ACTA SCIENTIFIC DENTAL SCIENCES

Volume 8 Issue 8 August 2024

Review Article

Artificial Intelligence: Tooth Re-Generation Now a Real Possibility? A Quick Review

Chetan Vinay Deshmukh[1]*, Vibhuti Dilip Mistry[2], Seema Deoman Kamble[3] and Amit Prabhakar Chaudhari[4]

[1]*Assistant Professor, Public Health Dentistry, Nair Hospital Dental College, Mumbai, India*

[2]*Assistant Professor, Periodontology and Oral Implantology, JMF's ACPM Dental College, Dhule, Maharashtra, India*

[3]*Associate Professor and Head, Public Health Dentistry, Nair Hospital Dental College, Mumbai, India*

[4]*Assistant Professor, Public Health Dentistry, Nair Hospital Dental College, Mumbai, India*

***Corresponding Author:** Chetan Vinay Deshmukh, Assistant Professor, Public Health Dentistry, Nair Hospital Dental College, Mumbai, India.

Received: July 05, 2024

Published: July 17, 2024

Abstract

The tooth is a complex organ of the Oral cavity that develops from a interaction of processes, cells and signalling factors. The tooth is an important organ of the body with respect to its primary functions of biting, chewing as also its supplementary functions of aesthetics and phonetics. Loss of teeth not only poses a significant burden on the health system but also reduces the human quality of life. Current Dental treatments, though have advanced over a period of time, have an inherent inadequacy not being at par with the natural tooth tissues - enamel, dentin, cementum, pulp, periodontal ligament, alveolar bone and gingiva.

As opposed to the conventional dental treatments, regenerative dentistry aims to mimic natural dental tissues and help have a natural replacement of dental tissues. The ambitious aim of regenerative dentistry has been the regeneration of the entire tooth. However, with the limited resources and technology at hand, tooth regeneration seemed a long way to go.

However, with the advent and disruption of Artificial Intelligence across several domains of dentistry, tooth regeneration now looks a promising possibility.

Keywords: Artificial Intelligence; Tooth Regeneration; Regenerative Dentistry; Tissue Engineering

Introduction

Teeth are an essential organ of the body with a wide array of utilities - primarily being mastication or chewing of food. The other important functions of the teeth include - aesthetics and phonetics - both closely associated with optimum quality of life. Therefore, diseases of the teeth and supporting structure are of particular significance and pose a major burden to the public health [1]. Tooth loss in its entirety is common, especially in elderly individuals [2,3]. The major etiological factors for loss of teeth include - dental caries, gingival and periodontal diseases, accidents and trauma and lastly developmental and genetic anomalies leading to missing teeth. The prime culprit in dental diseases and the most common cause of loss of teeth globally and has been the chief reason for loss of teeth [4,5]. Contemporary dental treatments to treat the loss of teeth include conventional dental fillings which are conservative in nature to dental prosthesis that replace missing teeth. Both the conservative restorations as well as the prosthesis employ materials such as the traditional silver amalgams, cements or composites or metal allows, ceramics or acrylic prosthesis respectively. These materials tried and tested for over decades have a proven track record for their efficacy as well as overall safety for dental use. However, despite their proven evidence with regards to efficacy and safety - the materials largely attempt to 'mimic' the natural tissues of the teeth but fail to imitate the tissues in their entirety [6].

An upcoming approach towards dental treatment is the idea of 'regenerative dentistry'. The approach integrates the extensive study of the biological mechanisms of development of tooth with special emphasis on exhaustive learning of the mechanisms of regeneration - healing and repair. Regenerative dentistry aims to imitate these biological phenomena into achieving the herculean task of regenerating certain tissues or more ambitiously - the entire tooth. However enticing the concept seems, there have been several limitations in achieving these goals - primarily being the complex nature of tooth and its development process.

The tooth consists of a collection of connective tissue components consisting of blood vessels and its derivative cells, nerves, stem cells, etc encased within a specialised hard tissue known as dentin which contains the processes of odontoblasts within its tubules. The dentin is further covered by either cementum in the root; or enamel - the hardest component in the tooth organ complex - in the crown portion. The cementum in turn is surrounded by a specialised ligament known as the Periodontal Ligament which dissipates the masticatory forces from the tooth to the alveolar bone around it using an elegantly placed set of fibres connecting the tooth to the surrounding tissues - or 'periodontium' which is surrounded by a collar of Oral mucosa known as gingiva. This combination of tooth and its surrounding tissues are responsible for the various functions carried out by the teeth [7].

The tooth and its supporting structures are a specialised organ system that grow as a result of a complex developmental process that occurs in multiple stages and involves several factors in tortuous and intertwined processes. The process commences in the 9-10th week post gestation with the formation two processes of epithelial processes forming the dental and vestibular laminae which are surrounded by the mesenchyme. The tooth is thus formed as a combination of the ectoderm and and the underlying mesoderm. Reciprocal interactions between epithelial and mesenchymal tissues play a fundamental role in the morphogenesis of teeth and regulate all aspects of tooth development. It develops in stages termed as - the Bud stage, Cap Stage, and the Bell stages - Early and Advanced stages. The root formation continues even after the tooth have erupted into the oral cavity. The 20 deciduous teeth are developed first and the 32 permanent teeth buds continue developing after the eruption of the deciduous dentition. The development of tooth involves the interaction and reciprocal action between several growth factors that are responsible for signalling as well as cell differentiation such as Transferin, Fibroblast Growth Factor, Polypeptide Growth Factors, Epithelial Growth Factors (EGF) and others, thus proving that the growth of a 'simple' tooth involves a complex mechanism of development and involves a host of tissues, cells and signalling factors [8-13].

Therefore it can be safely deduced that achieving the potential to imitate tooth and its supporting structures and its developmental processes is a mammoth task. With the limited resources and technology available to us until recently, regeneration of a tooth seemed a far fetched dream. However the advent of Artificial Intelligence has ushered in a future that looks promising.

Artificial intelligence (AI) is a technology in which machines mimic intelligent human behavior. To better understand human-technology interactions in the clinical setting, augmented intelligence has been proposed as a cognitive extension of AI in health care, highlighting its assistive and supplemental role for medical practitioners. While genuinely autonomous medical robotic devices remain out of reach, the virtual component of AI, known as software-type algorithms, is widely used in dentistry. Because of their advanced data analysis capabilities, these virtual algorithms are expected to improve the accuracy and efficacy of dental diagnosis, provide visualised anatomic guidance for treatment, simulate and evaluate prospective results, and forecast the occurrence and prognosis of oral diseases [14].

AI models, such as convolutional neural networks and/or artificial neural networks, have demonstrated a variety of applications in endodontics, including studying the anatomy of the root canal system, forecasting the viability of dental pulp stem cells, measuring working lengths, pinpointing root fractures and periapical lesions, and forecasting retreatment procedure success. Future uses of this technology were discussed, including scheduling, patient care, drug-drug interactions, prognostic diagnosis, and robotic endodontic surgery. AI has shown accuracy and precision in endodontic disease identification, appraisal, and prediction. AI can help advance endodontic diagnosis and therapy, perhaps improving treatment outcomes. AI has similar uses in a variety of dental disciplines - but most importantly it has demonstrated its strengths with relation to a 'mapping' of dental anatomy and a 'analysis' of Oral Histology - especially with respect to Dental Stem cells in the pulp [15]. Therefore Artificial Intelligence can prove to be a valuable resource in achieving the ambitious aim of tooth regeneration.

This review aims to throw light upon the utility of Artificial Intelligence in Tooth Regeneration.

Methods

The current study being a review, encompassed the searching, studying and analysing of available literature with respect to Artificial Intelligence and Tooth Regeneration. Literature search was carried out using scientific databases and the available information was carefully perused and synthesised to form the review.

Artificial intelligence in tooth regeneration

Artificial intelligence (AI) is making significant strides in the field of tooth regeneration, offering new possibilities for dental restoration and treatment. Here's an overview of how AI is contributing to tooth regeneration.

The domain of tooth regeneration is witnessing a promising progress with the advent and contribution of Artificial Intelligence, opening up new frontiers for dental treatments. An overview of the current and possible uses of AI in influencing tooth regeneration are as follows:

Enhancing research and development

Data analysis

- **Genetic and molecular research**: AI algorithms have potential to analyze vast amounts of genetic and molecular data to identify key factors involved in tooth development and regeneration. This shall benefit the researchers to understand the biological processes and discover new therapeutic targets.
- **High-throughput screening**: AI can help accelerate the screening of potential drugs and biomaterials by predicting their efficacy in promoting tooth regeneration, significantly reducing the time required for research and development.

Tissue engineering

- **Scaffold design**: AI can outline and engineer scaffolds utilised in tissue engineering to support the growth, differentiation and maturing of dental stem cells. These scaffolds can be optimised for better integration with existing dental tissues.
- **Material optimisation**: AI can aid in the selection and optimisation of biomaterials that can support tooth regeneration, ensuring they have the necessary properties for successful implantation and growth.

Personalised Regenerative Treatments

Stem cell therapy

- **Stem cell differentiation**: AI models predict the optimal conditions for differentiating stem cells into dental tissues, enhancing the efficiency of stem cell therapies for tooth regeneration. They can customise the growth patterns of individual cell types using their respective signalling / growth factors.
- **Patient-specific treatments**: Perhaps the most important benefit of AI algorithm in Tooth regeneration shall be the 'customisation' of regenerative treatments siting patient specific needs. AI can analyse patient data, including genetic information and oral health history, to develop personalised stem cell treatments tailored to individual needs.

Growth factor delivery

- **Controlled release systems**: AI is a potent tool to design and optimise systems for the controlled release of growth factors, ensuring they are delivered at the right time and place to promote tooth regeneration. AI algorithm can help develop the timeline of the application of signalling factors / growth factors that shall mimic the natural developmental stages of the tooth.
- **Dosage optimisation**: AI algorithms can determine the optimal dosage and combination of growth factors required for effective tooth regeneration, minimising side effects and enhancing treatment outcomes.

Predictive modelling and simulation

Regenerative processes

- **Simulation of tooth development**: AI can simulate the complex processes of tooth development and regeneration, providing insights into how different factors interact and influence outcomes and thus also helping aid predicting the outcome.
- **Predicting treatment outcomes**: The predictive potential of AI algorithms have helped predict the outcomes of several treatments-interventions. AI models predict the success of various regenerative treatments based on patient-specific data, helping clinicians choose the most effective approach. This prediction of outcome using simulation can give an advanced insight into the prognosis of the treatment.

Risk assessment

- **Identifying complications**: The predictive tools of AI however are not restricted to determining the outcomes of the treatment alone. AI can predict potential complications and risks associated with tooth regeneration procedures, allowing for preventive measures and better planning and even cessation in case of deviation from the planned course of intervention.
- **Long-term prognosis**: A regenerated tooth is expected to mimic its natural counterpart with respect to its long term efficacy. Thus the AI based algorithms shall have an additional responsibility of analysing the long term prognosis of the regenerated tooth or tissue structure. This concern is also benefited by the fact that AI forecasts the long-term success and durability of regenerated teeth, guiding follow-up care and maintenance strategies.

Clinical applications and innovations

Bio-Printing

- **3D printing of dental tissues:** Artificial Intelligence has enhanced 3D bioprinting techniques and as such can also help to create dental tissues and structures with high precision, facilitating the development of customised regenerative solutions.
- **Integration with existing tissues:** Customised AI algorithms can also ensure that printed dental tissues integrate seamlessly with the patient's existing oral structures, promoting better functionality and aesthetics.

Minimally invasive techniques

- **Guided regeneration**: With the data analysis, highly precise scaffols, controlled release of signalling factors and a predictive tool to analyse the outcomes, risks and progrnosis, AI can develop minimally invasive techniques with better precision and accuracy for tooth regeneration, reducing patient discomfort and recovery time.
- **Monitoring regenerative progress**: AI-powered imaging and diagnostic tools have already started creating a shift in the imaging and radiography techniques. AI can thus help to monitor the progress of tooth regeneration in real-time, allowing for timely adjustments and interventions.

These potential benefits of AI in Tooth regeneration are though in a developing stage and exhaustive research needs to be carried out to integrate AI tools to perfect the tooth regeneration process.

Conclusion

AI is playing a crucial role in advancing tooth regeneration by enhancing research, personalizing treatments, and improving clinical outcomes. The integration of AI in regenerative dentistry holds the promise of developing more effective and tailored solutions for dental restoration, ultimately improving patient care and quality of life. As AI technology continues to evolve, its impact on tooth regeneration and overall dental health will likely expand, leading to innovative and transformative advancements in the field.

Bibliography

1. Righolt AJ., *et al*. "Global-, regional-, and country-level economic impacts of dental diseases in 2015". *Journal of Dental Research* 97.5 (2018): 501-507.

2. Kassebaum NJ., *et al*. "Global burden of severe tooth loss: a systematic re- view and meta-analysis". *Journal of Dental Research* 93.7 (2014): 20-28.

3. Kassebaum NJ., *et al*. "Global, regional, and national prevalence, inci- dence, and disability-adjusted life years for oral conditions for 195 countries, 1990-2015: a systematic analysis for the global burden of diseases, injuries, and risk factors". *Journal of Dental Research* 96.4 (2017): 380-387.

4. Kassebaum NJ., *et al*. "Global burden of untreated caries: a systematic review and metaregression". *Journal of Dental Research* 94.5 (2015): 650-658.

5. Petersen PE. "The world oral health report 2003: continuous im- provement of oral health in the 21st century-the approach of the WHO global oral health Programme". *Community Dental Oral Epidemiology* 31.1 (2003): 3-23.

6. Anusavice KJ., *et al*. "Phillips' science of dental materials". *Elsevier Health Sciences* (2012).

7. Nanci A and Ten Cate AR. "Ten Cate's Oral Histology: Development, structure, and function". St. Louis, Mo: Mosby (2003).

8. Kumar GS. "Orban's Oral Histology and Embryology-E-BOOK". *Elsevier Health Sciences* (2015).

9. Nelson SJ. "Wheeler's Dental Anatomy, Physiology and Occlusion-E-Book: Wheeler's Dental Anatomy, Physiology and Occlusion-E-Book". *Elsevier Health Sciences* (2014).

10. THESLEFF I and HURMERINTA K. "Tissue interactions in tooth development". *Differentiation* 18.1-3 (1981): 75-88.

11. Ali S., *et al*. "Tooth Development". *An Illustrated Guide to Oral Histology* 16 (2021): 1-3.

12. Balic A and Thesleff I. "Tissue interactions regulating tooth development and renewal". *Current Topics in Developmental Biology* 115 (2015): 157-186.

13. Partanen AM and Thesleff IR. "Growth factors and tooth development". *The International Journal of Developmental Biology* 33.1 (1989): 165-172.

14. Agrawal P and Nikhade P. "Artificial intelligence in dentistry: past, present, and future". *Cureus* 14.7 (2022).

15. Shan T., *et al*. "Application of artificial intelligence in dentistry". *Journal of Dental Research* 100.3 (2021): 232-244.