

Emerging Technologies and Therapies in Orthodontics and Pediatric Dentistry: A Comprehensive Review

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ABSTRACT

Advancements in digital dentistry, artificial intelligence (AI), biomaterials, and minimally invasive treatment protocols have transformed orthodontic and pediatric dentistry. These emerging technologies have enhanced diagnostic accuracy, reduced treatment duration, and improved patient comfort. This review discusses recent developments including digital imaging, AI-assisted orthodontics, 3D printing applications, clear aligner innovations, laser therapies, nanotechnology, regenerative dentistry, teledentistry, and behavioral management technologies. Clinical strengths, limitations, and future directions are also addressed. These innovations emphasize personalized, evidence-based, and patient-centered dental care.

Keywords: Orthodontics, Pediatric Dentistry, Clear Aligners,

Artificial Intelligence, 3D Printing, Regenerative Dentistry, Digital Dentistry, Biomaterials, Laser Therapy, Nanotechnology.

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Article History:

Received: 15-10-2025, Revised: 04-11-2025, Accepted: 29-11-2025

Access this article online

Website: www.ijmrp.com	Quick Response code 
DOI: 10.21276/ijmrp.2025.11.6.003	

1. INTRODUCTION

Orthodontics and pediatric dentistry have evolved significantly due to digitalization, advanced biomaterials, and artificial intelligence. Traditional procedures are increasingly being replaced by predictive, minimally invasive, and precision-based approaches that enhance treatment outcomes and patient satisfaction. The convergence of AI, 3D printing, nanotechnology, and regenerative medicine is reshaping clinical practice by improving diagnostics, enabling individualized therapy, and expanding treatment possibilities for children and adolescents [1–3].

2. DIGITAL TRANSFORMATION IN ORTHODONTICS AND PEDIATRIC DENTISTRY

2.1 Intraoral Scanners

Digital scanners provide accurate impressions, minimize discomfort, and support efficient appliance fabrication. They significantly reduce cross-infection risks and are particularly beneficial for pediatric patients [4,5].

2.2 Cone-Beam Computed Tomography (CBCT)

CBCT allows precise 3D evaluation of dental structures, root morphology, airway analysis, and craniofacial anomalies. Low-dose pediatric protocols increase safety and expand diagnostic capabilities [6–8].

3. ARTIFICIAL INTELLIGENCE (AI) IN DENTAL DIAGNOSTICS

AI-based systems automate cephalometric tracing, growth predictions, treatment planning, and remote monitoring. They improve accuracy and reduce clinician workload [9–11].

Orthodontic Applications

- Automated cephalometric landmark detection [12]
- Prediction of tooth movement and facial growth [13]
- Aligners and bracket position optimization [14]

Pediatric Dentistry Applications

- Early detection of caries from radiographs [15]
- Risk assessment and behavior prediction [16]

4. 3D PRINTING IN ORTHODONTICS AND PEDIATRIC DENTISTRY

3D printing enables rapid fabrication of orthodontic appliances, customized aligners, space maintainers, pediatric crowns, and surgical guides [17–19]. Resin materials now provide durable and biocompatible restorations for children [20].

5. CLEAR ALIGNER INNOVATIONS

Clear aligners have evolved with digital modeling, AI prediction software, and 3D printing. New materials improve elasticity and

control tooth movement [21]. Remote monitoring and compliance tracking further enhance results [22].

6. LASER AND PHOTOBIOMODULATION THERAPIES

Lasers support soft-tissue procedures, reduce orthodontic pain, accelerate tooth movement, and improve wound healing [23]. In pediatric dentistry, lasers are useful for caries removal, frenectomy, and pulpotomy with minimal discomfort [24,25].

7. NANOTECHNOLOGY AND BIOMATERIALS

Nano-enhanced composites and varnishes offer superior strength, antibacterial activity, and remineralizing properties [26]. Nanocoated brackets and archwires reduce friction and inhibit bacterial adhesion, helping reduce white-spot lesions during orthodontics [27].

8. REGENERATIVE DENTISTRY AND BIOMIMETICS

Regenerative endodontics using stem cells and growth factors improves outcomes for immature permanent teeth with necrotic pulps [28]. Biomimetic enamel peptides and scaffold-based therapies show promising results in tissue regeneration [29].

9. TELEDENTISTRY IN ORTHODONTICS AND PEDIATRIC DENTISTRY

Teledentistry expanded during the COVID-19 era, enabling remote consultations, aligner monitoring, emergency triage, and parent education [30,31]. It enhances access to care, especially for children in remote areas.

10. BEHAVIORAL AND PAIN-MANAGEMENT TECHNOLOGIES

Virtual reality, audiovisual distraction, and biofeedback technologies help reduce anxiety and improve behavior in pediatric dental settings [32,33].

11. FUTURE DIRECTIONS AND CHALLENGES

Future advancements include intelligent self-adjusting braces, biologically guided orthodontics, genetic therapies for craniofacial anomalies, smart biomaterials, and chairside bioprinting. Ethical considerations, cost, training, and data privacy remain major challenges [34,35].

12. CONCLUSION

Technological advancements are rapidly transforming orthodontic and pediatric dental practice. Integration of AI, 3D printing, modern biomaterials, nanotechnology, and regenerative strategies provides more predictable, minimally invasive, and patient-friendly care. Continued research and practitioner training will be essential for maximizing clinical benefits and ensuring safe and ethical implementation.

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Source of Support: Nil. **Conflict of Interest:** None Declared.

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Cite this article as: Ahmed Ali AlGhamdi, Abdullah Mubarak Alzahrani, Ahmed Nasser Aladwani, Omamah Mustafa Gholam, Kholoud Mohammad Baradah. Emerging Technologies and Therapies in Orthodontics and Pediatric Dentistry: A Comprehensive Review. *Int J Med Res Prof.* 2025 Nov; 11(6): 11-13. DOI:10.21276/ijmrp.2025.11.6.003