International Research Journal of Medicine and Surgery (IRJMedS), 2026;3(3):17-25 IRJMedS

Review Article | ISSN (O): 3048-6955 DOI: 10.47857/irjmeds.2026.v03i03.075

Artificial Teeth and Biological Tooth Regeneration Through USAG-1 Suppression: A Narrative Review

Ritik Kashwani*, Anukriti Kumari, Hemant Sawhney

Department of Oral Medicine and Radiology, School of Dental Sciences, Sharda University, Greater Noida, Uttar Pradesh, India. *Corresponding Author's Email: docritikkashwani@yahoo.com

Abstract

Tooth loss remains one of the most common oral health problems worldwide and continues to impose a substantial burden on aesthetics, nutrition, and quality of life. Conventional prosthetic rehabilitation with artificial teeth and dental implants restores function predictably, but it cannot fully reproduce the biology of a natural tooth. Recent work has highlighted the significance of suppressing Uterine Sensitization-Associated Gene-1 (USAG-1, also known as SOSTDC1) as a means of achieving biological tooth regeneration. This narrative review summarizes the published evidence on established modalities of artificial tooth replacement and on the emerging regenerative approach based on USAG-1 inhibition. The literature was searched in PubMed, Scopus, Embase, and Google Scholar for the period January 2015 to March 2026. USAG-1 is a secreted antagonist of the Bone Morphogenetic Protein (BMP) and Wnt pathways, both of which are essential to odontogenesis. Its suppression in animal models — by gene knockout, small interfering RNA, or neutralizing monoclonal antibodies — enhances BMP signalling and induces supernumerary tooth formation and the rescue of congenital tooth agenesis, with effects demonstrated in mice and subsequently in a non-rodent (ferret) model. A humanized anti-USAG-1 antibody has since completed non-clinical safety testing and entered first-in-human evaluation, marking the transition of this approach from preclinical proof of concept toward clinical translation. Artificial teeth remain the standard of care, but biological tooth regeneration represents a promising future alternative. Long-term clinical data on safety, efficacy, control of tooth morphology and eruption, and cost-effectiveness are still required before routine application can be considered.

Keywords: Artificial Teeth, BMP Signalling, Regenerative Dentistry, Tooth Regeneration, USAG-1, Wnt Pathway.

Introduction

Tooth loss remains one of the most prevalent chronic health conditions affecting adults worldwide and continues to impose a substantial burden on masticatory function, phonetics, facial aesthetics, and psychosocial wellbeing (1). Epidemiological data indicate that partial or complete edentulism affects a large proportion of the global adult population, with prevalence increasing markedly with age and disproportionately affecting individuals with limited access to preventive dental care (1). Beyond its functional and cosmetic consequences, tooth loss is consistently associated with reduced masticatory efficiency and nutrient intake, altered speech, diminished self-confidence, and lower scores on validated measures of oral health-related quality of life. Because of this considerable and largely preventable burden, the search for reliable, durable, and biologically compatible methods of tooth replacement has remained a central objective of restorative and regenerative dentistry for several decades. In parallel, an ageing global population and improved survival into later life mean that the absolute number of individuals living with tooth loss, and therefore the clinical demand for effective replacement strategies, is expected to continue rising in the coming decades. Traditionally, missing teeth have been replaced using removable dentures, fixed partial dentures, and dental implants, each offering a different balance of invasiveness, cost, and functional outcome (2). Removable prostheses are economical and non-invasive but are frequently limited by poor retention, accelerated alveolar bone resorption, and reduced masticatory efficiency. Fixed partial dentures restore aesthetics and function more predictably but require preparation of adjacent healthy teeth, with an attendant risk to pulpal and periodontal health. Osseointegrated dental implants have transformed prosthodontic practice over the past four decades and now represent the standard of care in many clinical situations, offering high long-term survival rates and strong patient satisfaction (3).

(Received 16th March 2026; Accepted 15th August 2026; Published 22nd August 2026)

Nevertheless, even the most advanced implant systems remain artificial substitutes: they lack a periodontal ligament and its proprioceptive function, cannot remodel physiologically in response to occlusal load, and carry a recognized risk of peri-implantitis, prosthetic complications, and continued marginal bone loss over time. These inherent limitations have provided much of the impetus for a fundamentally different approach to tooth loss, namely the biological regeneration of a functional, natural tooth rather than its prosthetic replacement.

Regenerative dentistry has emerged over the past two decades as a distinct field of investigation, aiming to restore lost dental tissues through stem cell-based therapy, tissue engineering, scaffold design, and targeted modulation of the molecular pathways that govern tooth development (4). Among the molecular strategies under investigation, suppression of Uterine Sensitization-Associated Gene-1 (USAG-1), also designated Sclerostin Domain-Containing Protein 1 (SOSTDC1), has attracted particular attention as a potential route to whole-tooth regeneration. USAG-1 is a secreted protein that functions as a dual antagonist of the Bone Morphogenetic Protein (BMP) and Wnt signalling pathways, both of which are indispensable to normal odontogenesis (5). Under physiological conditions, USAG-1 restrains BMP and Wnt activity to limit the number of teeth that form; when this restraint is experimentally removed, tooth-forming potential that would otherwise remain dormant can be reactivated, offering a plausible biological basis for regenerating a missing tooth in situ rather than replacing it with an artificial substitute. This mechanism is of particular interest because, unlike stem cell- or scaffold-based approaches that seek to build a tooth from external components, USAG-1 suppression aims to unlock a regenerative programme that is already latent within the patient's own dental tissues.

Experimental suppression of USAG-1, whether achieved by gene knockout, small interfering RNA, or neutralizing monoclonal antibodies, has been shown to induce supernumerary tooth formation and to rescue congenital tooth agenesis in animal models. Antibody-mediated USAG-1 neutralization has proved effective not only in mice but also in a non-rodent model, the ferret, indicating that the underlying biology is not confined to a single species and strengthening the rationale for eventual translation to humans (6). More than two decades of incremental preclinical work in this area have now culminated in the development of a humanized anti-USAG-1 antibody that has completed non-clinical safety testing and entered first-in-human evaluation, marking a tangible step from proof-of-concept biology toward a potentially applicable regenerative therapy (7).

Although individual preclinical studies on USAG-1 suppression have been published in the specialist molecular biology literature, comparatively few narrative syntheses have placed this emerging biological approach in direct comparison with the conventional prosthetic modalities that remain the current standard of care. By juxtaposing the two paradigms within a single review, this article aims to provide clinicians, researchers, and postgraduate trainees with an integrated, clinically oriented perspective on where biological tooth regeneration currently stands relative to established restorative practice, and on what obstacles must still be overcome before it can be considered a realistic clinical alternative.

This narrative review therefore aims to compile the current evidence on conventional artificial tooth replacement and on the emerging concept of biological tooth regeneration through USAG-1 suppression, and to outline the future clinical implications, challenges, and research directions of this evolving field. Specifically, the review addresses four objectives:

(a) to summarize the advantages and limitations of current artificial tooth replacement modalities;
(b) to describe the molecular basis by which USAG-1 suppression enables biological tooth regeneration;
(c) to appraise the preclinical and early clinical evidence supporting anti-USAG-1 therapy; and
(d) to identify the translational challenges and future research priorities that must be addressed before biological tooth regeneration can be considered for routine clinical use.

Methodology

Search Strategy

A full-text literature search was carried out in the PubMed (MEDLINE), Scopus, Embase, and Google Scholar databases. Studies published between January 2015 and March 2026 were considered, together with earlier seminal papers identified

through citation tracking where these were foundational to the topic. This fifteen-year window was chosen because it captures the period during which USAG-1 suppression evolved from an experimental gene-knockout phenomenon into an antibody-based strategy with genuine translational potential, culminating in first-in-human evaluation; foundational studies published before 2015 that established the basic biology of USAG-1 were incorporated through citation tracking to preserve conceptual completeness rather than being excluded purely on chronological grounds. The search used combinations of the following keywords: "Artificial Teeth," "Tooth Regeneration," "USAG-1," "SOSTDC1," "Regenerative Dentistry," "Stem Cells," "BMP signalling," and "Wnt pathway."

Study Selection Process

All records retrieved from the four databases were exported to a reference manager, and duplicate records were removed prior to screening. Two reviewers independently screened the titles and abstracts of all remaining records against the inclusion and exclusion criteria described below; records considered potentially eligible by either reviewer were retrieved and evaluated in full text. Disagreements regarding eligibility were resolved by discussion, with a third author consulted where consensus could not be reached. This sequential process, from initial identification through to the final set of included studies, is summarised in Figure 1.

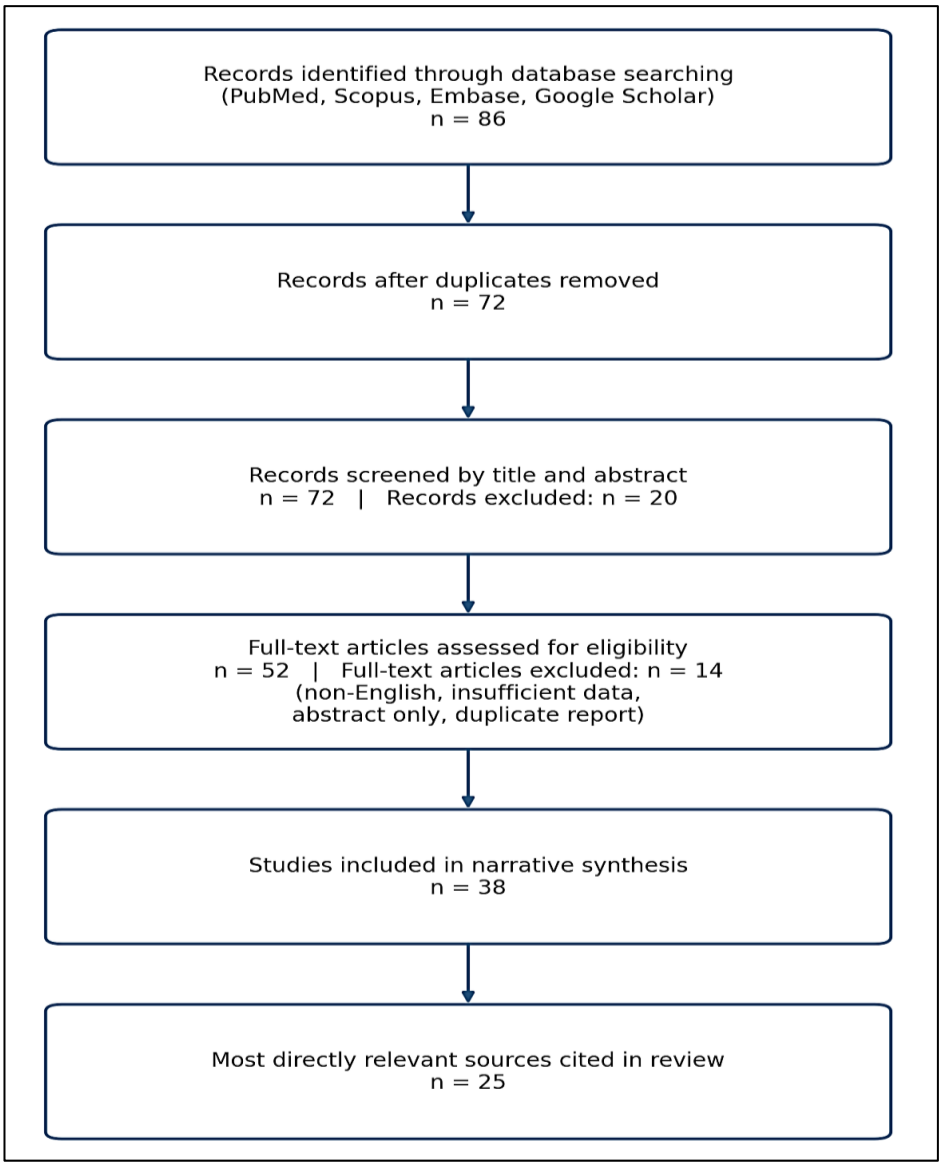

Figure 1: Flow Diagram of the Literature Search and Study Selection Process

Inclusion Criteria

Studies were eligible for inclusion if they were original research articles, randomized studies, experimental animal studies, clinical or preclinical regenerative studies, or review articles relevant to tooth regeneration and USAG-1 suppression.

Exclusion Criteria

Studies were excluded if they were non-English publications, case reports with insufficient data, conference abstracts without accompanying full text, or duplicate reports of the same dataset.

A total of 86 records were initially identified across the four databases. After removal of duplicates and screening of titles and abstracts, 52 records underwent full-text assessment, of which 38 fulfilled the inclusion criteria and informed this narrative synthesis; the 25 most directly relevant sources are cited to support key statements throughout the review.

Results

Conventional Artificial Teeth Replacement Modalities

Artificial tooth replacement remains the cornerstone of restorative dentistry. Common modalities include removable dentures, fixed dental prostheses, and osseointegrated implants (8). Advances in materials and digital workflows, including milled and three-dimensionally printed artificial teeth, have further improved the aesthetics and durability of these prostheses (9). Dental implants in particular demonstrate high survival rates and patient satisfaction; however, they lack periodontal ligament proprioception and the capacity for natural biological remodelling. Table 1 compares the principal conventional replacement options in terms of their advantages, limitations, and longevity.

Table 1: Comparison of Conventional Artificial Tooth Replacement Options

Modality	Advantages	Limitations	Longevity
Removable dentures	Economical, non-invasive	Poor stability, bone resorption	5–8 years
Fixed partial denture	Better aesthetics and function	Tooth preparation required	10–15 years
Dental implants	Excellent stability, osseointegration	Costly, peri-implantitis risk	15–25 years
Implant-supported prosthesis	Improved retention	Surgical intervention needed	Long-term

Biology of Tooth Development

Tooth development is regulated by reciprocal interactions between the oral epithelium and neural crest-derived mesenchyme, with multiple signalling pathways contributing to odontogenesis (10). The number of teeth formed is tightly constrained by these pathways, and disturbance of this regulation underlies both hypodontia and supernumerary tooth formation (11). BMP signalling in particular is central not only to crown morphogenesis but also to root development and regeneration (12). USAG-1 negatively regulates the BMP and Wnt pathways and thereby suppresses tooth formation. The principal signalling pathways involved in odontogenesis are summarized in Table 2.

Table 2: Major Molecular Pathways in Tooth Development

Signalling Pathway	Function in Odontogenesis
Bone Morphogenetic Protein (BMP) pathway	Tooth initiation and morphogenesis
Wnt signalling	Tooth bud formation
Fibroblast Growth Factor (FGF) pathway	Cell proliferation and differentiation
Sonic Hedgehog (SHH) pathway	Enamel knot signalling
Notch signalling	Cell fate determination

USAG-1 and Tooth Regeneration

USAG-1 (SOSTDC1) is a secreted protein that is highly expressed during tooth development and acts as a dual antagonist of BMP and Wnt signalling (13). Mice deficient in USAG-1 exhibit enhanced BMP signalling and develop supernumerary teeth, establishing the gene as a negative regulator of tooth number (14). The balance between USAG-1 and BMP-7 was subsequently shown to govern

whether supernumerary structures form, supporting the idea that a single target molecule can be manipulated to increase tooth number (15). Several modes of suppression have proved effective in animal models. Local application of USAG-1 small interfering RNA reversed arrested tooth formation in Runx2-deficient mice, a model of congenital tooth agenesis, and demonstrated that a cationized gelatin carrier can serve as a practical delivery system (16). Analysis of premolar supernumerary teeth indicated that these arise principally from a latent third dentition, supporting the concept that humans retain dormant tooth-forming potential that could be reactivated (17). On this basis, a targeted molecular strategy for controlling tooth number was proposed as a route to tooth regenerative medicine (18).

The pivotal demonstration came from the use of neutralizing monoclonal antibodies. Systemic administration of an anti-USAG-1 antibody relieved congenital tooth agenesis arising from several distinct genetic abnormalities in mice, and confirmed that the effect is mediated through enhanced BMP rather than Wnt signalling; the same antibody induced a supernumerary maxillary incisor resembling a third dentition in postnatal ferrets, although a higher dose, repeated administration, and immunosuppression were required in this non-rodent model (6). A humanized anti-USAG-1 antibody, designated TRG035, has since undergone non-clinical safety studies and been manufactured as a Good Manufacturing Practice (GMP) investigational formulation in preparation for clinical trials, with congenital tooth agenesis — hypodontia and oligodontia — as the initial target indication (19). Reports indicate that a first-in-human Phase I trial was initiated at Kyoto University Hospital in 2024 to assess safety and tolerability in adults with tooth loss, with a planned transition to Phase II in patients with congenital tooth agenesis; these trial data have not yet been published in the peer-reviewed literature and should therefore be interpreted with caution (20). The key studies on USAG-1 suppression and tooth regeneration are summarized in Table 3.

Table 3: Key Studies on USAG-1 Suppression and Tooth Regeneration

Year	Model	Intervention	Principal finding	Reference
2008	USAG-1-deficient mice	Gene knockout	Enhanced BMP signalling; supernumerary tooth formation	(14)
2014	Mouse incisor explants	BMP-7 supplementation; USAG-1 modulation	BMP-7–USAG-1 balance regulates supernumerary organ formation	(15)
2021	Runx2-deficient mice	Local USAG-1 siRNA in cationized gelatin	Topical suppression rescued arrested tooth formation	(16)
2021	Msx1−/− and EDA1 mutant mice; ferrets	Anti-USAG-1 neutralizing antibody	Rescue of congenital agenesis in mice; supernumerary incisor in ferrets	(6)
2024	Preclinical / humanized antibody	Humanized anti-USAG-1 (TRG035)	Non-clinical safety completed; GMP formulation prepared for Phase I	(19)

Stem Cells and Tissue Engineering in Tooth Regeneration

Stem-cell-based regeneration constitutes another major area of regenerative dentistry. Dental pulp stem cells, stem cells from the apical papilla, and periodontal ligament stem cells all demonstrate odontogenic potential and have been investigated for the repair and regeneration of dental tissues (21). Scaffold-based bioengineering approaches, in which cells are combined with biomimetic matrices to guide the formation of tooth-like structures, provide the structural support necessary for organized development (22). Combination approaches integrating stem cells, biomimetic scaffolds, and molecular regulation of signalling may represent the future of regenerative oral rehabilitation. Table 4 lists the main dental stem cell sources and their regenerative potential.

Table 4: Stem Cell Sources Used in Tooth Regeneration

Stem Cell Source	Regenerative Potential
Dental pulp stem cells	Dentin-pulp complex regeneration
Stem cells from apical papilla	Root formation
Periodontal ligament stem cells	Periodontal regeneration
Gingival mesenchymal stem cells	Soft tissue repair
Induced pluripotent stem cells	Whole tooth engineering

Discussion

To the authors' knowledge, this is among the first narrative reviews to place conventional prosthetic tooth replacement and the emerging molecular strategy of USAG-1 suppression side by side within a single, clinically oriented synthesis, rather than treating these as separate bodies of literature; this integrated perspective is the principal contribution of the present review.

Despite the relative novelty of regenerative options, conventional artificial teeth remain the standard treatment for tooth loss, as they offer predictable results and are widely available clinically (8). Titanium dental implants in particular achieve high survival rates with high patient satisfaction. However, the architecture of a natural tooth and the sensory feedback it provides through the periodontal ligament cannot be duplicated by artificial prostheses (3, 9).

Recent advances in regenerative dentistry have shifted attention toward the biological replacement of teeth, and suppression of USAG-1 is among the most promising molecular targets in this field (18). A past research showed that neutralization of USAG-1 with anti-USAG-1 antibodies in mice could successfully rescue missing teeth, with restoration of BMP signalling activating pathways that had been dormant in the tooth germ; the same antibody produced supernumerary tooth formation in ferrets, a non-rodent model with both deciduous and permanent dentitions, which strengthens the translational case (6).

Tooth regeneration in these models is achieved principally through activation of BMP signalling, with Wnt playing a contributory role. USAG-1 is a negative regulator of both pathways, and its inhibition permits the initiation of odontogenic signalling (12, 15). This represents a paradigm shift from artificial prosthetic rehabilitation toward biological organ regeneration. The observation that supernumerary premolars derive largely from a latent third dentition provides a biological rationale for why such reactivation may be feasible in humans (17).

The regenerative potential of these approaches is further supported by stem cell technology. Dental pulp stem cells and induced pluripotent stem cells can differentiate into odontoblast-like cells and contribute to tooth tissue engineering (21), while scaffold-based strategies provide the structural framework for bioengineered teeth (22).

Although promising, several obstacles remain. Most of the evidence derives from animal studies, and although a humanized antibody has entered first-in-human testing (19, 20), long-term human safety and efficacy data are not yet available in the peer-reviewed literature. Because USAG-1 is also expressed in the kidney and other tissues, the systemic consequences of its inhibition require careful evaluation (13). Further challenges include the ethical implications of access and equitable distribution, potential immune responses, and precise control of tooth number, shape, position, and eruption timing (23). Disturbances of eruption are themselves a recognized and complex clinical problem, and a regenerated tooth that fails to erupt in the correct position would be of limited benefit (24). Multicentre trials and standardized regeneration protocols will be needed to carry these findings from the bench to the dental patient chair (25).

Nevertheless, biological tooth regeneration through USAG-1 suppression could reshape the dentistry of the future by allowing the replacement of a missing tooth with a natural one rather than a prosthesis. With the continued development of molecular modulation, stem cell engineering, and tissue engineering, regenerative dentistry may in time become a standard clinical reality.

Limitations

This review has several limitations that should be considered when interpreting its conclusions. First, as a narrative rather than a systematic review, it did not employ a formal risk-of-bias

assessment or a fixed, fully reproducible search protocol, and the selection of the 25 most directly relevant sources, while structured, retains an element of author judgement. Second, the great majority of the evidence on USAG-1 suppression is derived from rodent and, to a lesser extent, ferret models; the extent to which these findings will translate to human tooth development, which follows a different time course and involves a more complex permanent dentition, remains to be established. Third, the search was restricted to English-language publications, which may have excluded relevant data published in other languages. Finally, because much of the antibody-based work originates from a small number of research groups, the possibility of publication bias and limited independent replication cannot be excluded.

Future Directions and Practical Implications

Several priorities can be identified for the field going forward. Clinically, the most immediate need is for peer-reviewed reporting of the ongoing first-in-human trial of the humanized anti-USAG-1 antibody, including safety, tolerability, and any early efficacy signal in adults with tooth agenesis (19, 20). Mechanistically, further work is required to define whether USAG-1 suppression can be spatially and temporally controlled with sufficient precision to regenerate a tooth of normal size, shape, and position, rather than an ectopic or malformed structure, and to clarify the systemic consequences of inhibiting a protein that is also expressed outside the dental tissues (13). From a translational perspective, combining molecular USAG-1 suppression with scaffold-based and stem cell-based strategies may offer a route to greater control over tooth morphogenesis than either approach alone (21, 22). Practically, clinicians should be aware that biological tooth regeneration is not yet an available treatment option; conventional prosthetic rehabilitation remains the appropriate standard of care, and patients should not be counselled to defer conventional treatment in anticipation of regenerative alternatives that are still in early clinical development. Multicentre trials, standardized regeneration protocols, and long-term follow-up data on morphology, eruption, and function will all be required before this approach can be considered for routine practice (25).

Conclusion

Artificial teeth remain the mainstay of tooth replacement, yet they carry inherent biological limitations. Research in regenerative dentistry has shown that inhibition of USAG-1 is sufficient to promote endogenous tooth regeneration by enhancing BMP and, to a lesser extent, Wnt signalling. Anti-USAG-1 antibodies have produced consistent regenerative effects in rodent and ferret models, and a humanized antibody has now progressed to first-in-human evaluation for congenital tooth agenesis. Although application in routine human clinical practice remains at an early stage, biological tooth regeneration represents a potentially paradigm-shifting development in restorative dentistry. Long-term clinical studies are required to establish safety, efficacy, control of tooth morphology and eruption, and appropriate clinical protocols before this approach can be adopted more widely.

Abbreviations

BMP: Bone Morphogenetic Protein, FGF: Fibroblast Growth Factor, GMP: Good Manufacturing Practice; SHH: Sonic Hedgehog, siRNA: small interfering RNA, SOSTDC1: Sclerostin Domain-Containing Protein 1, USAG-1: Uterine Sensitization-Associated Gene-1.

Acknowledgement

None.

Author Contributions

Ritik Kashwani: conceptualization, literature search, data extraction, and manuscript writing. Anukriti Kumari: critical review and editing of the manuscript. Hemant Sawhney: critical review and editing of the manuscript. All authors read and approved the final version of the manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Data Availability

Data sharing is not applicable to this article, as no new data were created or analyzed in this review.

Declaration of Artificial Intelligence (AI) Assistance

AI-assisted technology was used only for grammar correction and language refinement during preparation of the manuscript. The final content

and scientific accuracy were reviewed and approved by the authors.

Ethics Approval

Ethical approval was not required, as this is a narrative review of previously published literature and did not involve human participants or animals.

Funding

None.

References

1. Imam AY. Impact of tooth loss position on oral health-related quality of life in adults treated in the community. J Pharm Bioallied Sci. 2021;13(Suppl2):S969-74. doi: 10.4103/jpbs.jpbs_87_21
2. Gbadebo OS, Lawal FB, Sulaiman AO, *et al*. Dental implant as an option for tooth replacement: the awareness of patients at a tertiary hospital in a developing country. Contemp Clin Dent. 2014;5(3):302-6. doi: 10.4103/0976-237X.137914
3. AlRowis R, Albelaihi F, Alquraini H, *et al*. Factors affecting dental implant failure: a retrospective analysis. Healthcare (Basel). 2025;13(12):1356. doi: 10.3390/healthcare13121356
4. Balfaki M, Salimi E. Revolutionary regeneration therapy utilizing dental stem cells and state-of-the-art nanotechnology devices to heal injured teeth and tissues. Avicenna J Med Biotechnol. 2025;17(2):83-97. doi: 10.18502/ajmb.v17i2.18559
5. Zhang F, Song J, Zhang H, *et al*. Wnt and BMP signaling crosstalk in regulating dental stem cells: implications in dental tissue engineering. Genes Dis. 2016;3(4):263-76. doi: 10.1016/j.gendis.2016.09.004
6. Murashima-Suginami A, Kiso H, Tokita Y, *et al*. Anti-USAG-1 therapy for tooth regeneration through enhanced BMP signaling. Sci Adv. 2021;7(7):eabf1798. doi: 10.1126/sciadv.abf1798
7. Ravi V, Murashima-Suginami A, Kiso H, *et al*. Advances in tooth agenesis and tooth regeneration. Regen Ther. 2023; 22:160-8. doi: 10.1016/j.reth.2023.01.004
8. Ali Hassan MA, Elhadi RM, Osman M, *et al*. Choosing between fixed and removable prosthetic modalities for completely edentulous patients: a systematic review of evidence-based outcomes. Cureus. 2026; 18(1):e101213. doi: 10.7759/cureus.101213
9. Tzanakakis EG, Pandoleon P, Sarafianou A, *et al*. Adhesion of conventional, 3D-printed and milled artificial teeth to resin substrates for complete dentures: a narrative review. Polymers (Basel). 2023; 15(11):2488. doi: 10.3390/polym15112488
10. Puthiyaveetil JS, Kota K, Chakkarayan R, *et al*. Epithelial-mesenchymal interactions in tooth development and the significant role of growth factors and genes with emphasis on mesenchyme - a review. J Clin Diagn Res. 2016;10(9):ZE05-9. doi: 10.7860/JCDR/2016/21719.8502
11. Wang XP, Fan J. Molecular genetics of supernumerary tooth formation. Genesis. 2011;49(4):261-77. doi: 10.1002/dvg.20715
12. Liu C, Guo H, Shi C, *et al*. BMP signaling in the development and regeneration of tooth roots: from mechanisms to applications. Front Cell Dev Biol. 2023;11:1272201. doi: 10.3389/fcell.2023.1272201
13. Faraahi Z, Baud'huin M, Croucher PI, *et al*. Sostdc1: a soluble BMP and Wnt antagonist that is induced by the interaction between myeloma cells and osteoblast lineage cells. Bone. 2019; 122:82-92. doi: 10.1016/j.bone.2019.02.012
14. Murashima-Suginami A, Takahashi K, Sakata T, *et al.* Enhanced BMP signaling results in supernumerary tooth formation in USAG-1 deficient mouse. Biochem Biophys Res Commun. 2008;369(4):1012-6. doi: 10.1016/j.bbrc.2008.02.135
15. Kiso H, Takahashi K, Saito K, *et al*. Interactions between BMP-7 and USAG-1 (Uterine Sensitization-Associated Gene-1) regulate supernumerary organ formations. PLoS One. 2014;9(5):e96938. doi: 10.1371/journal.pone.0096938
16. Mishima S, Takahashi K, Kiso H, *et al.* Local application of Usag-1 siRNA can promote tooth regeneration in Runx2-deficient mice. Sci Rep. 2021;11:13674. doi: 10.1038/s41598-021-93256-y
17. Kiso H, Takahashi K, Mishima S, *et al.* Third dentition is the main cause of premolar supernumerary tooth formation. J Dent Res. 2019;98(9):968-74. doi: 10.1177/0022034519858282
18. Takahashi K, Kiso H, Murashima-Suginami A, *et al.* Development of tooth regenerative medicine strategies by controlling the number of teeth using targeted molecular therapy. Inflamm Regen. 2020;40:21. doi: 10.1186/s41232-020-00130-x
19. Takahashi K, Kiso H, Mihara E, *et al*. Development of a new antibody drug to treat congenital tooth agenesis. J Oral Biosci. 2024; 66(4):1-9. doi: 10.1016/j.job.2024.10.002
20. Moradi Z, Karimi M, Kolahdouz S, *et al.* USAG-1 and regenerative dentistry, therapeutic implications and future directions: review of the literature. Clin Exp Dent Res. 2026; 12(1):e70301. doi: 10.1002/cre2.70301
21. Zhang W, Yelick PC. Tooth repair and regeneration: potential of dental stem cells. Trends Mol Med. 2021;27(5):501-11. doi: 10.1016/j.molmed.2021.02.005
22. Yelick PC, Sharpe PT. Tooth bioengineering and regenerative dentistry. J Dent Res. 2019; 98(11):1173-82. doi: 10.1177/0022034519861903
23. Monteiro N, Yelick PC. Advances and perspectives in tooth tissue engineering. J Tissue Eng Regen Med. 2017; 11(9):2443-61. doi: 10.1002/term.2134

24. Roulias P, Kalantzis N, Doukaki D, *et al*. Teeth eruption disorders: a critical review. Children (Basel). 2022;9(6):771. doi: 10.3390/children9060771

25. Smith EE, Yelick PC. Progress in bioengineered whole tooth research: from bench to dental patient chair. Curr Oral Health Rep. 2016;3(4):302-8. doi: 10.1007/s40496-016-0110-2

How to Cite: Kashwani R, Kumari A, Sawhney H. Artificial Teeth and Biological Tooth Regeneration Through USAG-1 Suppression: A Narrative Review. Int Res J Med Surg. 2026;3(3):17-25.
DOI: 10.47857/irjmeds.2026.v03i03.075