures, and match aesthetic restoration shades. This accuracy ensures restorations integrate perfectly with natural teeth and reduce treatment failure [31].

Again, 3D printing revolutionizes restorative dentistry. Printing dental prostheses, interim restorations, clear aligners, and biomimetic scaffolds is transforming dental care by lowering treatment time and cost. Custom-designed tooth structures injected with live cells may be possible with bioprinting, enabling biological tooth replacement instead of synthetic restorations .[32]

Biomimetic and Minimal Invasive Methods

Minimally invasive techniques that preserve tooth structure will dominate restorative dentistry in the future. Strong bonding and high-performance resins in adhesive dentistry will decrease tooth preparation. This shift follows biomimetic principles, which replicate tooth characteristics and disperse mechanical stress to protect tooth integrity.

Advanced resin infiltration methods may treat early caries lesions without drilling. These procedures use highly flowable resins to strengthen demineralized enamel without damaging tooth structure. As bioengineered materials improve, we should anticipate more conservative and attractive ways to fix voids and structural faults[33].

Future of Tooth Repair and Replacement: Regenerative Dentistry

Regenerative dentistry, which uses the body's inherent healing powers to rebuild teeth, is an intriguing new restorative dental trend. Researchers are investigating stem cells, growth factors, and tissue engineering to restore dentin, enamel, and teeth [34].

Injecting stem cell-infused scaffolds into injured teeth to regenerate dentin and pulp tissue appears promising. Stem cells develop and differentiate into dental tissues on biocompatible scaffolds. This technology might replace root canals with regenerative endodontics, maintaining tooth health. Gene therapy may also promote tooth regrowth. Scientists target dental tissue growth genes to promote tooth healing. Patients might rebuild tooth structures spontaneously via regenerative methods, eliminating the need for fillings, crowns, and dental implants [35].

Personal, aesthetic dentistry

Patient expectations for aesthetic results are rising, making individualized dentistry more vital. Future advances in digital smile design (DSD) and AI-driven aesthetic analysis will allow for highly individualized restorations that match an individual's facial characteristics, dental proportions, and personality. Digital processes will allow patients to see their smile alterations before committing to treatment, boosting satisfaction and confidence. Ceramic and composite advances will also enhance cosmetic dentistry. Restorations like ultra-thin veneers, transparent zirconia, and multi-layered ceramics will look like real teeth. AI-assisted shade-matching devices will also eliminate incompatibilities between restorations and a patient's natural dentition.

Sustainability and Green Innovations

Technology and sustainability are key to restorative dentistry's future. Environmental concerns regarding dental materials and procedures are driving researchers to produce eco-friendly and biodegradable materials. Dental products with BPA-free composites, recyclable impression materials, and environmental packaging are developing. Digital dentistry reduces impression and lab waste, helping to sustainability. In-office CAD/CAM milling and 3D printing decrease throwaway materials and improve workflows and efficiency [36].

5. Conclusion

New biomaterials, digital workflows, regenerative methods, and minimally invasive methods are shaping restorative and cosmetic dentistry. Bioactive and self-healing materials will extend restorative life and reduce replacements. Nanotechnology will continue to provide stronger, more attractive, and biocompatible restorations that replicate natural tooth structures. AI integration in diagnostics and treatment planning will improve accuracy, enabling early dental problem diagnosis and individualized therapies. Digital dentistry, including CAD/CAM and 3D printing, will improve restorative accuracy, efficiency, and patient comfort. With advances in stem cell research and tissue engineering, regenerative dentistry might replace dental restorations with biological components. Additionally, less invasive and biomimetic approaches will continue to preserve tooth structure, reduce patient pain, and improve treatment results.

Growing usage of digital smile design (DSD) and AI-driven aesthetic analysis will enable more tailored and predictable aesthetic treatments, improving patient satisfaction. Eco-friendly materials and digital processes that reduce waste and environmental effects will also be important in sustainable dentistry. Restorative and cosmetic dentistry will become more accurate, patient-friendly, and physiologically integrated as these technologies advance, improving long-term dental health and aesthetic outcomes.

REFERENCES

[1] Singer L, Fouda A, Bourauel C. Biomimetic approaches and materials in restorative and regenerative dentistry. BMC oral health. 2023;23(1):105.

[2] Yazdanian M, Rahmani A, Tahmasebi E, Tebyanian H, Yazdanian A, Mosaddad SA. Current and advanced nanomaterials in dentistry as regeneration agents: an update. Mini Reviews in Medicinal Chemistry. 2021;21(7):899-918.

[3] Almosa N. Impact of Incorporating Nanoparticles to Adhesive Resin on the Demineralization of Enamel: A Systematic Review. Dentistry Journal. 2025;13(3):89.

[4] Wrzyszcz-Kowalczyk A, Dobrzynski M, Grzesiak-Gasek I, Zakrzewski W, Mysiak-Debska M, Nowak P, et al. Application of selected biomaterials and stem cells in the regeneration of hard dental tissue in paediatric dentistry—based on the current literature. Nanomaterials. 2021;11(12):3374.

[5] Zheng L, Li K, Ning C, Sun J. Study on antibacterial and fluoride-releasing properties of a novel composite resin with fluorine-doped nano-zirconia fillers. Journal of dentistry. 2021;113:103772.

[6] Thomas JC, Ravindran DM, Balaji S. Applications of lasers in soft tissue esthetics: A Review. Lasers in Dental Science. 2025;9(1):1-7.

[7] Sobhani-Nasab A, Banafshe HR, Atapour A, Khaksary Mahabady M, Akbari M, Daraei A, et al. The use of nanoparticles in the treatment of infectious diseases and cancer, dental applications and tissue regeneration: A review. Frontiers in Medical Technology. 2024;5:1330007.

[8] Marin E. History of dental biomaterials: biocompatibility, durability and still open challenges. Heritage Science. 2023;11(1):207.

[9] Bonny T, Al Nassan W, Obaideen K, Al Mallahi MN, Mohammad Y, El-Damanhoury HM. Contemporary role and applications of Artificial Intelligence in Dentistry. F1000Research. 2023;12:1179.

[10] Jbeniany M. Bonding protocol for indirect ceramic restorations in posterior teeth: recommendations for success 2024.

[11] Li C, Wang G, Wang S, Shen W, Zhang Y, Kang J, et al. Fluorapatite Glass-Ceramics in Dentistry: Synthesis, Properties, Forming Technology, Applications, Challenges, and Future Perspectives. Materials. 2025;18(4):804.

[12] Raszewski Z, Nowakowska-Toporowska A, Nowakowska D, Więckiewicz W. Update on acrylic resins used in dentistry. Mini Reviews in Medicinal Chemistry. 2021;21(15):2130-7.

[13] Soraya L, Najoua L, Houda L, Malika S-I, Souad EH. Latest Intelligent and Sustainable Materials for Dental Application. Handbook of Intelligent and Sustainable Smart Dentistry. 2024:87-129.

[14] Saleem R, Sahoo AK, Gupta S. Application of Smart Materials in Dental Sciences. Smart Materials for Science and Engineering. 2024:75-88.

[15] Gianfreda F, Bollero P. Dental Materials Design and Innovative Treatment Approach. MDPI; 2023. p. 85.

[16] Aati S. Development of 3D printed resin-based nanocomposites for dental prosthetic restorations. 2023.

[17] Shamsudin NAS, Rozainis NA, Rasdi Z. Investigation on the Impact of Bisphenol A Exposure from Dental Materials: A Systematic Review. Compendium of Oral Science. 2024;11(2):96-112.

[18] Spielman AI. Dental education and practice: past, present, and future trends. Frontiers in Oral Health. 2024;5:1368121.

[19] Bennetch L. The Development of the Novel Utilization of Dental Lasers for Soft and Hard Tissue Procedures.

[20] Meghana ISS, Bhat AR, Bhandary R, Thomas B. Potential of lasers in the realm of aesthetic dentistry: A narrative review. Journal of Health and Allied Sciences NU. 2023;13(03):313-22.

[21] Assadawy MI. Immediate Dental Implant Practical Steps at Your Fingertips: Shineeks Publishers; 2021.

[22] Buchholz VS. Facial harmony: dental aesthetics and digital smile analysis. A systematic review. 2022.

[23] Alharkan HM. Integrating digital smile design into restorative Dentistry: A narrative review of the applications and benefits. The Saudi Dental Journal. 2024;36(4):561-7.
[24] Wang D, Han S, Yang M. Tooth diversity underpins future Biomimetic replications. Biomimetics. 2023;8(1):42.
[25] Tharoor S. The Impact of Biomimetic Approaches in Restorative Dentistry: Enamel-Like Restorative Solutions. Journal of dental care. 2024;1(1):81-7.
[26] Zanelatto DG, Moreira JC. Major clinical approaches to tooth whitening techniques and differences in terms of sensitivity and protection: a systematic review. MedNEXT Journal of Medical and Health Sciences. 2024;5(2).
[27] Akabane STF, Danelon M, Nunes GP, Gruba AS, de Souza-Costa CA, de Oliveira Duque CC, et al. Evaluation of the aesthetic effect, enamel microhardness and trans-amelodentinal cytotoxicity of a new bleaching agent for professional use containing trimetaphosphate and fluoride. Journal of the Mechanical Behavior of Biomedical Materials. 2021;114:104225.
[28] Aldhalai M, Almansour HH, Alyami SAH, Al-Thibah IAA, Alnasaib YJ, AlYami MMA. Advancements in Restorative Dentistry: A Systematic Review of Techniques and Materials. Journal of Ecohumanism. 2024;3(8):889-98.
[29] Saeed Al-Harbi AO, Shobayli SM, Alotaiby MS, Al Sayed AE, Abdallah Al-otaibi AM, Abdullah Alsomaly AT, et al. A Review on Biomaterials in Dentistry: Innovations and Applications. Journal of International Crisis & Risk Communication Research (JICRCR). 2024;7.
[30] Alaoffey AS, Asiri MA, Alhazmi TAA, Alshetaiwi AA, Almobarak AM, Alqasir YH, et al. Digital dentistry: transforming diagnosis and treatment planning through CAD/CAM and 3D printing. Egyptian Journal of Chemistry. 2024.
[31] Dhopte A, Bagde H. Smart smile: revolutionizing dentistry with artificial intelligence. Cureus. 2023;15(6).
[32] Allani H. Interdisciplinary applications of artificial intelligence (AI) in dentistry: a focus on endodontics, oral pathology, prosthodontics, orthodontics and periodontics 2024.
[33] El-Farag SAA, Elerian FA, Elsherbiny AA, Abbas MH. Impact of different CAD/CAM materials on internal and marginal adaptations and fracture resistance of endocrown restorations with: 3D finite element analysis. BMC Oral Health. 2023;23(1):421.
[34] Inchingolo AM, Inchingolo AD, Nardelli P, Latini G, Trilli I, Ferrante L, et al. Stem Cells: Present Understanding and Prospects for Regenerative Dentistry. Journal of Functional Biomaterials. 2024;15(10):308.
[35] Abdelrahman MRA. Unlocking regenerative potential: stem cell and tissue engineering innovations for permanent dental restoration. Discover Medicine. 2024;1(1):113.
[36] Speroni S, Polizzi E. Green Dentistry: State of the Art and Possible Development Proposals. Dentistry Journal. 2025;13(1):38.