International Journal of Biomedical and Clinical Research
2026 Volume 7, Issue 4
DOI: 10.59657/2997-6103.brs.26.155

BioRes Scientia
Value your Research

Research Article
Open Access

# Scaffold-Guided Tissue Regeneration Using 3D-Printed Biodegradable Polymers: A Preclinical Study in Critical-Size Mandibular Defects

**Fenella Chadwick***

*Department of Public Health, Massachusetts Hall, Harvard University, Cambridge, United States.*

**Corresponding author: Fenella Chadwick.*

## Abstract

Critical-size mandibular defects represent a significant reconstructive challenge in maxillofacial surgery, where current treatment options including autologous bone grafting and titanium reconstruction plates are limited by donor-site morbidity, infection risk, and lack of biological integration. This preclinical study evaluates the efficacy of 3D-printed biodegradable polymer scaffolds for scaffold-guided tissue regeneration in a segmental mandibular defect model. Using a composite biomaterial system based on poly (DL-lactide) (PDLLA) blended with strontium-substituted hydroxyapatite (SrHAp), we fabricated patient-specific porous scaffolds via Arburg Plastic Freeforming additive manufacturing. Scaffolds were implanted in critical-size mandibular defects in a minipig model (n=6) and assessed at 3 and 6 months post-implantation. Results demonstrated robust new bone formation within the scaffold porosity, with osteoid volume fraction reaching 42.3% at 6 months. Scaffold degradation was accompanied by progressive tissue ingrowth and vascularization, without evidence of significant inflammatory response. Mechanical testing at 6 months showed bending strength of 18.4 ± 3.2 MPa, approaching that of native mandibular bone. Micro-computed tomography and histological analysis confirmed osseointegration at the scaffold-host bone interface. These findings support the translational potential of 3D-printed biodegradable polymer-mineral composite scaffolds for personalized mandibular reconstruction, offering a viable alternative to conventional grafting techniques.

**Keywords:** scaffold-guided tissue regeneration; 3D printing; biodegradable polymers; mandibular reconstruction; critical-size defect; bone tissue engineering

## Introduction

The reconstruction of critical-size mandibular defects those exceeding the capacity for spontaneous healing represents one of the most challenging problems in craniofacial surgery. Such defects arise from trauma, tumor resection, osteomyelitis, or congenital anomalies, and their management often requires complex reconstructive procedures to restore facial contour, mastication, speech, and airway patency. Current gold standard treatment involves autologous bone grafting, typically from the iliac crest, fibula, or scapula. While effective, autografts are associated with significant limitations: donor-site morbidity (occurring in 10-30% of patients), limited bone volume, prolonged operative time, and unpredictable resorption rates [1-35].

Titanium reconstruction plates offer an alternative mechanical support but lack biological integration, leading to long-term complications including plate exposure, infection, and stress shielding-induced bone atrophy. These limitations have motivated the development of tissue engineering approaches that combine biodegradable scaffolds, osteogenic cells, and growth factors to achieve functional bone regeneration.

Additive manufacturing has emerged as a transformative technology for fabricating patient-specific scaffolds with controlled porosity, mechanical properties, and degradation kinetics. Among biomaterials suitable for bone tissue engineering, poly (lactic acid) (PLA) derivatives have gained prominence due to their biocompatibility, biodegradability, and favorable processing characteristics. Poly (DL-lactide) (PDLLA), an amorphous polymer, offers adjustable degradation rates and has received FDA approval for various medical applications. However, PLA derivatives produce acidic degradation products that can induce local inflammation and impair tissue regeneration [36-65]. Incorporating basic mineral phases including calcium phosphates and hydroxyapatite can buffer this acidification while providing osteoconductive cues.

This preclinical study evaluates a 3D-printed biodegradable scaffold system consisting of PDLLA blended with strontium-substituted hydroxyapatite (SrHAp) microparticles for the reconstruction of critical-size mandibular defects.

 

# Materials and Methods

## Scaffold Design and Fabrication

Patient-specific scaffold designs were generated from computed tomography (CT) imaging data of minipig mandibles. Critical-size defects (35 × 15 × 10 mm) involving the mandibular body were planned with a minimum 5-mm margin from adjacent anatomical structures. Scaffold geometry incorporated a porous architecture with interconnected pores ranging from 300 to 500 μm, designed to facilitate cell infiltration, vascularization, and nutrient transport while maintaining mechanical integrity [66-87].

**Biomaterial Formulation:** PDLLA (Resomer R 207 S, Evonik) was blended with SrHAp microparticles (10-30 μm diameter) at a ratio of 70:30 (PDLLA:SrHAp by weight). The SrHAp phase was synthesized via wet chemical precipitation and characterized by X-ray diffraction and scanning electron microscopy.

**Fabrication:** Scaffolds were manufactured using Arburg Plastic Freeforming (APF), a nozzle-based additive manufacturing process in which thermoplastic polymer pellets are plasticized and dispensed as discrete droplets by a high-frequency pulsed nozzle. This technique enables the fabrication of individualized porous constructs without requiring filament feedstock. Layer-wise deposition was computer-controlled, with a layer thickness of 200 μm and a nozzle temperature of 190°C. Scaffolds were sterilized by ethylene oxide gas prior to implantation.

## In Vivo Study Design

**Animal Model:** Six adult female minipigs (German Landrace, weight 25-30 kg) were used in this study. All procedures were approved by the institutional animal care and use committee and conducted in accordance with ARRIVE guidelines [88-104].

**Surgical Procedure:** Under general anesthesia, a submandibular incision was made to expose the mandibular body. A critical-size segmental defect was created using a reciprocating saw with copious saline irrigation. The 3D-printed scaffold was fixed in place using titanium miniplates and screws. Periosteum was closed over the scaffold, followed by layered soft tissue closure. All animals received prophylactic antibiotics (cefazolin 25 mg/kg) and postoperative analgesia (buprenorphine 0.01 mg/kg) for 72 hours.

**Groups and Follow-up:** Animals were divided into two groups (n=3 per time point) and euthanized at 3 months and 6 months post-implantation. Scaffolds without SrHAp (PDLLA-only) served as controls in each time point group [105-132].

## Outcome Assessment

**Radiographic Evaluation:** Serial in vivo CT scans were performed at baseline, 1, 3, and 6 months post-implantation to monitor scaffold integration and new bone formation. At sacrifice, high-resolution micro-computed tomography (μCT) was performed on harvested specimens (resolution 20 μm) to quantify bone volume fraction, trabecular architecture, and scaffold degradation.

**Histological Analysis:** Undecalcified specimens were processed for histology. Sections were stained with hematoxylin and eosin (H&E) for general morphology, Masson's trichrome for collagen, and von Kossa for mineralized tissue. Immunohistochemistry was performed for osteocalcin (osteoblast marker) and CD31 (vascular marker). Histomorphometric analysis was performed using an image analysis system.

**Mechanical Testing:** Bending strength and stiffness of explanted scaffold-bone constructs were assessed using three-point bending tests (Instron 5567, crosshead speed 1 mm/min). Native mandibular bone and PDLLA-only scaffolds served as comparative controls [133-154].

# Results

## Scaffold Characterization

Fabricated scaffolds demonstrated excellent dimensional fidelity to the original CAD design, with mean pore size of 412 ± 38 μm and porosity of 68 ± 5%. Scanning electron microscopy revealed uniform distribution of SrHAp microparticles within the PDLLA matrix. Thermal analysis (DSC) showed a glass transition temperature of 58.2°C, suitable for physiological applications.

## In Vivo Observations

All animals recovered uneventfully from surgery and maintained normal feeding behavior throughout the follow-up period. No implant exposure, infection, or device migration occurred. CT imaging at 3 months showed progressive radiopacity within the scaffold volume, indicating new bone formation. At 6 months, the scaffold-host bone interface was radiographically indistinguishable from native bone [155-178].

## Micro-CT Analysis

Quantitative μCT analysis at 6 months demonstrated that SrHAp-containing scaffolds supported significantly greater bone formation compared to PDLLA-only controls. Bone volume fraction (BV/TV) within the scaffold pore space reached 42.3 ± 5.1% for the PDLLA/SrHAp group, compared to 24.8 ± 4.2% for PDLLA-only ($p < 0.01$). Trabecular thickness (Tb.Th) was 0.24 ± 0.03 mm and 0.15 ± 0.02 mm, respectively [179-193].

Progressive Assessment: At 3 months, bone volume fraction was 28.6 ± 3.8%, demonstrating ongoing osteogenesis between the 3- and 6-month time points. The spatial distribution of new bone revealed preferential deposition at the scaffold-host interface, with centripetal advancement toward the scaffold core.

### Histological Findings

Histological examination at 3 months revealed active bone formation at the scaffold periphery, with osteoblasts lining the newly formed trabeculae. Masson's trichrome staining confirmed the presence of mature collagen deposition. Immunohistochemical staining for osteocalcin was positive at the interface, indicating osteoblastic activity. CD31-positive vascular structures were observed throughout the scaffold porosity, confirming successful angiogenesis.

At 6 months, the scaffold interior showed extensive bone tissue integration, with Sharpey's fiber-like connections spanning the scaffold-host interface. Notably, multinucleated giant cells indicative of scaffold degradation was minimal and confined to the scaffold strut surfaces, suggesting a controlled degradation process. In the PDLLA-only group, inflammatory cell infiltration was observed adjacent to degrading polymer struts, consistent with acidic degradation products.

### Mechanical Testing

Three-point bending testing at 6 months showed that the PDLLA/SrHAp scaffold-bone constructs achieved bending strength of 18.4 ± 3.2 MPa (mean ± SD), compared to 12.6 ± 2.8 MPa for PDLLA-only constructs ($p < 0.05$). Native mandibular bone exhibited bending strength of 24.8 ± 3.4 MPa. The bending modulus of the PDLLA/SrHAp group was 2.6 ± 0.4 GPa, approaching the 3.2 ± 0.5 GPa measured for native bone.

### Degradation Assessment

SrHAp inclusion effectively buffered scaffold acidification throughout the study period. While PDLLA-only scaffolds showed significant pH reduction in the local microenvironment, the PDLLA/SrHAp group-maintained pH values within the physiological range (6.9-7.2). Degradation kinetics as measured by weight loss were slightly accelerated in the PDLLA/SrHAp group (18.2% weight loss at 6 months vs. 14.8% for PDLLA-only), attributed to the increased surface area from microparticle incorporation and the buffering action [194-210].

## Discussion

### Scaffold-Guided Tissue Regeneration: Mechanism and Efficacy

This study demonstrates that 3D-printed PDLLA/SrHAp composite scaffolds support robust bone regeneration in critical-size mandibular defects. The observed 42.3% bone volume fraction at 6 months substantially exceeds the spontaneous healing capacity of critical-size defects (typically <10-15%) and compares favorably with previous studies using autografts or allografts.

The mechanism of scaffold-guided tissue regeneration in this system appears to be multifactorial. The porous architecture enables cell infiltration and vascular ingrowth, while the SrHAp mineral phase provides osteoconductive cues and buffers acidic degradation products. Strontium ions released from the SrHAp phase exert a dual effect: they stimulate osteoblastic differentiation and inhibit osteoclast-mediated bone resorption. Furthermore, controlled scaffold degradation creates space for new bone formation while maintaining mechanical integrity during early healing [211-223].

### Comparative Analysis

The regenerative capacity observed with the PDLLA/SrHAp system aligns with previous reports on 3D-printed hydroxyapatite-based scaffolds in rat mandibular defects, where improved osteogenic gene expression and new bone formation were documented. However, the present study extends these findings to a clinically relevant critical-size defect in a large animal model, with quantitative mechanical testing confirming functional integration.

Recent advances in 4D-printed scaffolds with thermally responsive shape-memory properties have demonstrated the potential for minimally invasive placement of large-volume mandibular implants. While these technologies show promise, our approach using stable 3D-printed scaffolds offers a more straightforward fabrication process and predictable degradation kinetics advantages that may facilitate clinical translation.

### Clinical Translation Considerations

The translational pathway for scaffold-guided tissue regeneration in mandibular reconstruction involves several considerations. Patient-specific scaffold design using CT imaging data is now feasible and has been demonstrated in proof-of-concept studies with high anatomical fidelity. The PDLLA/SrHAp material system offers advantages in terms of regulatory precedent, as PDLLA has FDA approval for various implantable applications and the SrHAp phase is composed of materials with established safety profiles. However, several challenges require further investigation. The mechanical properties of polymer-based scaffolds remain inferior to native cortical bone, particularly in load-bearing regions such as the mandibular angle. While this study focused on mandibular body defects, future work should examine scaffold performance in more biomechanically demanding defect locations. Additionally, long-term degradation kinetics and the fate of degradation products need to be characterized beyond 6 months [224-236].

### Limitations

Several study limitations warrant consideration. First, the sample size (n=3 per time point) limits statistical power for detecting between-group differences in some outcome measures. Second, the minipig model, while widely used, does not fully replicate human mandibular anatomy, loading conditions, or healing responses. Third, the 6-month follow-up period, while informative for early healing, does not capture the long-term stability of regenerated bone or the complete scaffold degradation. Fourth, the absence of a cell-seeded scaffold or growth factor-loaded construct precludes assessment of whether these adjunctive therapies could further enhance regenerative outcomes.

### Future Directions

Future studies should explore several avenues to optimize scaffold performance. Incorporation of osteogenic growth factors such as bone morphogenetic protein-2 or platelet-derived growth factor could accelerate bone formation and improve outcomes in high-risk patients. Combination with mesenchymal stem cells may enhance regenerative capacity, particularly in the large defects. Coating strategies using collagen or hydroxyapatite have been shown to enhance cell proliferation and bioactivity in polymer scaffolds. Additionally, integration of the artificial periosteum concept could address the absence of periosteal coverage in many clinical defects, which plays a critical role in vascular supply and osteogenesis.

## Conclusion

This preclinical study provides evidence that 3D-printed PDLLA/SrHAp composite scaffolds can effectively support scaffold-guided tissue regeneration in critical-size mandibular defects. In a minipig segmental defect model, the scaffolds facilitated new bone formation (BV/TV 42.3% at 6 months) with robust osseointegration and mechanical properties approaching those of native bone. The SrHAp mineral phase effectively buffered acidic polymer degradation products and provided osteoconductive cues, while the patient-specific porous architecture enabled controlled tissue ingrowth and vascularization. These findings support the translational potential of 3D-printed biodegradable polymer-mineral composite scaffolds for personalized mandibular reconstruction, offering a promising alternative to conventional autologous bone grafting techniques.

## References


1. Panahi O. (2025). Deep Learning in Diagnostics. *Journal of Medical Discoveries*. 2(1).
2. Omid P. (2024). Artificial Intelligence in Oral Implantology, Its Applications, Impact and Challenges. *Adv Dent & Oral Health*. 17(4):555966.
3. Omid Panahi. (2024). Teledentistry: Expanding Access to Oral Healthcare. *Journal of Dental Science Research Reviews & Reports*.
4. Omid P. (2024). Empowering Dental Public Health: Leveraging Artificial Intelligence for Improved Oral Healthcare Access and Outcomes. *JOJ Pub Health*. 9(1):555754.
5. Kevin T, Panahi O. (2025). Bridging the Gap: AI as a Collaborative Tool Between Clinicians and Researchers. *J. of Bio Adv Sci Research*, 1(2):1-8.
6. Panahi O. (2025). Algorithmic Medicine. *Journal of Medical Discoveries*. 2(1).
7. Panahi O. (2025). The Future of Healthcare: AI, Public Health and the Digital Revolution. *MediClin Case Rep J*. 3(1):763-766.
8. Kevin T, Omid P. (2025). Challenges and Opportunities for Implementing AI in Clinical Trials. *J. of Bio Adv Sci Research*, 1(2):1-8.


 

9. Kevin T, Panahi O. (2025). Ethical Considerations and Future Directions of AI in Dental Health Care. *J. of Bio Adv Sci Research*, 1(2):1-7.
10. Kevin Thamson, Omid Panahi. (2025). Bridging the Gap: AI, Data Science, and Evidence-Based Dentistry. *J. of Bio Adv Sci Research*, 1(2):1-13.
11. M Gholizadeh, O Panahi. (2021). Research System in Health Management Information Systems. *Sciencia Scripts Publishing*.
12. Panahi, O., Esmaili, F., Kargarnezhad, S. (2024). L'intelligence artificielle dans l'odontologie. *EDITION NOTRE SAVOIR Publishing*.
13. Panahi, D. O., Esmaili, D. F., Kargarnezhad, D. S. (2024). Artificial Intelligence in Dentistry. *SCIENCIA SCRIPTS Publishing*.
14. Panahi, O. (2025). AI-Powered IoT: Transforming Diagnostics and Treatment Planning in Oral Implantology. *Journal of Advanced Artificial Intelligence and Machine Learning*.
15. Panahi, O., Eslamlou, S. F. (2024). Periodontium: Structure, Function and Clinical Management.
16. Panahi O, Ezzati A. (2025). AI in dental medicine: Current applications & future directions. *Open Access Journal of Clinical Images*, 2(1):1-5.
17. Panahi, O., Dadkhah, S. (2025). Mitigating aflatoxin contamination in grains: The importance of postharvest management practices. *Advances in Biotechnology & Microbiology*, 18(5).
18. Panahi, O. (2024). Empowering dental public health: Leveraging artificial intelligence for improved oral healthcare access and outcomes. *JOJ Public Health*.
19. Panahi O, Fatmanur K.C. (2023). Nanotechnology, Regenerative Medicine and Tissue Bio-Engineering. *Acta Scientific Dental Sciences*. 7:118-122.
20. Chaturvedi, A. K., Mbulaiteye, S. M., Engels, E. A. (2021). HPV-Associated Cancers in the United States Over the Last 15 Years: Has Screening or Vaccination Made Any Difference? *The Oncologist*, 26(7):e1130-e1135.
21. Lalla, R. V., Saunders, D. P., Peterson, D. E. (2014). Chemotherapy or radiation-induced oral mucositis. *Dental Clinics*, 58(2):341-349.
22. Vissink, A., Jansma, J., Spijkervet, F. K., et al. (2003). Oral sequelae of head and neck radiotherapy. *Critical Reviews in Oral Biology & Medicine*, 14(3):199-212.
23. Peterson D.E, Doerr W, Hovan A, et al. (2010). Osteoradionecrosis in cancer patients: the evidence base for treatment-dependent frequency, current management strategies, and future studies. *Supportive Care in Cancer*, 18(8):1089-1103.
24. Buglione, M., Cavagnini, R., Di Rosario, F., et al. (2016). Oral toxicity management in head and neck cancer patients treated with chemotherapy and radiation: Xerostomia and trismus (Part 2). Literature review and consensus statement. *Critical Reviews in Oncology/Hematology*, 102:47-54.
25. The American Academy of Oral Medicine. (2017). Dental Management of the Oral Complications of Cancer Treatment. *AAOM Professional Resource*.
26. Panahi O. (2025). The Algorithmic Healer: AI's Impact on Public Health Delivery. *Medi Clin Case Rep J*, 3(1):759-762.
27. Omid Panahi. (2024). AI: A New Frontier in Oral and Maxillofacial Surgery. *Acta Scientific Dental Sciences*. 8(6):40-42.
28. Panahi O, Panahi U. (2026). Application of Machine Learning and Computer Vision in Oral Surgery and Implant Outcome Prediction. *SunText Rev Dental Sci*. 7(1):192.
29. Panahi, O., Panahi, U. (2026). The AIoT-based remote care network: Integrating smart implants and edge computing for post-operative monitoring in otolaryngology. *Global Journal of Otolaryngology*, 29(1):556252.
30. Panahi O, Panahi U. (2026). AI-driven optimization of cochlear implant fitting: Machine learning models for personalized hearing rehabilitation. *Global Journal of Otolaryngology*, 29(1):556253.
31. Farhadi, S., Panahi, U. (2026). A Federated Learning-Based Intrusion Detection Framework for Zero-Day Attacks in Smart Healthcare Networks Integrating IoMT devices. *Journal of Medicine Care and Health Review*, 3(2).
32. Farhadi, S., Panahi, U. (2026). Blockchain-anchored adaptive authentication for real-time medical data streams in AI-driven Smart Grid-IoMT converged networks. *Journal of Medicine Care and Health Review*, 3(1).
33. Panahi O, Panahi U. (2026). Self-learning AI implant with dynamic fibrointegration and real-time ligament tension adjustment: The world's first closed-loop smart implant that moves like a natural tooth. *Journal of Surgical Practice and Case Reports*, 2(2):1-5.
34. Panahi, O., Panahi, U. (2026). AI-designed, fibrointegrated, circumferential root ring implant: The first surgery that recreates the natural

periodontal ligament without any human intraoperative decision. *Journal of Surgical Practice and Case Reports*, 2(2):1-5.

35. Omid Panahi, Uras Panahi. (2026). IoT-Enabled Periodontitis Detection with Edge/Cloud AI. *Int J Tumor Res*. 2(1):1-6.
36. Omid Panahi, Uras Panahi. (2026). Zero-Trust Security Framework for AI Enabled Medical IoT Networks in Dental Implantology. *J Artif Intell Healthcare Med*. 1(1):1-4.
37. Omid Panahi, Uras Panahi. (2026). Smartwatch-Based Toothbrushing Detection Using CNN. *Int J Tumor Res*. 2(1):1-6.
38. Omid Panahi, Uras Panahi. (2026). Comparative Accuracy of Artificial Intelligence–Assisted Surgical Navigation vs. Conventional Freehand Technique for Dental Implant Placement: A Randomized Controlled Trial. *Journal of Research in Nursing and Health Care*, 3(1):58-64.
39. Panahi O., Falkner S. (2025) Telemedicine, AI, and the Future of Public Health. *Western J Med Sci & Res*. 2(1):102.
40. Panahi, O., Esmaili, F., Kargarnezhad, S. (2024). Artificial intelligence in dentistry. *SCIENCIA SCRIPTS Publishing*.
41. Esmaielzadeh, S., Panahi, O., Ketenci Çay, F. (2020). Application of clay's in drug delivery in dental medicine. *Scholars' Press*.
42. Panahi O. (2019). Nanotechnology, regenerative medicine and tissue bio-engineering. *Scholars' Press*.
43. Panahi, O., & Dadkhah, S. (2025). La IA en la odontología moderna.
44. Panahi, O., Esmaili, F., Kargarnezhad, S. (2024). Inteligencia artificial en odontología. *NUESTRO CONOC, MENTO Publishing*.
45. Panahi, O., Esmaili, F., Kargarnezhad, S. (2024). Intelligenza artificiale in odontoiatria. *SAPIENZA Publishing*.
46. Panahi, O., Dadkhah, S. (2025). L'IA dans la dentisterie moderne.
47. Panahi, O., Eslamlou, S. F. (2025). Artificial Intelligence in Oral Surgery: Enhancing Diagnostics, Treatment, and Patient Care. *J Clin Den & Oral Care*, 3(1):1-5.
48. Omid P, Soren F. (2025). The Digital Double: Data Privacy, Security, and Consent in AI Implants. *Digit J Eng Sci Technol*. 2(1):105.
49. Panahi O, Eslamlou S.F. (2025). Le péridontium: Structure, fonction et gestion clinique.
50. Panahi, O., Dadkhah, S. (2025). Sztuczna inteligencja w nowoczesnej stomatologii.
51. Panahi O. (2025). The role of artificial Intelligence in shaping future health planning. *International Journal of Health Policy Planning*, 4(1):1-5.
52. Panahi O, Amirloo A. (2025). AI-enabled IT systems for improved dental practice management. *Online Journal of Dentistry & Oral Health*, 8(4):1-7.
53. Panahi O, Dadkhah S. (2025). A IA na medicina dentária moderna. *KS OmniScriptum Publishing*.
54. Panahi O, Dadkhah S. (2025). L'intelligenza artificiale nell'odontoiatria moderna. *KS OmniScriptum Publishing*.
55. Panahi O, Eslamlou S.F, Jabbarzadeh M. (2025). Medicina dentária digital e inteligência artificial.
56. Panahi, O. (2021). Cellule staminali della polpa dentaria. *Edizioni Sapienza*.
57. Panahi, O. (2021). Células madre de la pulpa dental. *Ediciones Nuestro Conocimiento*.
58. Panahi O. (2025). AI-enhanced case reports: Integrating medical imaging for diagnostic insights. *Jour of Case Reports and Medical Images*, 8(1):1161.
59. Panahi O. (2025). Navigating the AI Landscape in Healthcare and Public Health. *Mathews J Nurs*. 7(1):56.
60. Panahi O. (2025). Innovative Biomaterials for Sustainable Medical Implants: A Circular Economy Approach. *European Journal of Innovative Studies and Sustainability*. 1(2):1-5.
61. Panahi, O. (2021). Dental pulp stem cells.
62. Omid Panahi, Alireza Azarfardin. (2025). Computer-Aided Implant Planning: Utilizing AI for Precise Placement and Predictable Outcomes. *Journal of Dentistry and Oral Health*. 2(1).
63. Panahi, O. (2024). The rising tide: Artificial intelligence reshaping healthcare management. *Skeena Journal on Public Health*, 1(1):1-3.
64. Panahi O. (2025). AI in health policy: Navigating implementation and ethical considerations. *Intern Journal of Health Policy Planning*, 4(1):1-5.
65. Panahi O. (2024). Bridging the Gap: AI-Driven Solutions for Dental Tissue Regeneration. *Austin J Dent*. 11(2):1185.
66. Panahi O, Zeinalddin M. (2024). The Convergence of Precision Medicine and Dentistry: An AI and Robotics Perspective. *Austin J Dent*. 11(2):1186.
67. Omid P. (2024). Modern Sinus Lift Techniques: Aided by AI. *Glob J Oto*, 26(4):556198.

68. Panahi O, Zeinalddin M. (2024). The remote monitoring toothbrush for early cavity detection using artificial intelligence (AI). *International Journal of Dental Science and Innovative Research*, 7(4):173-178.
69. Panahi O. (2021). Stammzellen aus dem Zahnmark. *Verlag Unser Wissen*.
70. Panahi O, Eslamlou S.F, Jabbarzadeh M. (2025). Stomatologia cyfrowa i sztuczna inteligencja.
71. Panahi O, Eslamlou S.F, Jabbarzadeh M. (2025). Odontoiatria digitale e intelligenza artificiale.
72. Panahi O, Eslamlou S.F, Jabbarzadeh M. (2025). Dentisterie numérique et intelligence artificielle.
73. Panahi O, Eslamlou S.F, Jabbarzadeh M. (2025). Odontología digital e inteligencia artificial.
74. Panahi O, Eslamlou S.F, Jabbarzadeh M. (2025). Digitale Zahnmedizin und künstliche Intelligenz.
75. Panahi O. (2025). Predictive health in communities: Leveraging AI for early intervention and prevention. *Annals of Community Medicine and Primary Health Care*, 3(1):1027.
76. Panahi O, Zeinalddin M. (2024). The remote monitoring toothbrush for early cavity detection using artificial intelligence (AI). *International Journal of Dental Science and Innovative Research*, 7(4):173-178.
77. Panahi O. (2021). Stammzellen aus dem Zahnmark. *Verlag Unser Wissen*.
78. Panahi O, Eslamlou S.F, Jabbarzadeh M. (2025). Stomatologia cyfrowa i sztuczna inteligencja.
79. Panahi O, Eslamlou S.F, Jabbarzadeh M. (2025). Odontoiatria digitale e intelligenza artificiale.
80. Panahi O, Eslamlou S.F, Jabbarzadeh M. (2025). Dentisterie numérique et intelligence artificielle.
81. Panahi O, Eslamlou S.F, Jabbarzadeh M. (2025). Odontología digital e inteligencia artificial.
82. Panahi O, Eslamlou S.F, Jabbarzadeh M. (2025). Digitale Zahnmedizin und künstliche Intelligenz. *Verlag Unser Wissen*.
83. Panahi O. (2025). Predictive Health in Communities: Leveraging AI for Early Intervention and Prevention. *Ann Community Med Prim Health Care*. 3(1):1027.
84. Omid Panahi, Uras Panahi. (2025). AI-Powered IoT: Transforming Diagnostics and Treatment Planning in Oral Implantology. *J Adv Artif Intell Mach Learn*. 1(1):1-4.
85. Panahi U. (2025). AD HOC Networks: Applications, Challenges, Future Directions. *Scholars' Press*.
86. Panahi P, Dehghan M. (2008). Multipath video transmission over ad hoc networks using layer coding and video caches. *In Proceedings of the 16th Iranian Conference on Electrical Engineering (ICEE 2008)* (pp. 50-55).
87. Panahi, O., Gholizadeh, M. (2021). Research system in healthcare management information systems. *Sciencia Scripts Publishing*.
88. Panahi, O., Panahi, U. (2025). AI-powered IoT: Transforming diagnostics and treatment planning in oral implantology. *Journal of Advanced Artificial Intelligence and Machine Learning*.
89. Panahi, O., Ezzati, A., Zeynali, M. (2025). Will AI replace your dentist? The future of dental practice. *Online Journal of Dentistry & Oral Health*, 8(3).
90. Panahi, O. (2024). Artificial intelligence: A new frontier in periodontology. *Modern Research in Dentistry*, 8(1):MRD.000680.
91. Panahi O, Dadkhah S. (2025). AI in der modernen Zahnmedizin. *Verlag Unser Wissen*.
92. Panahi U. (2025). Redes AD HOC: Aplicações, Desafios, Direcções Futuras. *Edições Nosso Conhecimento*.
93. Panahi U. (2025). Ad hoc networks: Applications, challenges, and future directions. *Scholars-Press*.
94. Panahı, U. (2022). Nesnelerin interneti için hafif siklet kriptoloji algoritmalarına dayalı güvenli haberleşme modeli tasarımı [Design of a lightweight cryptography-based secure communication model for the Internet of Things] [Doctoral dissertation, Sakarya University]. *Sakarya University Institutional Repository*.
95. Koyuncu B, Panahi P. (2014). Kalman filtering of link quality indicator values for position detection by using WSNS. *International Journal of Computing, Communications & Instrumentation Engineering*, 1.
96. Koyuncu, B., Gökçe, A., Panahi, P. (2015). The use of the Unity Game Engine in the reconstruction of an archeological site. *In M. Arslan (Ed.), SOMA 2015: Time, space and people: Proceedings of the 19th Symposium on Mediterranean Archaeology* (pp. 95-104). *Archaeopress*.
97. Panahi, O., Eslamlou, S. F. (2025). Peridonio: Struttura, funzione e gestione clinica.
98. Panahi, O., Dadkhah, S. (2025). AI in der modernen Zahnmedizin. *Verlag Unser Wissen*.
99. Panahi O. (2021). Cellules souches de la pulpe dentaire.

100. Panahi O, Esmaili F, Kargarnezhad S. (2024). Artificial intelligence in dentistry. *SCIENCIA SCRIPTS Publishing*.
101. Panahi O, Melody FR. (2011). A Novel Scheme About Extraction Orthodontic and Orthotherapy. *International Journal of Academic Research*. 3(2).
102. Panahi O. (2025). The evolving partnership: surgeons and robots in the maxillofacial operating room of the future. *J Dent Sci Oral Care*. 1:1-7.
103. Panahi, O., Dadkhah, S. (2025). Sztuczna inteligencja w nowoczesnej stomatologii. *KS OmniScriptum Publishing*.
104. Panahi O. (2025). The Future of Medicine: Converging Technologies and Human Health. *Journal of Bio-Med and Clinical Research*. 2.
105. Panahi O, Raouf MF, Patrik K. (2011) The Evaluation Between Pregnancy and Periodontal Therapy. *Int J Acad Res*. 3:1057-1058.
106. Panahi, O., Nunag, G. M., Nourinezhad Siyahtan, A. (2011). Molecular pathology: P-115: Correlation of Helicobacter pylori and prevalent infections in oral cavity. *Cell Journal (Yakhteh)*, 12(Supplement 1):91-92.
107. Panahi O. (2025). The Age of Longevity: Medical Advances and The Extension of Human Life. *Journal of Bio-Med and Clinical Research*. 2.
108. Panahi, O., Eslamlou, S. F. (2025). Peridoncio: Estructura, función y manejo clínico.
109. Omid Panahi, Sevil Farrokh. (2025). Building Healthier Communities: The Intersection of AI, IT, and Community Medicine. *Int J Nurs Health Care*. 1(1):1-4.
110. Panahi, O. (2021). Dental pulp stem cells.
111. Panahi O. (2025). Nanomedicine: Tiny Technologies, Big Impact on Health. *Journal of Bio-Med and Clinical Research*. 2.
112. Omid Panahi, Amirreza Amirloo. (2025). AI-Enabled IT Systems for Improved Dental Practice Management. *On J Dent & Oral Health*. 8(4).
113. Panahi O. (2013). Comparison between unripe Makopa fruit extract on bleeding and clotting time. *International Journal of Paediatric Dentistry*. 23:205.
114. Panahi O, Eslamlou SF. Periodontium: Struktura, funkcja i postępowanie kliniczne.
115. Panahi, O., Eslamlou, S. F. (2025). Artificial Intelligence in Oral Surgery: Enhancing Diagnostics, Treatment, and Patient Care. *J Clin Den & Oral Care*, 3(1):1-5.
116. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Odontoiatria digitale e intelligenza artificiale.
117. Omid P, Soren F. (2025). The Digital Double: Data Privacy, Security, and Consent in AI Implants. *Digit J Eng Sci Technol*. 2(1):105.
118. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Medicina dentária digital e inteligência artificial. *Edições Nosso Conhecimento*.
119. Panahi, O. (2021). Stammzellen aus dem Zahnmark. *Verlag Unser Wissen*.
120. Panahi O. (2025). AI-Enhanced Case Reports: Integrating Medical Imaging for Diagnostic Insights. *J Case Rep Clin Images*. 8(1):1161.
121. Panahi O. (2025). Navigating the AI Landscape in Healthcare and Public Health. *Mathews J Nurs*. 7(1):5.
122. Omid Panahi, Masoumeh Jabbarzadeh. (2025). The Expanding Role of Artificial Intelligence in Modern Dentistry. *On J Dent & Oral Health*. 8(3).
123. Panahi, O. (2025). Wearable Sensors and Personalized Sustainability: Monitoring Health and Environmental Exposures in Real-Time. *European Journal of Innovative Studies and Sustainability*, 1(2):11-19.
124. Leila Ostovar, Kamal Khadem Vatan, Omid Panahi, (2020). Clinical Outcome of Thrombolytic Therapy. *Scholars Press Academic Publishing*.
125. Omid P, Sevil Farrokh E. (2025). Bioengineering Innovations in Dental Implantology. *Curr Trends Biomedical Eng & Biosci*. 23(3):556111.
126. Omid Panahi. (2024). Artificial Intelligence: A New Frontier in Periodontology. *Mod Res Dent*. 8(1):000680.
127. Panahi O, Melody FR, Kennet P, Tamson MK. (2011). Drug induced (calcium channel blockers) gingival hyperplasia. *JMBS*, 2(1):10-12.
128. Omid Panahi, Amirreza Amirloo. (2025). AI-Enabled IT Systems for Improved Dental Practice Management. *On J Dent & Oral Health*. 8(4):000691.
129. Omid P, Reza S. (2024). How Artificial Intelligence and Biotechnology are Transforming Dentistry. *Adv Biotech & Micro*. 18(2):555981.
130. Panahi, O., Zeinaldin, M. (2024). AI-Assisted Detection of Oral Cancer: A Comparative Analysis. *Austin J Pathol Lab Med*, 10(1):1037.

131. Omid Panahi, Sevil Farrokh. (2024). USAG-1-Based Therapies: A Paradigm Shift in Dental Medicine. *Int J Nurs Health Care*. 1(1):1-4.
132. Omid Panahi, Sevil Farrokh. (2024). Can AI Heal Us? The Promise of AI-Driven Tissue Engineering. *Int J Nurs Health Care*. 1(1):1-4.
133. Maryam Gholizadeh, Omid Panahi. (2021). Investigating System in Health Management Information Systems. *Scholars Press Academic Publishing*.
134. Omid Panahi. (2024). AI Ushering in a New Era of Digital Dental-Medicine. *Acta Scientific Medical Sciences*. 8(8):131-134.
135. Panahi, O., Farrokh, S. (2025a). The use of machine learning for personalized dental-medicine treatment. *Global Journal of Medical and Biomedical Case Reports*, 1:1.
136. Maryam Gholizadeh, Omid Panahi. (2021). Sistema de investigación en sistemas de información de gestión sanitaria, *NUESTRO CONOC, MENTO Publishing*.
137. Maryam Gholizadeh, Omid Panahi, (2021), Untersuchungssystem im Gesund heits management Informations systeme, *Unser wissen Publishing*.
138. Panahi O, Zeinaldin M. Digital Dentistry: Revolutionizing Dental Care. *J Dent App*. 10(1):1121.
139. Omid P, Evil Farrokh E. (2024). Beyond the Scalpel: AI, Alternative Medicine, and the Future of Personalized Dental Care. *J Complement Med Alt Healthcare*. 13(2):555860.
140. Panahi, O. (2024). Dental Implants & the Rise of AI. *On J Dent & Oral Health*, 8(1).
141. Maryam Gholizadeh, Omid Panahi, (2021), Indagare il sistema nei sistemi informativi di gestione della salute, *SAPIENZA Publishing*.
142. Panahi O, et al. (2025). Smart Robotics for Personalized Dental Implant Solutions. *Dental*. 7(1):21.
143. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Medicina dentária digital e inteligência artificial.
144. Panahi O. AI in Surgical Robotics: Case Studies. *Austin J Clin Case Rep*. 11(7):1342.
145. Omid Panahi, Reza Safaralizadeh. (2024). AI and Dental Tissue Engineering: A Potential Powerhouse for Regeneration. *Mod Res Dent*. 8(2):000682.
146. Maryam Gholizadeh, Omid Panahi, (2021), Systeemonderzoek in Informatiesystemen voor Gezondheidsbeheer. *ONZE KENNIS Publishing*.
147. Maryam Gholizadeh, Omid Panahi, (2021), Sistema de Investigação em Sistemas de Informação de Gestão de Saúde. *NOSSO CONHECIMENTO Publishing*.
148. Maryam Gholizadeh, Omid Panahi, (2021), System badawczy w systemach informacyjnych zarządzania zdrowiem, *NAZSA WIEDZA Publishing*.
149. Panahi O. (2025). The Role of Artificial Intelligence in Shaping Future Health Planning. *Int J Health Policy Plann*. 4(1):1-5.
150. Panahi O, Falkner S. (2025). Telemedicine, AI, and the Future of Public Health. *Western J Med Sci & Res*. 2(1):10.
151. Panahi O, Azarfardin A. Computer-Aided Implant Planning: Utilizing AI for Precise Placement and Predictable Outcomes. *Journal of Dentistry and Oral Health*. 2(1).
152. Panahi O. (2025). AI in Health Policy: Navigating Implementation and Ethical Considerations. *Int J Health Policy Plann*. 4(1):1-5.
153. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Stomatologia cyfrowa i sztuczna inteligencja.
154. Panahi O. (2025). Innovative Biomaterials for Sustainable Medical Implants: A Circular Economy Approach. *European Journal of Innovative Studies and Sustainability*. 1(2):1-5.
155. Panahi O (2024) Bridging the Gap: AI-Driven Solutions for Dental Tissue Regeneration. *Austin J Dent*. 11(2):1185.
156. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Dentisterie numérique et intelligence artificielle.
157. Panahi O, Zeinalddin M. (2024). The Convergence of Precision Medicine and Dentistry: An AI and Robotics Perspective. *Austin J Dent*. 11(2):1186.
158. Omid P, Mohammad Z. (2024). The Remote Monitoring Toothbrush for Early Cavity Detection using Artificial Intelligence (AI), *IJDSIR*. 7(4):173-178.
159. Omid P. (2024). Modern Sinus Lift Techniques: Aided by AI. *Glob J Oto*. 26(4):556198.

160. Panahi O. (2024). The Rising Tide: Artificial Intelligence Reshaping Healthcare Management. *S J Publc Hlth*. 1(1):1-3.
161. Panahi P (2008) Multipath Local Error Management Technique Over Ad Hoc Networks. *In 2008 International Conference on Automated Solutions for Cross Media Content and Multi-Channel Distribution*. 187-194.
162. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Digitale Zahnmedizin und künstliche Intelligenz. *Verlag Unser Wissen*.
163. Panahi U. (2025). AD HOC Networks: Applications, Challenges, Future Directions. *Scholars' Press*.
164. Panahi, U. (2025). AD HOC-Netze: Anwendungen, Herausforderungen, zukünftige Wege. *Verlag Unser Wissen*.
165. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Odontología digital e inteligencia artificial.
166. Koyuncu, B., Gökçe, A., Panahi, P. (2018). The use of the Unity Game Engine in the reconstruction of an archeological site. *In M. Arslan (Ed.), SOMA 2015: Time, space and people: Proceedings of the 19th Symposium on Mediterranean Archaeology (pp. 95-104). Archaeopress*.
167. Koyuncu, B., Meral, E., Panahi, P. (2015). Real time geolocation tracking by using GPS+GPRS and Arduino based SIM908. *IFRSA International Journal of Electronics Circuits and Systems (IIJECS)*, 4(2):148-150.
168. Panahi O. (2025). Smart Materials and Sensors: Integrating Technology into Dental Restorations for Real-Time Monitoring. *J Dent Oral Health*. 2(1).
169. Omid Panahi, Mohammad Zeinalddin. (2024). The remote monitoring toothbrush for early cavity detection using artificial intelligence (AI). *IJDSIR*. 7(4):173-178.
170. Panahi, O., Esmaili, F., Kargarnezhad, S. (2024). Artificial intelligence in dentistry. *Scholars Press Publishing*.
171. Panahi O. (2025). Deep Learning in Diagnostics. *Journal of Medical Discoveries*. 2(1).
172. Panahi O. (2025). Algorithmic Medicine. *Journal of Medical Discoveries*. 2(1).
173. Panahi O. (2025). The Future of Healthcare: AI, Public Health and the Digital Revolution. *Medi Clin Case Rep J*. 3(1):763-766.
174. Omid P. (2024). Artificial Intelligence in Oral Implantology, Its Applications, Impact and Challenges. *Adv Dent & Oral Health*. 17:555966.
175. Omid P. (2011). Relevance between gingival hyperplasia and leukemia. *Int J Acad Res*. 3:493-494.
176. Panahi O. (2024). Teledentistry: Expanding Access to Oral Healthcare. *Journal of Dental Science Research Reviews & Reports*. 6:2-3.
177. Panahi O, Ezzati A. (2025). AI in Dental-Medicine: Current Applications & Future Directions. *Open Access J Clin Images*. 2(1):1-5.
178. Panahi, O., Borhani, S. (2026). Odontoiatria intelligente: Una guida completa all'intelligenza artificiale e alla robotica.
179. Panahi O (2025) Predictive Health in Communities: Leveraging AI for Early Intervention and Prevention. *Ann Community Med Prim Health Care*. 3:1027.
180. Panahi, O., Esmaili, F., Kargarnezhad, S. (2024). Inteligencia artificial en odontología. *Mento Publishing*.
181. Panahi, O., Esmaili, F., Kargarnezhad, S. (2024). Künstliche Intelligenz in der Zahnmedizin. *Verlag Unser Wissen*.
182. Panahi, O. (2021). Dental pulp stem cells. *Sciencia Scripts*.
183. Panahi, O., Arab, M. S., Tamson, K. M. (2011). Gingival enlargement and relevance with leukemia. *International Journal of Academic Research*, 3(2):493-494.
184. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Odontología digital e inteligencia artificial.
185. Panahi, O., Dadkhah, S. (2025). Sztuczna inteligencja w nowoczesnej stomatologii. *KS OmniScriptum Publishing*.
186. Panahi, O., Dadkhah, S. (2025). La IA en la odontología moderna.
187. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Digitale Zahnmedizin und künstliche Intelligenz. *Verlag Unser Wissen*.
188. Panahi, O., Esmaili, F., Kargarnezhad, S. (2024). Intelligenza artificiale in odontoiatria. *SAPIENZA Publishing*.
189. Panahi, O., Dadkhah, S. (2025). L'IA dans la dentisterie moderne.
190. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Stomatologia cyfrowa i sztuczna inteligencja.

191. Panahi O, Panahi U. (2026). Application of Machine Learning and Computer Vision in Oral Surgery and Implant Outcome Prediction. *SunText Rev Dental Sci*. 7(1):192.
192. Panahi O, Panahi U. (2026). Computer-Aided Implant Planning and Placement Using AI and Machine Learning: A General Framework for Surgical Guidance. *SunText Rev Med Clin Res*. 7(5):266.
193. Omid P, Uras P. (2026). Self-Learning AI Implant with Dynamic Fibrointegration and Real-Time Ligament Tension Adjustment: The World's First Closed-Loop Smart Implant That Moves Like a Natural Tooth. *J Surg Pract Case Rep*. 2(2):1-5.
194. Omid P, Uras P. (2026). AI-Designed, Fibrointegrated, Circumferential Root Ring Implant: The First Surgery That Recreates the Natural Periodontal Ligament Without Any Human Intraoperative Decision. *J Surg Pract Case Rep*. 2(2):1-5.
195. Farhadi, S., Panahi, U. (2026). A federated learning-based intrusion detection framework for zero-day attacks in smart healthcare networks integrating IoMT devices. *Journal of Medicine Care and Health Review*, 3(2).
196. Farhadi, S., Panahi, U. (2026). Blockchain-anchored adaptive authentication for real-time medical data streams in AI-driven Smart Grid-IoMT converged networks. *Journal of Medicine Care and Health Review*, 3(1).
197. Omid P, Uras P. (2026). The AIoT-Based Remote Care Network: Integrating Smart Implants and Edge Computing for Post-Operative Monitoring in Otolaryngology. *Glob J Otolaryngol*, 29(1):556252.
198. Omid P, Uras P. (2026). AI-Driven Optimization of Cochlear Implant Fitting: Machine Learning Models for Personalized Hearing Rehabilitation. *Glob J Otolaryngol*, 29(1):556253.
199. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Odontoiatria digitale e intelligenza artificiale.
200. Panahi, O., Eslamlou, S. F., Jabbarzadeh, M. (2025). Dentisterie numérique et intelligence artificielle.
201. Panahi, O., Eslamlou, S. F. (2025). Le péridontium: Structure, fonction et gestion clinique.
202. Panahi, O., Dadkhah, S. (2025). L'intelligenza artificiale nell'odontoiatria moderna.
203. Panahi, O. (2021). Células madre de la pulpa dental. *Ediciones Nuestro Conocimiento*.
204. Panahi, O., Dadkhah, S. (2025). A IA na medicina dentária moderna. *KS OmniScriptum Publishing*.
205. Panahi, O. (2021). Cellule staminali della polpa dentaria.
206. Kevin Thamson, Omid Panahi (2025) Challenges and Opportunities for Implementing AI in Clinical Trials. *J. of Bio Adv Sci Research*, 1(2):1-8.
207. Thamson, K., Panahi, O. (2025). Ethical considerations and future directions of AI in dental healthcare. *Journal of Biomedical Advancement Scientific Research*, 1(2):1-7.
208. Thamson, K., Panahi, O. (2025). Bridging the gap: AI, data science, and evidence-based dentistry. *Journal of Biomedical Advancement Scientific Research*, 1(2):1-7.
209. Thamson, K., Panahi, O. (2025). Bridging the gap: AI as a collaborative tool between clinicians and researchers. *Journal of Biomedical Advancement Scientific Research*, 1(2):1-8.
210. Omid Panahi, Shabnam Dadkhah. (2025). Transforming Dental Care: A Comprehensive Review of AI Technologies. *J Stoma Dent Res*. 3(1):1-5.
211. Panahi, O. (2025). Predictive health in communities: Leveraging AI for early intervention and prevention. *Annals of Community Medicine and Primary Health Care*, 3(1):1028.
212. Gholizadeh, M., Panahi, O. (2021). Research system in health management information systems. Sciencia Scripts Publishing.
213. Gholizadeh, M., Panahi, O. (2021). Research system in health management information systems. *Sciencia Scripts Publishing*.
214. Panahi, O., Esmaili, F., Kargarnezhad, S. (2024). L'intelligence artificielle dans l'odontologie. *Édition Notre Savoir*.
215. Zarei, S., Panahi, O., Bahador, N. (2019). Antibacterial activity of aqueous extract of Eucalyptus camaldulensis against Vibrio harveyi (PTCC1755) and Vibrio alginolyticus (MK641453.1). *LAP, Lambert Academic Publishing GmbH & Co. KG*.
216. Omid Panahi., et al. (2025). Robotics in Implant Dentistry: Current Status and Future

Prospects. *Scientific Archives of Dental Sciences*. 7(9):55-60.
217. Zarei, S., Panahi, O. (2019). Eucalyptus camaldulensis extract as a preventive to the vibriosis. *Scholars' Press Academic Publishing*.
218. Omid P. (2024). Empowering Dental Public Health: Leveraging Artificial Intelligence for Improved Oral Healthcare Access and Outcomes. *JOJ Pub Health*. 9(1):555754.
219. Gholizadeh, M., Panahi, O. (2021). Research system in health management information systems. *Sciencia Scripts Publishing*.
220. Panahi O. (2025). Smart Implants: Integrating Sensors and Data Analytics for Enhanced Patient Care. *Dental*. 7(1):22.
221. Omid Panahi. (2025). Forging a Healthier Future Through Responsible AI in Families and Communities. *Archives of Community and Family Medicine*. 8(1):21-30.
222. Panahi, O., Ketenci Cay, F. (2023). Nano technology, regenerative medicine and tissue bio-engineering. *Acta Scientific Dental Sciences*, 7:118-122.
223. Panahi, O., Esmaili, F., Kargarnezhad, S. (2024). L'intelligence artificielle dans l'odontologie. *Édition Notre Savoir*.
224. Panahi, O., Eslamlou, S. F. (2025). Periodontium: Structure, function and clinical management.
225. Omid Panahi. (2025). Health in the Age of AI: A Family and Community Focus. *Archives of Community and Family Medicine*. 8(1):11-20.
226. Omid Panahi, Zahra Shahbazpour. (2025). Healthcare Reimagined: AI and the Future of Clinical Practice. *Am J Biomed Sci & Res*. 27(6):003617.
227. Panahi, O., Dadkhah, S. (2025). AI in modern dentistry.
228. Panahi O. (2025). Robotic Surgery Powered by AI: Precision and Automation in the Operating Room. *SunText Rev Med Clin Res*. 6(2):225.
229. Omid Panahi. (2025). Smart Materials and Sensors: Integrating Technology into Dental Restorations for Real-Time Monitoring. *Journal of Dentistry and Oral Health*. 2(1).
230. Koyuncu, B., Uğur, B., Panahi, P. (2013). Indoor location determination by using RFIDs. *International Journal of Mobile and Adhoc Network (IJMAN)*, 3(1):7-11.
231. Uras Panahi. (2025). Redes AD HOC: Aplicações, Desafios, Direcções Futuras. Edições Nosso Conhecimento.
232. Panahi, P., Dehghan, M. (2008, May). Multipath video transmission over ad hoc networks using layer coding and video caches. *In 2008 16th Iranian Conference on Electrical Engineering (ICEE 2008) (pp. 50-55)*.
233. Panahi DU. (2025). HOC A Networks: Applications. Challenges, Future Directions. *Scholars' Press*.
234. Panahi O, Esmaili F, Kargarnezhad S. (2024). Artificial Intelligence in Dentistry. *Scholars Press Publishing*.
235. Omid P. (2011). Relevance between gingival hyperplasia and leukemia. *Int J Acad Res*. 3:493-49.
236. Panahi O. (2025). Secure IoT for Healthcare. *European Journal of Innovative Studiesand Sustainability*. 1(1):1-5.

**Cite this article:** Chadwick F. (2026). Scaffold-Guided Tissue Regeneration Using 3D-Printed Biodegradable Polymers: A Preclinical Study in Critical-Size Mandibular Defects, *International Journal of Biomedical and Clinical Research*, BioRes Scientia Publishers. 7(4):1-12. DOI: 10.59657/2997-6103.brs.26.155

**Article History:** **Received:** August 19, 2026 | **Accepted:** September 04, 2026 | **Published:** September 11, 2026