

# The Use of Bio-Inks and the Era of Bioengineering and Tooth Regeneration

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## ABSTRACT

**Objective:** To review existing literature and provide an update on the current use of Bio-Inks and potential future use. **Material and Methods:** A MeSH keyword search was conducted to find out relevant articles for this short review. **Results:** Bio inks used in 3D printing grafting require various properties essential for the selection. Combining multiple methods and improved properties is essential for developing successful bio-inks for 3D grafting of functional tissues and tooth pulp regeneration from stem cells. To date, researchers have made many efforts to grow teeth based on stem cells and inculcate regeneration of teeth along with surrounding tissues like alveolar bones and periodontal ligaments. **Conclusion:** 3D printing with Bio-Inks requires strict adherence to safety protocols for successful outcomes, making it difficult to employ this routinely.

**Keywords:** Regeneration; Bioengineering; Tooth; Stem Cells.

## Introduction

Dental caries is considered to be one of the most common causes of early tooth loss if left untreated [1]. Therefore, nonbiological (artificial) dental implants are being increasingly used to manage tooth loss [2]. This treatment modality is standard because the approach focuses on rapid recovery from tooth loss and promises a natural appearance. Nevertheless, differences exist between a natural tooth and an artificial implant, which might frequently cause alveolar tooth loss [2].

Around 64% of the patients undergo alveolar bone loss after receiving a dental implant within two months of the treatment [3]. To solve the issues, researchers are working on developing cell-based artificial teeth that have the same physiological properties as natural teeth, which can be used as an alternative to dental implants.

## Tooth Regeneration

The demand for tissue regeneration and transplantation of tissues and organs is increasing with every passing day. Recent advancements in the field of bioengineering, along with regenerative medicine, have made it possible to regenerate various damaged body parts of functioning organs. 3D bioprinting has made it possible to rehabilitate tissues and organs. It has revolutionized the world of tissue engineering over the past few decades. Since 1990 researchers have been working on skin regeneration, tissue grafting, and bio-fabrication. For decades 3D bioprinting has been used by micro engineers in manufacturing tissue structures from stem cells [4,5]. In recent decades, 3D printing has been used in the bio-fabrication of functional organs and working tissues advancing the medical field. Bio inks used in 3D printing grafting require various properties essential for the selection. Combining multiple methods and improved properties is necessary for developing successful bio-inks for 3D grafting of functional tissues and tooth pulp regeneration from stem cells [5].

To date, researchers have made many efforts to grow teeth based on stem cells and inculcate regeneration of teeth along with surrounding tissues like alveolar bones and periodontal ligaments [6]. In addition, bioengineers and oral biologists frequently carry out studies based on tooth germ, aiming to implant stem cells into animals and study successive tooth formation [7]. These methods ensure the formation of composite tissue, which is similar to a real-life human tooth (Figure 1).

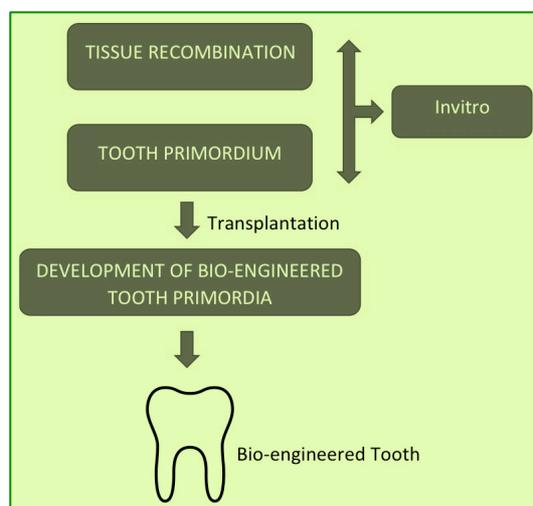


Figure 1. The Bio-engineering process.

Scaffold-based methods are commonly introduced for artificial tooth regeneration stem cells [8]. These methods have been reported to be successful in producing somewhat tooth-shaped tissues but failed to produce a patient-specific tooth shape composite tissue composed of pulp, dentin, and enamel [9]. Studies focused on achieving structural and compositional similarities between a fabricated tooth and a three-dimensional (3D) patient-specific tooth is pivotal for future clinical applications. Furthermore, there are limitations to tooth germ-based approaches; it is difficult to control the size and shape of the tooth, and it is hard to culture the primary biological sources for the preparation of germ structures. Lastly, scaffold-based methods are not suitable for regenerating tooth alike tissues for the reason that it cannot meticulously replace various cells in a proper pre-defined manner.

In tooth tissue engineering, the shape and design of the tooth must be patient-specific, as it is essential for clinical applications. Different problems can arise during some dental treatments, especially orthodontics. If the size and shape of the tooth are not matched correctly, this can also lead to diverse issues like facial asymmetry, problems in speech pronunciation, and impaired mastication [10,11]. Researchers used Computed tomography CT and applied it to data in 3D bioprinting, which was then converted to a printing code. This successfully illustrated that bio-ink and 3D hybrid bioprinting were used to design 3D patient-specific cellular components of tooth tissue in a pre-defined manner [5]. Researchers have developed various bio-inks to fabricate different tissues so that their characteristics match those of human body tissues and organs.

## Conclusion

Despite 3D printing becoming more affordable in the past few years, there are several costs involved that include materials, equipment maintenance, and the requirement of highly skilled professionals. It also requires strict adherence to safety protocols for successful outcomes, making it difficult to employ this routinely. However, these costs should come down with time, and this technology should have an ever-increasing role in dentistry in the future.

## Authors' Contributions

ST		---	Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing - Original Draft and Writing - Review and Editing.
SA		<a href="https://orcid.org/0000-0002-2421-0753">https://orcid.org/0000-0002-2421-0753</a>	Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing - Original Draft and Writing - Review and Editing.
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All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

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## Conflict of Interest

The authors declare no conflicts of interest.

## Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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