

4D printing in dentistry: emerging horizons and challenges

 **Miguel Á. Saravia-Rojas¹,**
 **Rocio Geng-Vivanco²**

¹ Universidad Peruana
Cayetano Heredia, Faculty of
Stomatology. Lima, Peru.

² University of São Paulo,
School of Dentistry of Ribeirão
Preto, Department of Dental
Materials and Prosthodontics.
Ribeirão Preto, SP, Brazil.

Received: September 03, 2024

Accepted: January 14, 2025

Online: September 30, 2025



Open access article

© The authors

© Revista Estomatológica Herediana

Dear Editor:

The technological revolution has transformed every aspect of daily life, including dental practice. Among these innovations, 4D printing has emerged as a promising development that could redefine the field. This technology combines three-dimensional fabrication with a fourth dimension: time (1). In essence, 4D printing enables the creation of three-dimensional structures capable of transforming over time under the influence of external stimuli such as temperature, light, or humidity (2).

In dentistry, 4D printing is being explored for the fabrication of customized surgical guides and orthodontic devices that dynamically adapt to the conditions of the oral cavity, resulting in a more precise fit and improved retention. This represents a significant improvement in both comfort and efficiency for patients. Moreover, 4D-printed materials can adapt to mechanical stresses within the oral cavity, which is crucial for ensuring proper fit and long-term retention (2).

4D printing could transform how individual patient needs are addressed, optimizing clinical time and enhancing the patient experience. However, as with any disruptive technology, its adoption presents several challenges. The cost of materials and production equipment can be extremely high. In addition, the development and implementation of these materials require advanced technical knowledge, which implies a steep learning curve for professionals (3). From a technical perspective, one of the most significant challenges is ensuring the durability and biocompatibility of these materials within the complex oral environment (4).

Regulatory and ethical challenges must also be addressed to ensure the safety and efficacy of treatments. The approval of new 4D materials requires rigorous evaluation processes, and the possibility that these materials may alter their functional properties raises concerns regarding the predictability and control of dental treatments (5).

Cite as:

Saravia-Rojas MÁ, Geng-Vivanco R. 4D Printing in dentistry: emerging horizons and challenges. Rev Estomatol Herediana. 2025; 35(3): 247-248.
DOI: 10.20453/reh.v35i3.5747

Despite these challenges, 4D printing opens a promising path in dentistry. As educators and professionals, it is imperative to foster research in this area and to explore strategies that enable its integration into routine clinical practice. Commitment to continuing education and interdisciplinary collaboration will be key to maximizing the positive impact of this technology.

In summary, 4D printing has the potential to transform modern dentistry by providing more efficient and personalized solutions. The adoption of this technology requires overcoming technical and regulatory challenges, while also paving the way toward a more innovative and patient-centered future (6).

Corresponding author:

Miguel Ángel Saravia Rojas

✉ miguel.saravia@upch.pe

REFERENCES

1. Perambudhuru Y, Goyal L, Dewan M, Mahajan A, Chaudhari PK. Application of 4D printing in dentistry: a narrative review. *J Adv Periodontol Implant Dent* [Internet]. 2024; 16(1): 55-63. Available from: <https://doi.org/10.34172/japid.2024.003>
2. Javaid M, Haleem A, Singh RP, Rab S, Suman R, Kumar L. Significance of 4D printing for dentistry: materials, process, and potentials. *J Oral Biol Craniofac Res* [Internet]. 2022; 12(3): 388-395. Available from: <https://doi.org/10.1016/j.jobcr.2022.05.002>
3. Tigmeanu CV, Ardelean LC, Rusu LC, Negrutiu ML. Additive manufactured polymers in dentistry, current state-of-the-art and future perspectives - A review. *Polymers* [Internet]. 2022; 14(17): 3658. Available from: <https://doi.org/10.3390/polym14173658>
4. Cai H, Xu X, Lu X, Zhao M, Jia Q, Jiang HB, et al. Dental materials applied to 3D and 4D printing technologies: a review. *Polymers* [Internet]. 2023; 15(10): 2405. Available from: <https://doi.org/10.3390/polym15102405>
5. Palanisamy S. Exploring the horizons of four-dimensional printing technology in dentistry. *Cureus* [Internet]. 2024; 16(4): e58572. Available from: <https://doi.org/10.7759/cureus.58572>
6. Shie MY, Shen YF, Astuti SD, Lee AK, Lin SH, Dwijaksara NL, et al. Review of polymeric materials in 4D printing biomedical applications. *Polymers* [Internet]. 2019; 11(11): 1864. Available from: <https://doi.org/10.3390/polym11111864>