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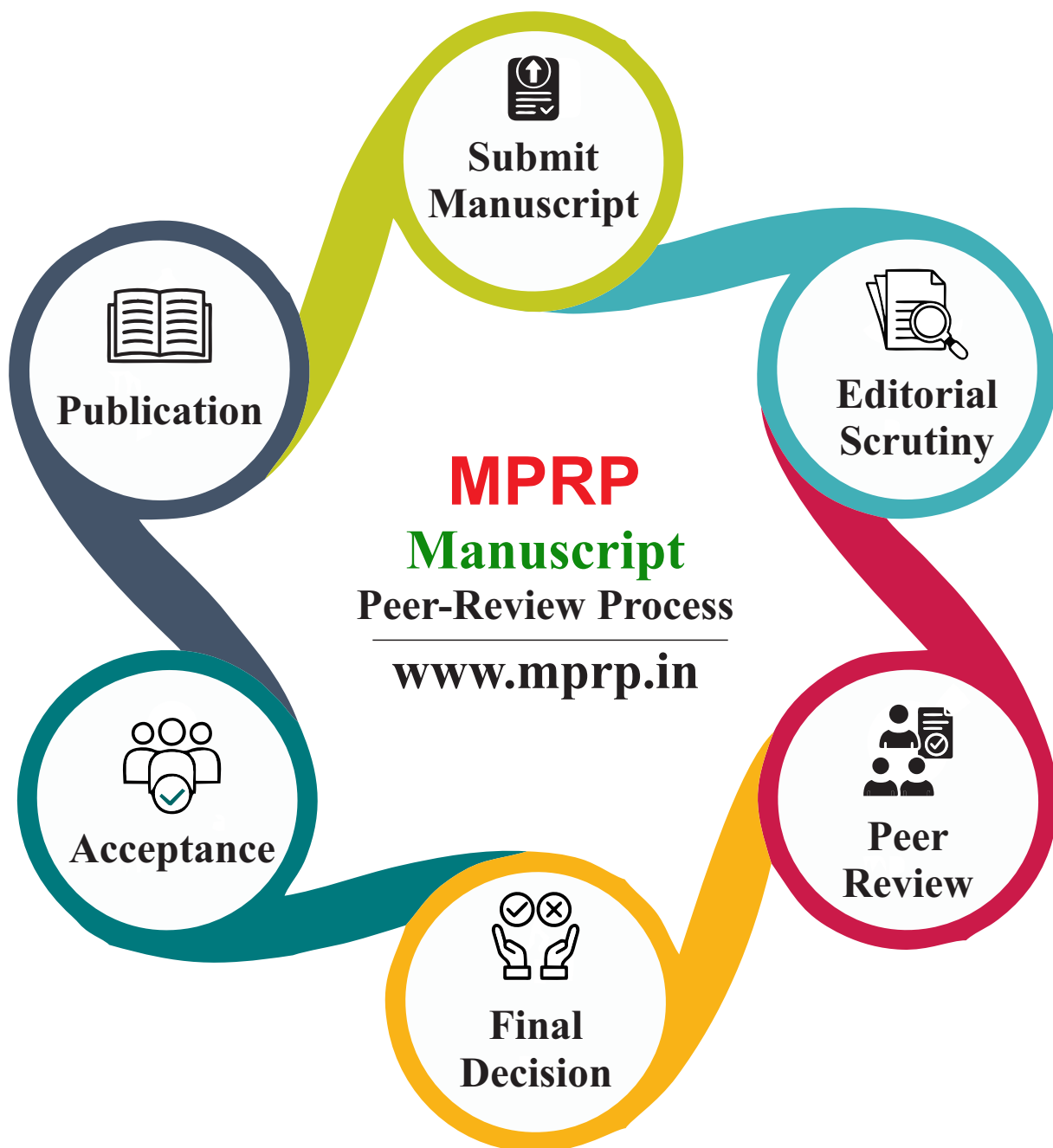
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Editorial

Digital transformation in dentistry: The expanding role of intraoral scanners and CAD-CAM technology

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The field of dentistry is undergoing a profound transformation driven by rapid advancements in digital technology. Among the most significant innovations are intraoral scanners (IOS) and computer-aided design/computer-aided manufacturing (CAD-CAM) systems, which are redefining clinical workflows, enhancing precision, and improving patient experiences. As we move toward a fully digital era, these technologies are no longer adjuncts but essential components of modern dental practice.

1. Evolution of Digital Dentistry

Traditional dental workflows have long relied on elastomeric impressions, gypsum casts, and manual laboratory procedures. These methods, although reliable, are associated with limitations such as patient discomfort, dimensional inaccuracies, and increased procedural time. The advent of intraoral scanners and CAD-CAM systems has enabled direct digital data acquisition and streamlined prosthetic fabrication, significantly improving efficiency and precision.^{1,2}

Recent literature highlights that digital scanning technologies have revolutionized diagnostic capabilities and treatment planning, allowing clinicians to capture detailed three-dimensional representations of oral structures with high accuracy.³

2. Clinical Applications and Advantages

The clinical applications of IOS and CAD-CAM systems have expanded across multiple domains, including prosthodontics, implantology, orthodontics, and maxillofacial rehabilitation.² Digital impressions demonstrate improved patient comfort, reduced chairside time, and enhanced communication with dental laboratories.

Contemporary studies (2024–2025) have shown that intraoral scanners provide high trueness and precision, even in complex clinical scenarios such as subgingival margin capture and full-arch implant rehabilitation.^{4–5}

CAD-CAM systems further enhance restorative outcomes by enabling standardized fabrication of prostheses, reducing operator variability, and ensuring consistent marginal adaptation. The ability to fabricate restorations using both subtractive (milling) and additive (3D printing) methods has significantly improved clinical outcomes.⁶

3. Technological Advancements and Integration

Recent innovations in digital dentistry (2023–2025) have focused on cloud-based workflows, artificial intelligence (AI), and enhanced scanner technologies. The evolution of intraoral scanners now includes features such as real-time data processing, photogrammetry, and improved soft tissue capture, contributing to greater clinical accuracy and efficiency.⁷

Furthermore, integration with CBCT imaging enables guided implant surgery, facilitating prosthetically driven implant placement with higher predictability.⁸ The emergence of AI-based models for analyzing intraoral scan data has opened new avenues for automated diagnosis and treatment planning, further enhancing clinical decision-making.⁹

4. Challenges and Limitations

Despite significant advancements, certain limitations persist. The high initial cost of equipment, need for technical expertise, and variability in accuracy for full-arch scans remain challenges for widespread adoption.^{5,10} Additionally, data management and standardization across different software platforms require further refinement.

5. Future Perspectives

The future of digital dentistry is strongly aligned with AI integration, machine learning, and fully automated workflows. Emerging technologies are expected to enable real-time diagnostics, predictive treatment planning, and personalized dental care. Continuous improvements in

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scanner accuracy, software algorithms, and biomaterials will further enhance the scope of CAD-CAM dentistry.⁹

6. Conclusion

Intraoral scanners and CAD-CAM technology represent a paradigm shift in modern dentistry, offering enhanced precision, efficiency, and patient-centered care. With continuous technological evolution and increasing accessibility, digital dentistry is poised to become the standard of care, transforming both clinical practice and dental education.

7. Conflict of Interest

None.

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Review Article

Sustainable orthodontics: Aligners, environmental contamination and the green responsibility ahead

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Abstract

The rapid evolution of clear aligner therapy has transformed orthodontic practice, offering patients an esthetic, comfortable and digitally driven alternative to traditional fixed appliances. However, this innovation has also introduced significant environmental and bioethical challenges. This review explores the composition of aligner materials, their environmental footprint, chemical toxicity and challenges associated with biomedical waste disposal. It further discusses emerging strategies to mitigate environmental contamination through sustainable materials, recycling initiatives and responsible clinical practices. The article emphasizes the crucial role of orthodontists in promoting eco-conscious treatment systems and calls for collaborative action between researchers, clinicians and manufacturers toward a greener orthodontic future.

Keywords: Aligners, Orthodontics, Environmental sustainability, Thermoplastic polymers, Recycling, BPA, Biodegradable materials.

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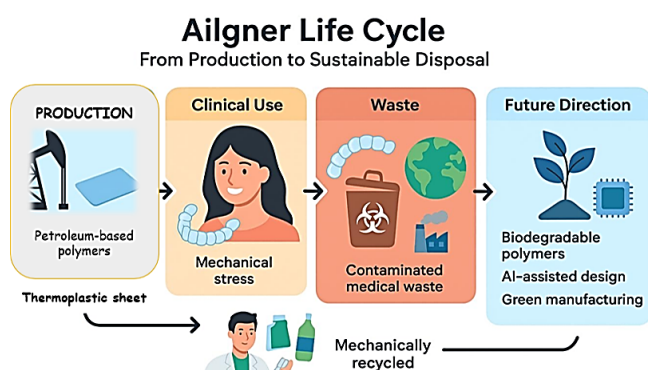


Figure 1. Aligner life cycle from production to sustainable disposal

Orthodontics has witnessed a profound transformation over the past two decades, largely driven by the introduction and rapid advancement of clear aligner therapy. Unlike traditional fixed appliances, which rely on brackets and archwires, aligners provide a removable, nearly invisible alternative that appeals particularly to adult patients seeking esthetic and convenient treatment options. The integration of digital technologies, including three-dimensional (3D) intraoral scanning, computer-aided design and manufacturing (CAD/CAM), and artificial intelligence-based treatment planning, has further revolutionized the field by enhancing precision, predictability, and patient-specific customization.¹

Initially, orthodontic esthetics were improved through the use of ceramic and polycarbonate brackets; however, the advent of transparent thermoplastic aligners marked a paradigm shift in clinical practice. These aligners are

fabricated using advanced polymeric materials that combine transparency, flexibility, and strength, enabling controlled tooth movement through sequential staging. As a result, aligner therapy has become one of the fastest-growing segments in orthodontics worldwide.

Despite these clinical advantages, the increasing reliance on disposable thermoplastic materials has raised critical environmental concerns. Each patient undergoing aligner therapy typically uses multiple sets of plastic trays over the course of treatment, contributing significantly to biomedical plastic waste. These materials are predominantly petroleum-based and non-biodegradable, leading to long-term environmental persistence and ecological harm. Furthermore, the production and disposal processes associated with aligners contribute to carbon emissions, microplastic generation, and potential release of toxic by-products.

In addition to environmental considerations, there is growing concern regarding the biocompatibility and chemical safety of aligner materials. The potential leaching of substances such as bisphenol A (BPA) under intraoral conditions has prompted investigations into their toxicological effects, including endocrine disruption and metabolic disorders. Consequently, the concept of sustainability in orthodontics has emerged as a critical area of research and clinical responsibility.

This review aims to provide a comprehensive analysis of aligner materials, their environmental and biological implications, and the strategies available to mitigate their ecological impact. By integrating material science,

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environmental awareness, and clinical practice, the article highlights the need for a paradigm shift toward sustainable orthodontics.²

2. Review Methodology

This systematic review was conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to evaluate the environmental impact, material composition, and biocompatibility of clear aligner therapy.

2.1. Search strategy

A comprehensive literature search was performed across electronic databases including PubMed, Scopus, and Web of Science for studies published between January 2000 and December 2024. The search strategy incorporated combinations of the following keywords:

“clear aligners,” “thermoplastic polymers,” “polyurethane,” “PET-G,” “biodegradable materials,” “bisphenol A,” “microplastics,” and “dental waste management.”

Boolean operators (AND, OR) were used to refine the search.

2.2. Study selection

A total of 85 records were identified through database searching. After removal of 15 duplicates, 70 articles were screened based on titles and abstracts.

Of these, 40 studies were excluded due to lack of relevance.

The remaining 30 full-text articles were assessed for eligibility. After full-text review, 15 articles were excluded for the following reasons:

Irrelevant to aligner materials or sustainability (n = 3)

Insufficient or unclear data (n = 6)

1. Non-English publications (n = 3)
2. Conference abstracts or incomplete reports (n = 3)
3. Finally, 15 studies were included in the qualitative synthesis.

2.3. Inclusion criteria

1. Studies evaluating clear aligner materials or polymers
2. Articles addressing environmental impact or sustainability
3. Studies investigating BPA release or biocompatibility
4. Peer-reviewed publications in English

2.3. Exclusion criteria

1. Studies unrelated to orthodontic aligners
2. Editorials, opinion articles without supporting data
3. Conference abstracts or unpublished data
4. Non-English articles

2.4. Data extraction and analysis

Relevant data from selected studies were extracted and categorized into key themes:

1. Material composition and mechanical properties
2. Environmental impact and waste generation
3. Chemical toxicity (e.g., BPA release)
4. Recycling and sustainability strategies

A qualitative synthesis was performed to identify trends, gaps, and future research directions in sustainable orthodontics.³⁻⁴

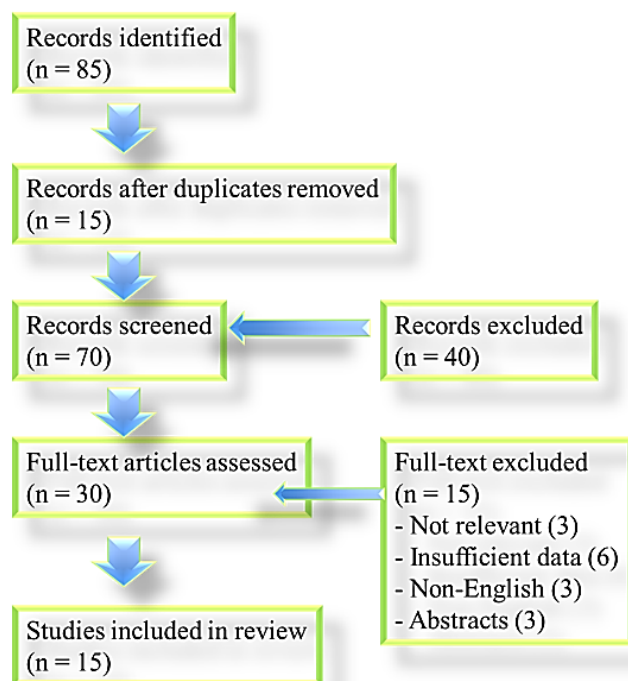


Figure 2. PRISMA flow diagram illustrating the systematic process of literature identification, screening, eligibility assessment, and inclusion. A total of 85 records were identified through database searching, of which 15 duplicates were removed. After screening 70 records, 40 were excluded based on titles and abstracts. Thirty full-text articles were assessed for eligibility, and 15 were excluded due to irrelevance, insufficient data, non-English language, or being conference abstracts. Finally, 15 studies were included in the qualitative synthesis.

3. Discussion

3.1. Composition and mechanical properties of clear aligners

The development of modern orthodontic aligners relies heavily on advancements in polymer science. Polymers are macromolecules composed of repeating monomeric units linked through covalent bonds, forming long chains with unique structural and functional properties. Their versatility, cost-effectiveness, and adaptability make them ideal for a wide range of biomedical applications, including orthodontic appliances.⁵

Clear aligners are primarily fabricated from thermoplastic polymers such as polyethylene terephthalate glycol (PET-G), thermoplastic polyurethane (TPU), and multilayered copolymers. These materials are selected based on their ability to provide a balance between flexibility and stiffness, which is essential for delivering controlled orthodontic forces while allowing easy insertion and removal.

Within the oral environment, aligner materials are exposed to a complex and dynamic milieu characterized by saliva, enzymes, fluctuating pH levels, and temperature variations. These factors can influence the physical and chemical stability of the polymers, leading to degradation and potential alteration of mechanical properties. For instance,

exposure to acidic or alkaline conditions may accelerate hydrolytic degradation, while temperature fluctuations can induce thermal expansion and contraction, affecting the fit and performance of the aligner.

Mechanical properties such as elastic modulus, stress relaxation, and creep behavior play a crucial role in determining the effectiveness of tooth movement. Aligners must maintain consistent force delivery over time; however, viscoelastic relaxation can result in a gradual decrease in force, potentially compromising treatment outcomes. Additionally, repeated occlusal loading during mastication may lead to deformation or fracture of the material.⁶

Thermal behavior is another critical consideration. Polymers do not exhibit a sharp melting point but instead undergo a gradual transition from a glassy to a rubbery state at the glass transition temperature (T_g). For aligner materials, the T_g must remain well above intraoral temperatures to ensure dimensional stability and mechanical integrity. Techniques such as differential scanning calorimetry (DSC) are used to evaluate these thermal properties.

Furthermore, polymer aging—both physical and chemical—can affect aligner performance. Physical aging involves structural relaxation and increased brittleness, while chemical aging includes oxidation and hydrolysis leading to chain scission. These processes may compromise transparency, strength, and biocompatibility, highlighting the need for continuous material innovation.

3.2. Polymer structure and thermal behavior

Polymers are macromolecules composed of repeating structural units connected through covalent bonds (Figure 3). The molecular architecture and weight distribution of these chains determine the material's thermal and mechanical characteristics. Unlike small molecules with well-defined melting points, polymers exhibit complex phase transitions due to the entanglement of their long chains and the coexistence of amorphous and crystalline regions.

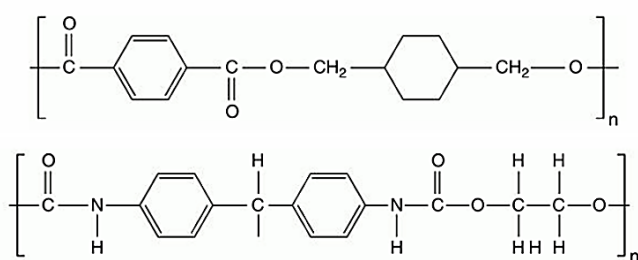


Figure 3. a: chemical structure of polyethylene terephthalate glycol material (PET-G), 3b: chemical structure of polyurethane material (PU)

Clear aligners are fabricated from thermoplastic polymers—materials that soften upon heating and solidify upon cooling without undergoing chemical change. Two widely utilized thermoplastic polymers in aligner fabrication are polyethylene terephthalate glycol (PETG) and thermoplastic polyurethane (TPU). PETG, a copolymer of polyethylene terephthalate and glycol, exhibits enhanced flexibility and reduced brittleness compared to PET due

to glycol's ability to inhibit crystallization. TPU, on the other hand, is a versatile elastomer that can be chemically tailored for specific hardness and elasticity, offering superior impact resistance, flexibility and chemical stability in moist environments.

Both materials are transparent, biocompatible and suitable for thermoforming—a critical process in aligner fabrication. PETG and TPU are preferred not only for their clarity and strength but also for their recyclability and processability, aligning with current sustainability goals in dental material science.⁷

4. Glass Transition and Viscoelasticity

Unlike crystalline solids, polymers transition gradually from a rigid, glassy state to a more rubber-like state over a temperature range known as the glass transition temperature (T_g). Above T_g , the polymer chains gain sufficient mobility to deform under stress; below T_g , the material behaves as a hard, brittle solid. For aligner materials, the T_g must remain well above intraoral temperatures to ensure mechanical stability during use. Differential scanning calorimetry (DSC) is commonly employed to determine T_g , which for PETG is approximately 85°C. This thermal buffer ensures that aligners maintain their intended mechanical properties even under varying oral conditions (Figure 4).⁷

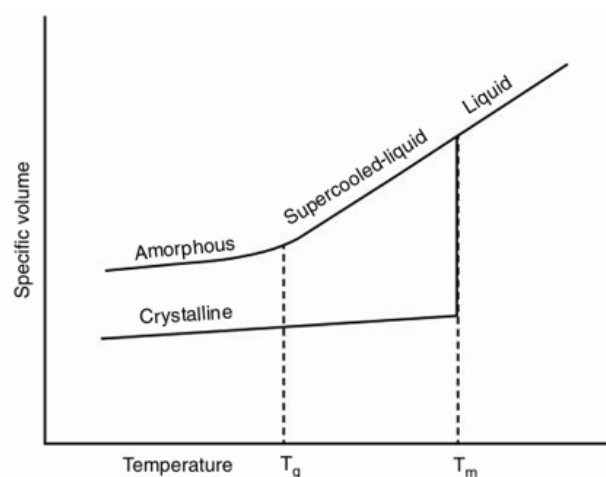


Figure 4. Specific volume versus temperature. T_m represents melting temperature and T_g represents glass transition temperature

5. Aging of Aligner Polymers

Polymeric materials used in aligners undergo physical and chemical aging during clinical use. Physical aging refers to the gradual relaxation of the polymer chains toward a lower energy state, leading to reduced free volume, increased stiffness and potential brittleness over time. Exposure to saliva and dietary components accelerates this process through molecular diffusion and plasticization where absorbed water or organic molecules increase chain mobility and reduce T_g , temporarily softening the material.⁷

Chemical aging, in contrast, involves irreversible reactions such as hydrolysis and oxidation, leading to chain scission, loss of strength and surface cracking. These processes compromise the aligner's mechanical performance, transparency and biostability. Therefore, modern aligner

materials are designed to resist both forms of degradation, ensuring predictable force delivery and esthetics throughout the wear cycle.⁷

Manufacturers must also maintain transparency regarding material composition and production processes, as even minor changes can influence the aligner’s performance and patient outcomes. Future research should focus on developing next-generation biopolymers that combine enhanced mechanical stability with improved biodegradability and environmental sustainability, paving the way for a more efficient and eco-conscious orthodontic

future.

Clear aligners are fabricated from advanced thermoplastic polymers such as polyurethane (PU), polyethylene terephthalate glycol (PET-G) and multilayered copolymers designed for controlled elasticity. These materials must exhibit a balance between flexibility allowing for insertion and removal and stiffness to deliver adequate orthodontic forces. The aligner’s biomechanical behavior depends on its elastic modulus, stress relaxation and deformation resistance under cyclic loading (Table 1).⁸

Table 1. Comparison of common thermoplastic materials used in clear aligners

Material	Base Composition	Mechanical Properties	Remarks
Polyurethane (PU)	Petroleumderived polymer	High flexibility, moderate stiffness	Common in pressure-formed aligners
PET-G	Polyethylene terephthalate glycol	Good clarity, high rigidity	Common in vacuum-formed systems
Polycarbonate	Bisphenol-based polymer	High strength, low flexibility	Limited due to BPA toxicity
Multilayer copolymers	PU + PET blends	Enhanced force retention	New-generation aligners

Table 2. Environmental consequences of improper disposal of aligner plastics

Disposal Method	By-products Released	Environmental Consequences
Landfill	Microplastics	Soil and groundwater contamination
Burning	Cyanides, phosgene	Air pollution, toxic gas emission
Ocean dumping	Microplastics	Marine life ingestion, ecological imbalance

Table 3. Summary of key studies evaluating BPA presence in orthodontic aligners

Author (Year)	Material Studied	BPA Detection	Clinical Implication
Iliadi et al., 2020	Various thermoplastics	Trace levels detected	Potential low-dose exposure risk
Schuster et al., 2018	Vacuum-formed PET-G	Minor BPA leaching	Recommend water pre-soak
Ryokawa et al., 2006	Thermoplastic aligners	Leaching reduced after 24h soak	Supports pre-treatment practice

Table 4. Classification of plastic recycling methods

Recycling Type	Process Description	Advantages / Limitations
Mechanical Recycling	Shredding and remolding of plastics	Simple but limited by contamination
Chemical Recycling	Depolymerization to monomers	High cost but retains material quality
Energy Recovery	Incineration for energy generation	Reduces waste but releases CO ₂

5.1. Environmental impact of thermoplastic waste

The environmental implications of clear aligner therapy are becoming increasingly significant in the context of global plastic pollution. Thermoplastic polymers used in aligners are predominantly derived from non-renewable petroleum resources and are resistant to natural degradation processes. As a result, discarded aligners contribute to the accumulation of persistent plastic waste in landfills and aquatic ecosystems.

A typical aligner treatment may involve the use of 20 to 40 trays per patient, each worn for one to two weeks. Considering the growing number of patients undergoing aligner therapy worldwide, the cumulative volume of plastic waste generated is substantial. Unfortunately, only a small fraction of this waste is recycled, primarily due to contamination and lack of appropriate recycling infrastructure for biomedical plastics.

Improper disposal methods, such as incineration or open burning, can release hazardous substances including dioxins, furans, cyanides, and phosgene gas. These emissions contribute to air pollution and pose serious health risks to both humans and wildlife. Similarly, landfill disposal leads

to the fragmentation of plastics into microplastics, which can infiltrate soil and groundwater systems, ultimately entering the food chain.

Marine pollution is another critical concern, as plastic waste often finds its way into oceans, where it is ingested by marine organisms. This not only affects biodiversity but also disrupts ecological balance and food safety. Microplastics derived from orthodontic materials may persist for decades, highlighting the urgent need for sustainable waste management solutions.

Thermoplastic aligners are predominantly petroleum-based and non-biodegradable. Once discarded, they contribute to long-term environmental pollution. Improper disposal or incineration releases harmful gases including cyanides, phosgene and dioxins. Globally, only about 9% of total plastic waste undergoes recycling, which highlights the scale of the orthodontic plastic challenge (Table 2).¹

5.2. Chemical additives and bisphenol a (BPA) exposure

The incorporation of chemical additives is essential for enhancing the physical properties of thermoplastic materials.

Bisphenol A (BPA), commonly used in the production of polycarbonate plastics and epoxy resins, improves transparency, durability, and resistance to impact. However, BPA is a well-known endocrine-disrupting chemical with potential adverse effects on human health.

Although many aligner manufacturers claim to use BPA-free materials, studies have demonstrated the presence of trace amounts of BPA released under simulated intraoral conditions. Factors such as temperature, mechanical stress, and exposure to saliva can influence the extent of BPA leaching. While the levels detected are generally low, chronic exposure over extended periods may pose cumulative health risks.

BPA has been associated with a range of biological effects, including hormonal imbalance, reproductive disorders, metabolic diseases, and increased risk of certain cancers. Its ability to mimic estrogen and interfere with endocrine signaling pathways has raised concerns regarding its safety, particularly in long-term orthodontic treatments.

Clinical recommendations to minimize BPA exposure include pre-soaking aligners in water before use, avoiding exposure to high temperatures, and limiting the reuse of worn aligners. Continued research and regulatory oversight are necessary to ensure the safety and transparency of orthodontic materials.

Bisphenol A (BPA) and other chemical additives improve the transparency and toughness of thermoplastics but pose toxicological concerns. While aligner manufacturers often claim BPA-free formulations, several independent studies have reported trace amounts of BPA release when aligners are exposed to heat, saliva and mechanical stress. Chronic exposure to BPA has been linked to endocrine disruption, infertility, metabolic disorders and carcinogenesis (Table 3).³

5.3. Recycling and waste management strategies

Effective waste management is a cornerstone of sustainable orthodontics. Recycling of thermoplastic materials presents a viable approach to reducing environmental impact; however, several challenges must be addressed. Since used aligners are considered biomedical waste, they require proper decontamination before recycling.

Mechanical recycling involves shredding and reprocessing plastics into secondary products, although this method may result in reduced material quality. Chemical recycling, on the other hand, breaks down polymers into their monomeric components, allowing for the production of high-quality materials but at a higher cost. Energy recovery through controlled incineration can reduce waste volume but contributes to carbon emissions.

Orthodontic clinics play a critical role in waste segregation and management. Implementing designated collection systems for used aligners, educating patients on proper disposal, and collaborating with recycling facilities can significantly improve sustainability outcomes. Additionally, manufacturers can adopt take-back programs and closed-loop recycling systems to minimize waste generation.

Mechanical recycling, which involves reprocessing

plastics into granules for non-medical use, is a viable solution. However, because aligners are intraoral devices, they are classified as contaminated medical waste and require decontamination before recycling. Orthodontic clinics should collect used aligners in labeled biomedical waste containers, followed by sterilization and transfer to specialized recycling facilities (Table 4).⁸⁻¹⁰

6. Future Directions: Toward Green Orthodontics

The future of orthodontics lies in the integration of sustainability with technological innovation. Research is increasingly focused on the development of biodegradable and bio-based polymers such as polylactic acid (PLA) and cellulose derivatives. These materials offer the potential to reduce environmental persistence while maintaining the mechanical properties required for clinical performance.¹¹⁻¹²

Advances in additive manufacturing and 3D printing have opened new avenues for aligner fabrication. By producing aligners directly from digital models, material wastage can be minimized, and production efficiency can be enhanced. Furthermore, the use of artificial intelligence in treatment planning can optimize aligner sequencing, reducing the total number of trays required per patient.

Sustainable packaging, reduced energy consumption during manufacturing, and the use of renewable resources are additional strategies that can contribute to a greener orthodontic ecosystem. Collaboration among researchers, clinicians, manufacturers, and policymakers is essential to drive innovation and establish standardized guidelines for environmentally responsible orthodontic care.

Emerging research focuses on the development of biodegradable or bio-based polymers such as polylactic acid (PLA) and cellulose acetate, which offer comparable transparency and elasticity to traditional plastics. The integration of 3D printing with recyclable resins could revolutionize aligner fabrication by minimizing material wastage. Artificial intelligence can further optimize treatment planning to reduce the number of aligners required per case, thereby lowering overall plastic consumption.¹³⁻¹⁵

7. Conclusion

Clear aligner therapy represents a significant advancement in modern orthodontics, combining esthetics, comfort, and technological precision. However, its environmental implications cannot be ignored. The widespread use of non-biodegradable thermoplastic materials has introduced new challenges related to plastic waste, chemical safety, and ecological sustainability.

Orthodontists have a crucial role in addressing these challenges by adopting responsible clinical practices, promoting patient awareness, and supporting sustainable innovations. The development of biodegradable materials, efficient recycling systems, and digital optimization techniques offers promising solutions for reducing the environmental footprint of orthodontic treatment.

Ultimately, the transition toward sustainable orthodontics requires a collective effort that balances clinical excellence with environmental responsibility. By embracing this

paradigm shift, the orthodontic community can contribute to a healthier planet while continuing to deliver high-quality patient care.

Aligner therapy exemplifies the harmony between technological innovation and patient-centered care, yet it presents environmental challenges that cannot be overlooked. Orthodontists must advocate for sustainable practices, including the responsible disposal and recycling of aligners. Collaborative efforts among manufacturers, clinicians, and environmental agencies are essential to establish standardized protocols for eco-friendly orthodontic care. The discipline of orthodontics has both the opportunity and the responsibility to lead the dental profession toward sustainability.

8. Source of Funding

None.

9. Conflict of Interest

None.

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Review Article

Fixed prosthetic rehabilitation of edentulous arches with tilted implant technique: A systematic review

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Abstract

Background: Edentulism adversely affects mastication, speech, esthetics, and quality of life. Tilted implant-supported fixed prostheses, particularly the All-on-4 concept, have emerged as an effective graftless rehabilitation option for edentulous arches.

Objective: To systematically evaluate the survival rates, clinical outcomes, biomechanical advantages, and complications associated with tilted implant-supported fixed prostheses in edentulous patients.

Materials and Methods: A systematic literature search was conducted using PubMed, MEDLINE, Scopus, and Cochrane databases for studies published in English. Randomized controlled trials, prospective studies, retrospective studies, and systematic reviews evaluating tilted implants in edentulous arches were included. Data regarding implant survival, marginal bone loss, prosthetic complications, and patient satisfaction were analyzed.

Results: Tilted implants demonstrated high survival rates ranging from 93% to 100% with favorable long-term outcomes. Marginal bone loss remained within clinically acceptable limits and was comparable to axial implants. Common biological complications included mucositis and peri-implantitis, while prosthetic complications mainly involved acrylic fractures and screw loosening. Immediate loading protocols showed high success and improved patient satisfaction.

Conclusion: Tilted implant-supported prostheses represent a predictable and effective treatment modality for rehabilitation of edentulous arches, offering reduced treatment time, elimination of bone grafting procedures, and high patient satisfaction.

Keywords: Dental Implants, Edentulous Mouth, Immediate Dental Implant Loading, Prosthesis Implant-Supported, Oral Rehabilitation, All-on-4 Concept.

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1. Introduction

Edentulism continues to be a prevalent condition worldwide, significantly impairing mastication, phonetics, facial esthetics, and overall quality of life.^{2,4} Conventional complete dentures, although widely used, are associated with several limitations including poor retention, instability, mucosal irritation, and psychological dissatisfaction among patients.^{1,2} These shortcomings have led to the development of implant-supported prosthetic solutions, which have become the gold standard for the rehabilitation of edentulous patients.^{1,3}

Globally, edentulism remains a significant public health concern, particularly among the elderly population.^{31,32} Epidemiological studies suggest that the prevalence of complete edentulism ranges between 7% and 69% depending on geographic region, socioeconomic status, and access to dental care.³¹ With increasing life expectancy, the demand for predictable and long-lasting prosthetic solutions continues to rise, further emphasizing the need for advanced implant-based rehabilitation techniques.^{2,32}

Fixed implant-supported prostheses offer superior

stability, improved masticatory efficiency, and enhanced patient comfort compared to removable options.^{1,18} However, the placement of implants in edentulous arches is often challenged by insufficient bone volume, particularly in the posterior maxilla and mandible due to resorption and anatomical limitations such as the maxillary sinus and inferior alveolar nerve.^{5,6}

To overcome these limitations, the concept of tilted implants was introduced.^{10,35} This technique involves angling posterior implants to maximize the use of available bone while avoiding anatomical structures.^{10,35} The All-on-4 protocol, introduced by Malo et al., utilizes two anterior axial implants and two posterior tilted implants to support a full-arch prosthesis.⁷ This approach eliminates the need for bone grafting procedures and allows immediate loading, thereby reducing treatment time and cost.^{7,8}

The evolution of implant dentistry has been marked by a transition from delayed loading protocols to immediate loading concepts, driven by improvements in implant surface technology and surgical techniques.^{3,17} The introduction of roughened implant surfaces and enhanced osseointegration

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capabilities has played a pivotal role in enabling tilted implant protocols.³³ Over time, these advancements have contributed to higher success rates and expanded the applicability of implant-supported rehabilitations in complex clinical scenarios.^{16,17}

In addition to surgical advantages, tilted implants have gained importance due to their role in enhancing cortical anchorage, particularly in areas of poor trabecular bone quality.³⁵ This allows improved primary stability, which is essential for immediate loading protocols.^{17,35} Moreover, advancements in digital implant planning and guided surgery have further improved the accuracy of tilted implant placement, reducing surgical risks and improving prosthetic outcomes.^{34,38} These developments have positioned tilted implant techniques as a cornerstone in modern implant prosthodontics.^{8,34}

Despite the growing adoption of tilted implant protocols, variability exists in reported outcomes, particularly concerning long-term survival, complication rates, and biomechanical behavior.^{14,18} Therefore, a comprehensive evaluation of existing literature is essential to establish evidence-based conclusions regarding the effectiveness and predictability of this technique.

Recent literature has demonstrated that tilted implants provide comparable survival rates to axially placed implants while offering significant biomechanical and clinical advantages.^{9,11,14} This systematic review aims to comprehensively evaluate the role of tilted implants in fixed prosthetic rehabilitation of edentulous arches.

2. Materials and Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

A comprehensive literature search was performed using PubMed, MEDLINE, Scopus, and Cochrane Library databases for studies published between January 2000 and March 2025. The search strategy included combinations of keywords and Boolean operators such as “tilted implants” AND “All-on-4,” “edentulous arch,” “full-arch rehabilitation,” “implant-supported prosthesis,” and “immediate loading”.⁷⁻¹⁰

The inclusion criteria comprised:

1. Human clinical studies
2. Randomized controlled trials
3. Prospective and retrospective studies
4. Systematic reviews published in
5. English Studies evaluating tilted implants in edentulous arches restored with fixed prostheses
6. Studies with clearly reported clinical outcomes and minimum follow-up duration of 12 months

The exclusion criteria included:

1. Animal studies
2. Case reports
3. Studies without clinical outcome data
4. Studies involving removable prostheses only
5. Duplicate publications

Data extraction focused on implant survival rates,

marginal bone loss, prosthetic complications, biological complications, and patient satisfaction.^{11,16,18-20} The methodological quality of included studies was assessed based on study design, follow-up duration, sample size, and reporting transparency.

The study selection process according to PRISMA guidelines is illustrated in Figure 1. The All-on-4 concept utilizing two anterior axial implants and two posterior tilted implants is illustrated in Figure 2.^{7,8}

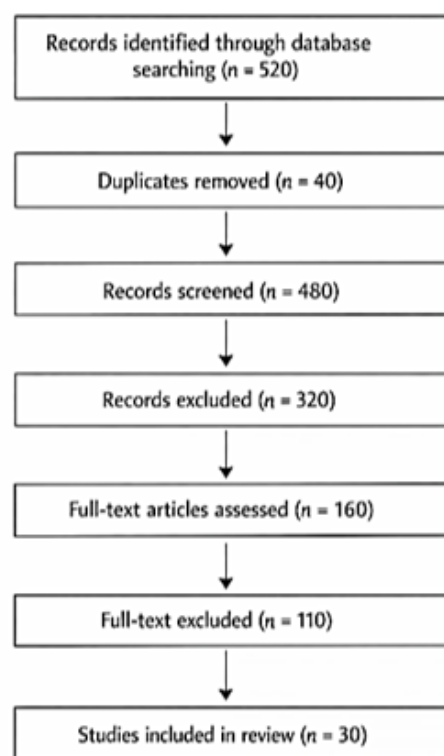


Figure 1. PRISMA flow diagram illustrating study selection process.

Figure 2 – All-on-4 Concept

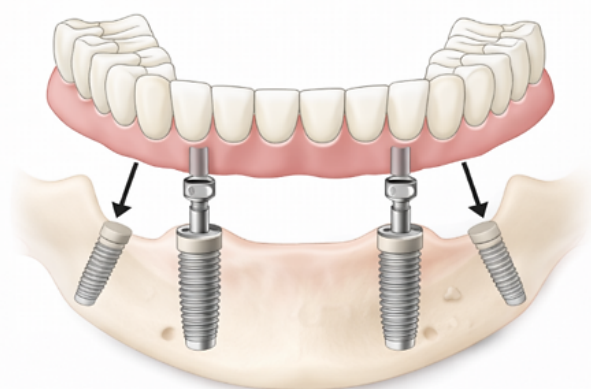


Figure 2. Schematic representation of All-on-4 concept showing two anterior axial and two posterior tilted implants.

Risk of bias assessment was performed qualitatively based on study design, sample size, follow-up duration, and reporting transparency.^{16,18} Randomized controlled

trials were considered to have lower risk of bias, while retrospective studies were evaluated cautiously due to potential selection and reporting biases.^{9,10,12}

3. Results

A total of 190 articles were initially identified through database searching. After removal of duplicates and screening based on titles and abstracts, full-text evaluation was performed for eligible studies. Finally, studies meeting predefined inclusion criteria were included in the qualitative analysis. The included studies demonstrated consistently high implant survival rates with favorable prosthetic and biological outcomes^{7,9–12,17,18}. The characteristics and outcomes of the included studies are summarized in Table 1.

Table 1. Summary of included studies

Author	Year	Study Design	Sample Size	Follow-up	Implant Survival Rate
Malo et al.	2003	Prospective Study	44 patients	1 year	96.7%
Krekmanov et al.	2000	Retrospective Study	25 patients	5 years	98%
Cavalli et al.	2012	Clinical Study	34 patients	73 months	100%
Francetti et al.	2012	Prospective Study	47 patients	3 years	97%
Babbush et al.	2011	Retrospective Study	165 patients	29 months	99%

The reviewed literature consistently demonstrated high survival rates for tilted implants used in full-arch rehabilitation.^{7,9–12,17} A retrospective study involving 34 patients and 136 implants reported a cumulative survival rate of 100% over a follow-up period ranging from 12 to 73 months.⁹ Other studies reported survival rates ranging between 93% and 99%, indicating that tilted implants perform comparably to axial implants.^{10–12} The major clinical outcomes reported in the included studies are summarized in Table 2.

Table 2. Summary of clinical outcomes of tilted implants

Parameter	Findings
Implant survival rate	93% – 100%
Follow-up duration	1–6 years
Immediate loading	Successful in majority
Bone loss	Within acceptable limits
Patient satisfaction	High

The consistently high survival rates across studies indicate strong clinical reliability of tilted implants.^{7,9–12} The narrow variation in survival percentages suggests reproducibility of outcomes across different populations and clinical settings.^{9,11,12} Immediate loading success further reinforces the role of primary stability achieved through cortical engagement.^{7,17,35}

Biological complications were relatively low and included mucositis and peri-implantitis.^{18,20,30} The incidence of mucositis was reported at approximately 11.76%, while peri-implantitis occurred in about 5.88% of patients.^{20,30} These complications were generally manageable with proper maintenance protocols and did not significantly

affect implant survival.^{18,20} The most commonly reported biological and prosthetic complications are summarized in Table 3.

Table 3. Reported complications in tilted implant rehabilitation

Complication	Incidence
Mucositis	~11.7%
Peri-implantitis	~5.8%
Acrylic fracture	14–29%
Screw loosening	~3%
Hygiene issues	~38%

Prosthetic complications were more frequently observed, particularly in provisional restorations.^{18,19} The most common issues included fracture or detachment of acrylic teeth, occurring in approximately 29% of cases, followed by minor acrylic fractures and occasional screw loosening.¹⁹ Despite these complications, prosthetic survival rates remained high, and most issues were easily correctable.^{18,19}

Immediate loading protocols were successfully implemented in the majority of cases, with provisional prostheses delivered within 48 hours of implant placement.^{7,12,17} This contributed to improved patient satisfaction and reduced treatment time.^{7,17}

Marginal bone loss around tilted implants was reported to be comparable to that observed in axially placed implants, with no statistically significant differences.^{11,14} This indicates that implant angulation does not adversely affect peri-implant bone stability when proper surgical and prosthetic protocols are followed.^{11,14,16}

Comparative analyses between tilted and axial implants revealed no statistically significant differences in marginal bone loss, supporting the biomechanical equivalence of both approaches.^{11,14} This finding highlights that implant angulation does not compromise osseointegration when appropriate surgical protocols are followed.^{14,16}

Long-term follow-up data from included studies indicate that tilted implant-supported prostheses maintain stable clinical performance over time.^{21,22,29} Minimal changes in marginal bone levels and sustained prosthetic integrity suggest that the technique is not only effective in the short term but also reliable for long-term rehabilitation.^{21,22} These findings reinforce the durability of tilted implants and support their use as a definitive treatment option for edentulous patients.^{18,21,29} Radiographic evaluation of full-arch rehabilitation with tilted implants is demonstrated in Figure 3.



Figure 3. Radiographic evaluation of full-arch rehabilitation using tilted implants.

4. Discussion

The tilted implant technique has significantly transformed the management of edentulous arches by providing a minimally invasive and efficient alternative to conventional implant placement.^{7,8,10} One of the primary advantages of this approach is the avoidance of bone grafting procedures, which are often associated with increased morbidity, cost, and treatment duration.^{5,13}

From an economic perspective, the tilted implant approach reduces overall treatment costs by eliminating the need for additional surgical procedures such as bone grafting or sinus lifts.^{7,13} This makes the treatment more accessible and appealing to a broader patient population.

In addition to clinical success, patient-reported outcomes play a crucial role in evaluating treatment efficacy. Studies have consistently demonstrated improvements in oral health-related quality of life (OHRQoL), including enhanced chewing ability, speech, comfort, and social confidence following tilted implant rehabilitation.^{2,4,18}

Biomechanically, tilted implants offer several advantages.^{14,15} By angling the posterior implants, the anteroposterior spread is increased, and the cantilever length is reduced, resulting in improved load distribution and reduced stress on the prosthesis.^{14,15} Finite element analysis studies have confirmed that tilted implants do not increase peri-implant bone stress when compared to axial implants.¹⁴

Clinically, the All-on-4 concept has demonstrated excellent outcomes in both maxillary and mandibular rehabilitations.^{7,23,24} The ability to immediately load implants enhances patient comfort and function, allowing for rapid restoration of esthetics and masticatory efficiency.^{7,17} Furthermore, the use of longer implants in tilted positions improves primary stability, which is critical for immediate loading protocols.^{17,35}

Another critical aspect is the role of prosthetic material selection in long-term success. Studies have shown that metal-acrylic prostheses are more prone to wear and fracture, whereas monolithic zirconia frameworks offer superior strength and reduced complication rates.^{18,19,36} However, zirconia may increase stress transmission to implants, necessitating careful occlusal design.³⁶ Therefore, material selection should be individualized based on patient-specific functional and esthetic requirements.

Despite these advantages, certain limitations must be considered. The technique is highly sensitive and requires careful planning using advanced imaging modalities such as CBCT.^{34,38} Additionally, prosthetic complications, particularly related to acrylic materials, remain a concern and necessitate regular follow-up and maintenance.^{18,19}

Accurate three-dimensional planning is essential for the success of tilted implant placement. Cone Beam Computed Tomography (CBCT) enables detailed evaluation of bone volume, density, and anatomical landmarks, allowing clinicians to determine optimal implant angulation and length.³⁸ Virtual implant planning software further facilitates prosthetically driven implant placement, minimizing surgical risks and improving precision.^{34,38} This integration of imaging and digital planning significantly enhances treatment predictability and reduces intraoperative complications.³⁴

The literature also highlights the importance of patient selection and adherence to strict maintenance protocols to minimize complications.^{20,30} Hygienic complications were reported in up to 38% of patients, emphasizing the need for proper oral hygiene and regular recall visits.³⁰

Furthermore, the emergence of digital workflows, including CAD/CAM fabrication and guided implant placement, has significantly enhanced the precision and predictability of tilted implant rehabilitation.^{34,37} These technologies reduce human error, improve prosthetic fit, and minimize chairside adjustments, thereby improving overall treatment outcomes.³⁷

Long-term studies have also demonstrated the durability and stability of implant-supported prostheses over extended follow-up periods, with titanium frameworks showing excellent mechanical performance and reduced complication rates.^{21,22,29} Furthermore, clinical studies evaluating the All-on-4 concept in maxillary rehabilitations have confirmed its effectiveness in complex anatomical conditions.^{23,24} Advances in implant materials and prosthetic frameworks, including PEEK and customized implants, have further enhanced treatment outcomes and reduced mechanical complications.²⁵⁻²⁷ Additionally, proper treatment planning and maintenance protocols remain critical factors influencing long-term success.^{28,30} The final prosthetic outcome following tilted implant rehabilitation is shown in Figure 4.



Figure 4. Final fixed prosthesis supported by tilted implants demonstrating functional and esthetic outcomes.

Limitations This systematic review has certain limitations

including heterogeneity among included studies, variability in follow-up duration, differences in prosthetic materials and designs, and inclusion of retrospective studies that may introduce selection bias. Furthermore, limited availability of long-term randomized controlled trials restricts definitive conclusions regarding long-term outcomes.

4.1. Future directions

Future research should focus on long-term randomized clinical trials evaluating tilted implant-supported prostheses beyond 10 years. Emerging technologies such as digital workflow integration, guided implant surgery, artificial intelligence-assisted treatment planning, and CAD/CAM prosthetics are expected to improve treatment precision and long-term outcomes. Additionally, development of advanced biomaterials with improved mechanical and esthetic properties may further reduce prosthetic complications and enhance patient satisfaction.

5. Conclusion

Tilted implant-supported fixed prostheses represent a reliable and predictable treatment option for the rehabilitation of edentulous arches. The technique offers high implant survival rates, reduced need for invasive surgical procedures, and improved patient satisfaction. While minor prosthetic and biological complications may occur, they are generally manageable and do not compromise overall treatment success.

6. Source of Funding

None.

7. Conflict of Interest

None.

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Original Research Article

Effectiveness of visual distraction tool in lowering the pain perception and anxiety levels of patients during surgical removal of impacted teeth: A randomized controlled study

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Abstract

Background: Surgical extraction of mandibular third molar has been a routine procedure in dental practice. Most patients often report with anxiety for such procedures which creates significant problems for the patients and dental practitioners. There are various techniques used to distract the patients' attention during clinical procedures. One such distraction tool is the use of virtual reality (VR). The objective of the study was to evaluate the effectiveness of visual distraction tool in lowering the pain perception and anxiety levels of patients during surgical removal of impacted teeth.

Materials and Methods: A Randomised controlled study was carried out over a period of 1 year on patients requiring surgical removal of impacted lower third molar, in the Oral and Maxillofacial Surgery outpatient department. Sixty patients, aged 18-30 years were divided into – study group (VR); control group. Perioperative evaluation of the vital parameters and pain and anxiety levels were tabulated using VAS and MDAS scale. The data obtained was subjected to statistical analysis using SPSS 26.0 software. Independent t-test and paired t-test was used to compare the variables.

Results: Highly significant difference was seen in the study group in terms of VAS and MDAS scale preoperatively and postoperatively at P value of 0.000. There was no statistically significant difference between study and control group at any given interval in terms of VAS and MDAS scale with P value>0.05. Intraoperatively, statistically significant difference was found in blood pressure between study and control group measured during administration of LA injection, bone guttering and closure with p value of 0.05.

Conclusion: The findings of the current study indicate that immersive VR distraction concept applied during impacted mandibular third molar surgery under local anesthesia can help reduce the patients' anxiety and acute pain levels.

Keywords: Behavioral modification, Dental anxiety, Surgical extraction, Virtual reality.

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1. Introduction

Surgical extraction of mandibular third molar has been a routine procedure in daily dental practice. Most patients often report with anxiety for such procedures. Dental anxiety is listed as the fifth most prevalent fear people experience.¹⁻³ The heightened anxiety experienced by patients during tooth extractions is linked to the administration of local anesthetic injections, the oral surgical procedure, and the anticipation of pain after surgery.^{4,5} Different clinical methods have been proposed and put into practice to help reduce dental anxiety in patients undergoing teeth extraction.⁶

Distraction or redirection is thought to divert focus and may help alter the perception of pain and anxiety.^{7,8} These techniques include methods such as relaxation, distraction, exposure therapy, hypnosis, and different forms of cognitive behavioral therapy.⁹⁻¹⁰ One effective distraction method is the use of virtual reality (VR).

Virtual distraction device is an innovative tool that involves a human technology interface utilizing 3D face-mounted displays with an extensive range of view.¹¹ VR generates virtual environments wherein the patients are engaged in a simulated environment that combines the audio,

visual, and kinesthetic sensory modalities sensations to divert the patient's attention into a virtual world, thereby alleviating both pain and stress associated with dental procedures^{12,11} Further, based on how engaging the presented stimuli are, the individual's concentration will be diverted from reality, resulting in less focus on real-world experiences, including painful stimuli.^{13,14}

Numerous studies in the literature emphasize the use of VR headsets to distract children during dental treatments and as a behavioral modification tool in pediatric dentistry.¹⁵⁻²¹ But there is lack of evidence on visual distraction tools and its application in reducing pain and anxiety during surgical removal of impacted teeth in adult patients. The number of studies addressing the management of anxiety and pain, especially during anesthetic block, is very limited. There is no study that has concluded the effectiveness, applicability and feasibility of virtual distraction tools for pain management and anxiety reduction during surgical removal of impacted teeth. The study aims to assess the efficiency of visual distraction tool in minimizing the pain perception and stress levels of individuals undergoing surgical removal of impacted teeth.

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2. Materials and Methods

Following institutional ethical committee approval (8467/IEC/2022), and in accordance with the Helsinki Declaration, this study was carried out for a duration of 1 year in Oral and Maxillofacial Surgery outpatient department on individuals requiring surgical removal of impacted lower third molar.



Figure 1. Following institutional ethical committee approval (8467/IEC/2022), and in accordance with the Helsinki Declaration, this study was carried out for a duration of 1 year in Oral and Maxillofacial Surgery outpatient department on individuals requiring surgical removal of impacted lower third molar.

2.1. Sample size estimation

The sample estimation was done with G-power statistics. Considering an anticipated incidence of around 0.071 to 0.429, with marginal error of 0.196 and a confidence level of 95%, the result suggested that minimum 30 participants were required for each group, leading to a total target sample size of 60.

$$n = (E^2 Z^2 \times p \times (1-p))$$

2.2. Inclusion and exclusion criteria

Patient selection included- age between 18 and 40 years, reporting with horizontally impacted lower third molar teeth (time-consuming and technique-sensitive), and fulfilling ASA criteria I and II. Patients of ASA criteria III and IV, psychiatric disorders, history of claustrophobia, and epilepsy were not considered in this study.



Figure 2. Patient selection included- age between 18 and 40 years, reporting with horizontally impacted lower third molar teeth (time-consuming and technique-sensitive), and fulfilling ASA criteria I and II. Patients of ASA criteria III and IV, psychiatric disorders, history of claustrophobia, and epilepsy were not considered in this study.

Before initiation of surgical procedure, all respondents were explained about the benefits, potential complications

and associated risks. Following this, valid informed consent was obtained from each patient. Participants were then assigned to two groups using computer-generated simple randomization.

1. Group 1: Study group (with the use of VR)
2. Group 2: control group (without the use of VR)

The study group's participants were exposed to Virtual reality technology starting from the administration of local anesthetic solution till closure of the wound. The VR technology consisted of a head-mounted immersive display and built-in headphones that were powered by a smartphone. Patients were shown relaxation videos created specifically for the VR format during the treatment. (Figure 1)

2.3. Surgical procedure

Under aseptic conditions, 2% lignocaine with adrenaline was used to give inferior alveolar nerve block and long buccal nerve block. (Figure 2) Local anesthesia was achieved. With no. 15 blade, standard Ward's incision was placed and the mucoperiosteal flap was elevated with Molt's no. 9 periosteal elevator. Buccal bone guttering was done using 702 bur, following which planned coronectomy was performed and extraction of the sectioned tooth fragment was done with desired armamentarium. Closure achieved by placing simple interrupted sutures with 3-O silk suture.

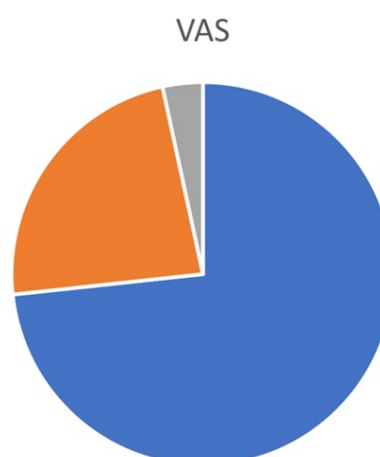


Figure 3. Modified dental anxiety scale of the study group
VAS - Visual Analogue Scale.

2.4. Assessment criteria

All the patients while sitting in the waiting area were asked to fill the preoperative Visual Analogue Scale (VAS), and Modified Dental Anxiety Scale (MDAS) to determine the preoperative pain and anxiety respectively. After completing the questionnaires, preoperative vital signs such heart rate (HR), blood pressure (BP), and oxygen saturation (SPO2) were assessed using pulse oximeter and digital BP apparatus.

Intraoperatively, the vital parameters were monitored during the time of LA administration, incision, bone guttering and closure. Following the surgical extraction, a postoperative VAS and MDAS scale was once more given to the patients to complete.

2.5. Statistical analysis

The data was analysed using SPSS 26.0 software (SPSS Inc., Chicago, IL), with $p < 0.05$ as level of significance. Descriptive statistics were employed to evaluate the mean and standard deviation of each group. For the testing of statistical hypotheses, independent t-test for dependent variables between the study and control group and paired t-test for pre-operative and post operative variables within the groups was used.

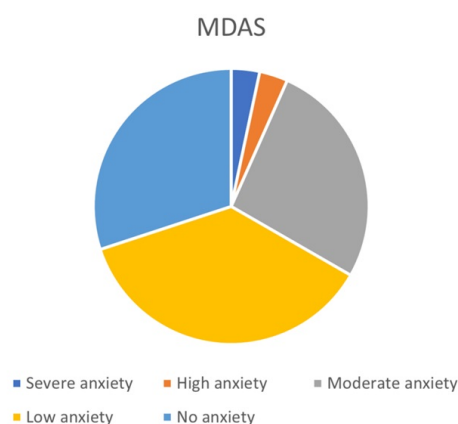


Figure 4. The data was analysed using SPSS 26.0 software (SPSS Inc., Chicago, IL), with $p < 0.05$ as level of significance.

Descriptive statistics were employed to evaluate the mean and standard deviation of each group. For the testing of statistical hypotheses, independent t-test for dependent variables between the study and control group and paired t-test for pre-operative and post operative variables within the groups was used.

MDAS - Modified Dental Anxiety Scale

3. Results

Of the 60 respondents, 33 were male and 27 were female, with an average age of 28 years. Among the respondents, 31 (17-males, 14-females) patients were operated on the left side and 29 (16-males, 13-females) on the right side.

Analysis of VAS scores obtained from patients intraoperatively in the study group has shown that 73.3% of the patients had mild pain, 23.3% patients have moderate pain and 3.4% had severe pain (Figure 3). The MDAS anxiety questionnaire obtained from all the participants of the study group during surgical extraction showed that about 3.33% of the patients had severe anxiety, 3.33% had high; 26.6% had moderate anxiety and about 36.6% of the patients had low anxiety. About 30% said that they were not anxious. (Figure 4)

Statistically, no significant difference was present between the two groups at any given interval in terms of VAS scale with p value > 0.05 . Similarly, no significant difference was evident respect to MDAS scale with p value > 0.05 .

Highly significant difference was present in the study group in terms of VAS scale preoperatively and postoperatively at p value of 0.000. Similarly, in the study group, there was a highly significant difference in the MDAS scale preoperatively and postoperatively with a p value of 0.000. (Table 1)

Intraoperatively, statistically significant difference was found in blood pressure between study and control group measured during administration of LA injection, incision, bone guttering and closure with p value of 0.05. However, there is not statistical difference in heart rate and oxygen saturation between the two groups. (Table 2)

Table 1. Comparison of VAS and MDAS within the study group

Parameter	Mean	N	Std. Deviation	t	p value
Visual analogue scale – Pre	1.8333	15	.53067	4.28	0.000*
Visual analogue scale – Post	1.3000	15	.53498	4.28	0.000*
Modified Dental Anxiety scale – Pre	3.2667	15	1.11211	5.19	0.000*
Modified Dental Anxiety scale – Post	2.1333	15	1.00801	5.19	0.000*

Statistical test applied: Paired samples t test; Asterick denotes highly significant at $p < 0.01$

Table 2. Comparison of intraoperative vital parameters between study and control group

Parameters	Group	N	Mean	Std. Deviation	T	P value
Heart rate	Study group	15	2.4667	.51640	0.00	1.00
Heart rate	Control group	15	2.4667	.51640	0.00	1.00
Oxygen saturation	Study group	15	2.0000	.00000	1.00	0.32
Oxygen saturation	Control group	15	1.9333	.25820	1.00	0.32
Blood pressure	Study group	15	2.4667	.51640	1.96	0.05*
Blood pressure	Control group	15	2.0667	.59362	1.96	0.05*

Statistical test applied: Independent t test. Asterick denotes highly significant at $p < 0.01$

4. Discussion

Dental anxiety can arise from various factors, including past negative experiences, exposure to alarming depictions of dentists by peers, the reclining position in the dental chair, the sight of needles, the sound of drills, and different odors present in the dental clinic.¹³⁻¹⁵ It results in heightened pain perception for the patient, regardless of the anesthetic methods employed^{22,23}. Wong and Lytle et al. reported that endodontic treatment and minor surgical procedures

were recognized as most anxiety-provoking treatments.²⁴ Therefore, a less invasive, safe and simple method should be used to reduce fear and anxiety caused by surgical treatment.²⁵ In this study, we utilized VR technology as a distraction tool to help minimize pain and anxiety during surgical removal of mandibular third molar impaction under local anaesthesia. VR works on the principle that nociception involves a significant cognitive element; by directing less attention to noxious stimuli, individuals may experience reduced pain.¹⁷ Hoffman et al. stated that the part of

brain involved in recognizing and signalling pain exhibit decreased activity when a patient is immersed in a virtual environment.²⁶

Heart rate and blood pressure are frequently used as dependent variables in behavioral studies, serving as parameters for assessing anxiety levels.²⁷ In this study, there was statistical difference found only in blood pressure recorded intraoperatively (p value of 0.05) with VR group showing decreased blood pressure. Similarly, in a study carried out by Alshatrat et al, he reported that intraoperative BP and HR were lower in participants exposed to VR than control or movie group.²⁸ Similar results were observed in a randomised control trial carried out by Pande et al where statistically significant difference was observed in vital parameters after treatment with maximum reduction in the VR group.²⁹ In this study, we found that during surgical extraction, 66.6% of the patients belonging to study group had low anxiety or no anxiety which is in contrast to the study conducted by Abhinav RP et al where he reported that 56% had moderate anxiety.¹³

Although the current study reported that no statistical significant difference was present between the two groups in respect to pain at any given interval but clinically patients with exposure to the VR were more comfortable during and after the surgical extraction of impacted teeth. However, Mladenovic et al stated that the respondents with the use of VR goggles had significantly lower pain values during the administration of anesthesia (p<0.001) as well as throughout the surgical procedure (p = 0.001).²⁵

The limitations of this study include less sample size. The VR technology model employed in this study is both easily accessible as well as straightforward to use. However, it has its own demerits such as huge size, limiting the surgeon's access to the operative field, which in turn prolonged the duration of surgery in the study group.³⁰

5. Conclusion

The study suggests that immersive VR is effective as a distraction tool in reducing pain and stress levels of patients during impacted mandibular third molar surgery. It is user-friendly, cost-effective, and eliminates the necessity for pharmacological agents to manage patient anxiety. In future, a customised VR device exclusively for minor oral surgical procedures need to be developed which will not hinder surgeon's access to the operative field and at the same time will not compromise patient's comfort.

6. Source of Funding

None.

7. Conflict of Interest

None.

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**Original Research Article****Evaluation of multiple impacted supernumerary teeth with an inverted supernumerary causing maxillary incisor impaction—a CBCT based study****Harvinder Singh¹, Yenika Manchanda^{1*}, Vinay Dua¹, Amanjot Kaur¹, Navjot Kaur²**¹Dept. of Orthodontic and Dentofacial Orthopedics, National Dental College and Hospital, Punjab, India²Dept. of Orthodontic and Dentofacial Orthopedics, Rayat Bahra Dental College and Hospital, Punjab, India**Abstract**

Impaction of maxillary incisors is a frequent concern in dental practice and is most commonly associated with the presence of supernumerary teeth in the anterior maxilla. While single supernumerary teeth are relatively common, the occurrence of multiple impacted supernumerary teeth—particularly with inverted orientation—is rare and poses significant diagnostic and treatment challenges. This case report describes a non-syndromic presentation of multiple impacted supernumerary teeth, including an inverted supernumerary tooth, resulting in impaction of a permanent maxillary central incisor.

An 11-year-old male patient presented with non-eruption of a permanent maxillary central incisor. Clinical examination revealed absence of the incisor with no signs of eruption, while the remaining dentition was appropriate for the patient's age. Cone beam computed tomography (CBCT) was performed for precise localization and assessment, which revealed two palatally impacted supernumerary teeth in the anterior maxilla. One of the supernumerary teeth exhibited an inverted orientation, with its crown directed toward the nasal floor, causing mechanical obstruction of the eruption pathway of the permanent maxillary central incisor. No clinical or radiographic features suggestive of syndromic association were identified.

A multidisciplinary treatment plan involving surgical removal of the impacted supernumerary teeth followed by orthodontic traction of maxillary central incisor using fixed mechanotherapy was formulated. This case highlights the diagnostic value of CBCT in identifying the number, orientation and spatial relationship of impacted supernumerary teeth and underscores its importance in guiding appropriate management of complex eruption disturbances.

Keywords: Supernumerary teeth, Inverted supernumerary tooth, Delayed eruption, Maxillary central incisor, Cone beam computed tomography**Received:** 12-02-2026 **Accepted:** 23-04-2026 **Available Online:** 23-05-2026

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For reprints contact: reprint@ipinnovative.com**1. Introduction**

Normal eruption of the maxillary incisors is a critical event in the development of functional and esthetic occlusion. This process depends on a coordinated interaction between tooth development, available space and the absence of physical or pathological obstruction. Any disruption in this balance may result in delayed eruption or impaction of the permanent incisors.

Among the various etiological factors responsible for eruption disturbances—such as retained primary teeth, odontogenic pathologies, trauma and developmental anomalies—supernumerary teeth represent the most common cause affecting the anterior maxilla. Supernumerary teeth are defined as teeth present in excess of the normal dental complement and are known to interfere mechanically with the eruption path of permanent incisors. Their prevalence varies across populations and shows a male predilection, with the majority occurring in the premaxillary region where they exert a direct influence on incisor eruption.^{1–3}

The effect of supernumerary teeth on eruption is not determined solely by their presence but is strongly influenced by their number, morphology and spatial orientation. Morphologically, supernumerary teeth may be classified as conical, tuberculate, supplemental or odontome-like.

Tuberculate and mal-positioned supernumerary teeth are more frequently associated with delayed eruption and impaction due to their larger size, delayed root development and tendency to occupy the eruptive pathway of permanent incisors. Clinically, this may result in prolonged retention of primary teeth, displacement or impaction of permanent incisors, root dilaceration and ectopic eruption.⁴

Tooth impaction occurs when a tooth fails to erupt into its normal functional position within the dental arch. While impaction of teeth is a relatively common finding, inversion of an impacted tooth is rare. An inverted tooth is characterized by an abnormal orientation in which the crown is directed superiorly toward the nasal floor and the root apex toward the alveolar crest. The exact etiology of inversion in supernumerary teeth is not fully understood; however, several developmental and local factors have been proposed to explain this unusual orientation.⁵

Supernumerary teeth are believed to arise from disturbances during the early stages of odontogenesis, particularly involving hyperactivity of the dental lamina or abnormal proliferation of odontogenic tissue.⁶ When this aberrant tooth germ develops in an altered position or orientation, it may result in an inverted eruption pattern.

One of the most accepted explanations for inversion

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is abnormal positioning of the tooth germ during early development. If the tooth germ is initially oriented upside down or displaced superiorly toward the nasal floor, subsequent growth and root formation occur in that altered direction, leading to an inverted tooth.²

Another contributing factor may be lack of eruptive space and physical constraints within the premaxillary region. The anterior maxilla is a confined area and the presence of adjacent developing teeth may redirect the path of least resistance for the supernumerary tooth, causing it to develop in an inverted orientation.²

Delayed or arrested eruption of a supernumerary tooth may also play a role. As surrounding permanent teeth continue to erupt and develop, the supernumerary tooth may become secondarily displaced or rotated, ultimately assuming an inverted position.

Additionally, genetic and hereditary influences have been suggested, as supernumerary teeth and their unusual orientations are more commonly observed in certain populations and often show a male predilection.⁶

Trauma and local environmental factors during early childhood have also been proposed, although their role remains less clearly defined. Inverted supernumerary teeth pose additional diagnostic and surgical challenges due to their atypical orientation and close proximity to vital anatomical structures.

The presence of multiple impacted supernumerary teeth, particularly when associated with inversion, significantly increases the risk of eruption failure of permanent incisors and complicates clinical management. Accurate localization and assessment of their relationship with adjacent teeth and anatomical structures are therefore essential. Cone beam computed tomography (CBCT) provides precise three-dimensional visualization, enabling effective diagnosis and treatment planning.

This case report describes a rare presentation of two impacted supernumerary teeth, one of which was inverted, leading to impaction of the maxillary central incisor in an 11-year-old male patient, highlighting the diagnostic value of CBCT in such complex eruption disturbances.

2. Objective

To report a rare case of multiple impacted supernumerary teeth, including an inverted supernumerary tooth, causing impaction of the maxillary central incisor in a pediatric patient, and to highlight the role of cone beam computed tomography in accurate diagnosis and treatment plan.

3. Case Report

Case Report: A male patient aged 11 years reported to the Department of Orthodontics and Dentofacial Orthopedics, National Dental College and Hospital, Derabassi with the chief complaint of absence of a permanent maxillary central incisor. The patient and parents expressed concern regarding delayed eruption of the anterior tooth, while all other permanent teeth appropriate for the age had erupted normally.

The patient's medical history was non-contributory. There was no history of systemic illness, syndromic association, dentofacial trauma, or family history of delayed

eruption or impacted teeth. The patient had not undergone any prior dental or orthodontic intervention for the present complaint.

Intraoral examination (Figure 1) showed permanent dentition with absence of eruption of the permanent maxillary central incisor(1). The surrounding mucosa showed no bulging or signs suggestive of imminent eruption. The remaining teeth in the arch were clinically present and appeared to be in normal alignment.



Figure 1. Intra-oral photographs

In order to determine whether the missing permanent tooth was impacted or congenitally absent, radiographic evaluation was advised. For precise localization and assessment of the spatial relationship of the impacted teeth with adjacent structures, a cone beam computed tomography (CBCT) scan of the maxilla was performed.

3.1. Radiographic evaluation (CBCT findings)

Cone Beam Computed Tomography (CBCT) (Figure 2) of the maxilla was performed, and three-dimensional volume-rendered reconstructions were evaluated to assess the dentoalveolar structures and the etiology of delayed eruption.

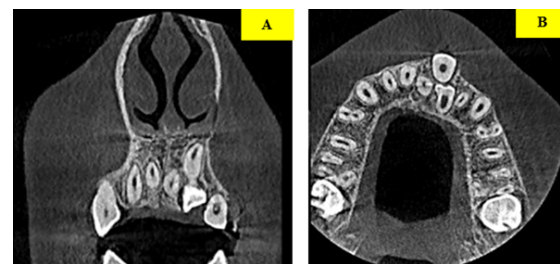


Figure 2. a: Coronal CBCT sections revealed multiple impacted supernumerary teeth in the anterior maxilla, one of which was inverted and located palatal to the maxillary incisors, in close proximity to the nasal floor, thereby interfering with the normal eruption pathway of the permanent incisors. 2b: Axial CBCT section demonstrates multiple palatally positioned, tooth-like radiopaque structures with independent follicular spaces in the anterior maxilla, consistent with impacted supernumerary teeth likely arising from dental lamina hyperactivity and obstructing normal incisor eruption.

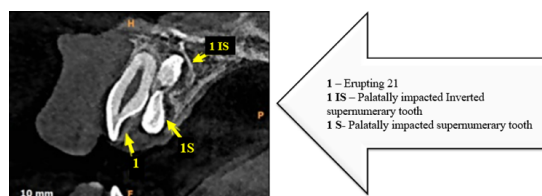
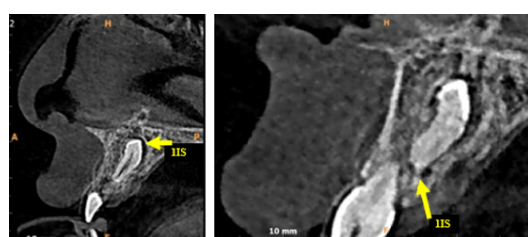


Figure 3. CBCT images revealed the presence of multiple supernumerary teeth in the anterior maxillary region

The CBCT images revealed the presence of multiple supernumerary teeth in the anterior maxillary region (Figure 3). Among these, one supernumerary tooth was identified in an inverted orientation, located in close proximity to the maxillary central incisor. The inverted supernumerary tooth (1IS) (Figure 4) was positioned superior to the crown of the permanent central incisor, with its crown directed superiorly toward the nasal floor and the root oriented inferiorly.



Inverted, palatally impacted supernumerary tooth at midline, with the crown directed superiorly, open root apex and close proximity to the apices of maxillary central incisor, resulting in delayed eruption

Figure 4. CBCT images revealing inverted supernumerary tooth

This inverted supernumerary tooth was found to mechanically obstruct the eruption pathway of the permanent maxillary central incisor, resulting in its failure/delay of eruption. The permanent central incisor exhibited complete crown formation with altered eruption trajectory due to the presence of the obstructing supernumerary tooth. The spatial relationship between the supernumerary tooth, the impacted central incisor and the surrounding alveolar bone was clearly delineated on the three-dimensional reconstruction.

Additional supernumerary tooth was noted in the anterior maxilla, contributing to localized crowding and alteration of normal tooth alignment (Figure 5). The CBCT images allowed accurate assessment of the number, position, orientation, and morphology of the supernumerary teeth, as well as their relationship to adjacent roots, cortical plates and the nasal floor.

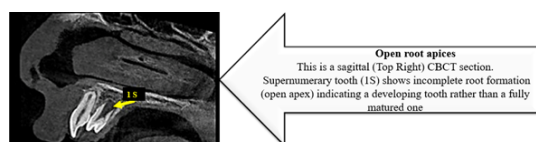


Figure 5. Additional supernumerary teeth were noted in the anterior maxilla

CBCT sagittal sections revealed the presence of two palatally impacted supernumerary teeth in the anterior

maxillary region (Figure 6). One supernumerary tooth (1IS) exhibited an inverted orientation, with the coronal portion positioned approximately 2.6 mm from the nasal floor, while its root apex was located near the apical region of tooth 11. The second supernumerary tooth (1S) was also palatally impacted, with its crown situated approximately 2.7 mm from the alveolar crestal level and the root apex directed toward the nasal floor at a distance of about 4.4 mm. Additionally, this tooth demonstrated incomplete root development with open apices, indicating an early stage of root formation. These CBCT findings clearly illustrate the spatial orientation, proximity to adjacent anatomical structures, and developmental status of the impacted supernumerary teeth, which are important considerations for diagnosis and surgical planning.

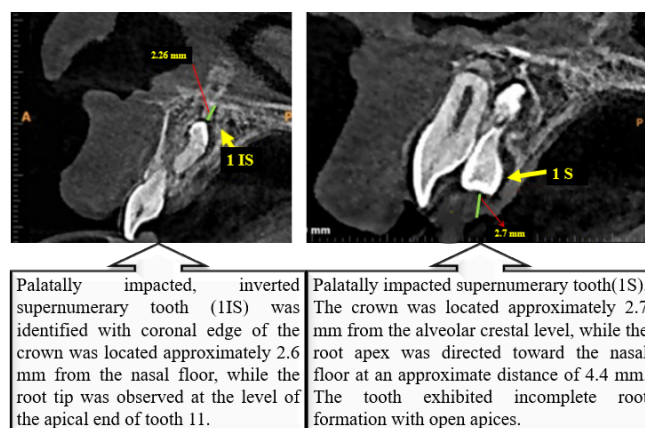


Figure 6. a: CBCT image revealing distance of inverted supernumerary tooth crown from nasal floor. 6b: CBCT image revealing distance of supernumerary tooth crown from alveolar crest level.

Overall, CBCT played a crucial role in identifying the multiple supernumerary teeth and the inverted supernumerary tooth directly responsible for eruption disturbance of the maxillary central incisor, thereby facilitating precise diagnosis and aiding in appropriate surgical and orthodontic treatment planning.

Based on the clinical and radiographic findings, a multidisciplinary treatment plan was formulated. The recommended treatment involved surgical removal of two impacted supernumerary followed with orthodontic traction of central incisor using fixed mechanotherapy. As treatment is currently in progress, final treatment outcomes could not be evaluated at the time of writing. The detailed treatment results and follow-up will be reported in a subsequent article.

4. Discussion

4.1. Tooth impaction and supernumerary teeth

Supernumerary teeth represent a developmental alteration in tooth number and are frequently associated with delayed eruption or impaction of adjacent permanent teeth. Their presence may cause mechanical obstruction, displacement, rotation, root resorption, or cystic changes. When located in the anterior maxilla, supernumerary teeth are a well-recognized cause of delayed eruption of maxillary central incisors. Early diagnosis through radiographic

evaluation is therefore essential to prevent long-term esthetic and functional complications.⁷

In the present case, multiple supernumerary teeth were identified in the anterior maxillary region, resulting in impaction of the permanent maxillary central incisor. The mechanical obstruction created by these teeth significantly compromised the natural eruption pathway of the permanent incisor.

4.2. Inverted supernumerary tooth

An inverted supernumerary tooth represents an uncommon developmental anomaly in which the tooth is positioned in a reversed orientation, with the crown directed superiorly and the root apex oriented inferiorly or vice versa depending on location. Inversion is more frequently reported in mesiodens but may also occur in other supernumerary teeth.

The abnormal orientation may further complicate eruption patterns by creating a mechanical obstruction to adjacent permanent teeth, altering eruption pathways, or increasing the risk of cystic changes. Radiographic evaluation is essential for accurate localization, assessment of proximity to adjacent roots and anatomical structures, and treatment planning.⁸

In the present case, the inverted positioning of the supernumerary tooth contributed significantly to the impaction of the maxillary central incisor. Its orientation and spatial relationship with the adjacent structures reduced the likelihood of spontaneous correction and reinforced the need for surgical intervention followed by orthodontic management.

4.3. Complexity due to multiple and inverted supernumerary teeth

While single supernumerary teeth are relatively common in the anterior maxilla, the presence of multiple supernumerary teeth—particularly with inversion—significantly increases treatment complexity. In the present case, the inverted orientation and spatial positioning of the supernumerary teeth created a substantial mechanical obstruction, not only preventing eruption but also altering the eruption trajectory of the permanent maxillary central incisor.

Unlike cases where removal alone permits spontaneous eruption, the combined factors of inversion, number of supernumeraries, and patient age reduced the likelihood of passive correction. This emphasizes the importance of individualized treatment planning rather than relying solely on conventional eruption expectations.⁹

4.4. Therapeutic considerations

Management options for impacted teeth associated with supernumerary teeth include:

1. Surgical removal of the supernumerary tooth followed by observation for spontaneous eruption.
2. Surgical removal combined with orthodontic traction of the impacted permanent tooth.
3. In rare cases, extraction of a non-viable or severely compromised permanent tooth followed by prosthetic replacement.

The choice of treatment depends on several factors, including patient age, stage of root development, position and

orientation of the impacted tooth, degree of obstruction, and overall occlusal considerations.

In younger patients with incomplete root formation and minimal displacement, spontaneous eruption following removal of the supernumerary tooth may be expected. However, when eruption is unlikely due to significant displacement, complete root development or prolonged impaction, active orthodontic intervention becomes necessary.

5. Rationale for Treatment Selection

In the present case, the presence of multiple supernumerary teeth created a substantial mechanical barrier to eruption. Although spontaneous eruption following surgical removal was considered, the patient's age and the advanced stage of root development reduced the predictability of passive eruption.

Extraction of the permanent maxillary central incisor with prosthetic replacement was not considered appropriate. The impacted incisor was morphologically normal and potentially functional. Extraction of a healthy permanent central incisor, particularly in a growing patient, is generally contraindicated due to the esthetic, functional, and psychological implications, as well as the limitations associated with prosthetic rehabilitation at a young age.

Furthermore, achieving optimal anterior guidance and long-term occlusal stability is best accomplished by preserving and aligning the natural tooth whenever feasible.

5.1. Therapeutic approach

Based on clinical and radiographic findings, surgical removal of the obstructing supernumerary teeth followed by orthodontic traction of the impacted central incisor was considered the most appropriate and conservative treatment option.

This approach aimed to eliminate the mechanical obstruction, facilitate controlled eruption, and achieve functional and esthetic rehabilitation while preserving the natural dentition. Early interdisciplinary management was essential to ensure a predictable and stable outcome.¹⁰

5.2. Timing of intervention and eruption potential

The probability of spontaneous eruption following supernumerary removal depends largely on patient age and stage of root development.¹¹ Literature suggests that teeth with incomplete root formation have a higher chance of erupting naturally once obstruction is eliminated.¹²

In the present case, the advanced stage of root development and prolonged impaction decreased this predictability. Delayed intervention could have further compromised periodontal health, increased risk of root resorption of adjacent teeth, or resulted in space loss. Therefore, early surgical exposure combined with orthodontic traction was considered more predictable than a wait-and-watch approach.

5.3. Preservation of the natural Incisor: A conservative priority

One of the most critical treatment decisions was the preservation of the impacted permanent central incisor. Although prosthetic replacement may be considered in cases

of ankylosis, severe dilaceration, or non-restorable pathology, the incisor in this case was morphologically normal and strategically important for esthetics and occlusion.¹³

Extraction of a healthy maxillary central incisor in a growing patient carries long-term esthetic, functional, and psychological consequences. Moreover, prosthetic rehabilitation in adolescents presents limitations due to continued craniofacial growth. Therefore, maintaining the natural tooth aligned with conservative principles of pediatric and orthodontic management.

5.4. Comparison with contemporary literature

Supernumerary teeth remain a well-documented cause of eruption disturbances in the anterior maxilla, but the literature largely focuses on single or normally oriented supernumeraries, with only scattered reports of inverted supernumerary teeth. Recent observational studies of supernumerary teeth in children and adolescents have reinforced the role of CBCT in accurately localizing impacted teeth and assessing their relationship with adjacent structures, particularly in complex maxillary cases.¹⁴ A systematic review of the radiologic features of double and inverted mesiodens highlighted the relative rarity of inverted orientation and underscored the diagnostic challenges such presentations pose compared with common mesiodentes.¹⁵ Inverted supernumerary teeth are often asymptomatic and discovered incidentally on imaging, yet they can alter the eruption pathway of permanent incisors and complicate management strategies.

Case reports and series published in the last several years continue to emphasize individualized management depending on orientation and anatomical complexity. For example, surgical approaches for inverted mesiodens may include access through the nasal floor when conventional routes are technically difficult due to crown orientation.¹⁶ Similarly, multiple impacted supernumerary teeth in otherwise healthy, non-syndromic patients have been reported (e.g., multiple supernumeraries requiring surgical removal and orthodontic management), though inversion was not specifically described in the majority of these cases.¹⁷ The limited reporting of multiple impacted supernumerary teeth with an inverted orientation affecting eruption of a central incisor distinguishes the current report from these recent publications.

Unlike many contemporary reports in which a single supernumerary tooth was extracted to facilitate spontaneous or orthodontically guided eruption, the coexistence of a second supernumerary and an inverted orientation in this patient created a more significant mechanical obstruction to eruption. CBCT imaging was essential in this case, confirming the unusual orientation and complex spatial relationship with the impacted central incisor, in line with current guidance recommending three-dimensional imaging for complex supernumerary impactions. Thus, this case adds to contemporary evidence by demonstrating the rare clinical scenario of multiple impacted supernumerary teeth, one inverted, affecting maxillary central incisor eruption and highlights the diagnostic and management considerations unique to such cases.

5.5. Clinical significance and lessons from this case

This case highlights three important clinical considerations:

1. Multiple and inverted supernumerary teeth significantly reduce the predictability of spontaneous eruption.
2. Age and root maturity must guide decision-making regarding observation versus active traction.
3. Preservation of a viable permanent incisor should remain the primary objective whenever feasible.

5.6. Limitations and future directions

The principal limitation of this report is that active orthodontic treatment is ongoing. While the rationale for extraction and treatment planning is presented, the absence of final alignment and long-term follow-up reduces the immediate clinical applicability of the report. We acknowledge that definitive outcomes including periodontal health, stability and esthetic results are the most valuable component of any case report. A follow-up publication is planned to present treatment completion and long-term stability.

6. Conclusion

Delayed eruption of maxillary incisors should prompt careful evaluation for underlying local etiological factors, with supernumerary teeth being the most common cause in the anterior maxilla. The present case highlights a rare non-syndromic presentation of multiple impacted supernumerary teeth, including an inverted supernumerary tooth, resulting in impaction of a permanent maxillary central incisor. Such atypical orientations significantly increase diagnostic complexity and influence treatment planning.

This report emphasizes the critical role of cone beam computed tomography in accurately identifying the number, position, and orientation of impacted supernumerary teeth and their relationship with adjacent anatomical structures. CBCT allows precise localization that is often not achievable with conventional two-dimensional imaging, thereby facilitating informed clinical decision-making.

Early diagnosis and appropriate intervention are essential to prevent prolonged impaction, esthetic concerns, and potential complications affecting adjacent teeth. Reporting rare presentations such as this contributes to the existing literature and enhances clinician awareness, enabling timely recognition and effective management of complex eruption disturbances involving inverted supernumerary teeth.

7. Source of Funding

None.

8. Conflict of Interest

None.

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Original Research Article

Inflammatory burden and periodontal tissue destruction: A biological perspective

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Abstract

Aim: The present systematic review is undertaken to critically assess and collate available evidence on pro-inflammatory markers like Macrophage inflammatory protein-1 α (MIP-1 α), interleukin-1 β (IL-1 β), and matrix metalloproteinase-8 (MMP-8) as chronic periodontitis risk factors with a focus on their diagnostic, prognostic, and therapeutic implications.

Materials and Methods: Electronic databases including PubMed, Cochrane, and Google Scholar were searched for studies published within the 10 years. Inclusion criteria comprised case-control studies, randomized controlled trials, and cohort studies focused on pro-inflammatory markers and chronic periodontitis. Exclusion criteria included non-English articles, case series, and reports with incomplete data. 19 clinical studies were included after screening and quality assessment.

Results: A total of 1370 studies were initially identified, of which 19 studies fulfilled the inclusion criteria. Elevated levels of pro-inflammatory markers were consistently observed in patients with chronic periodontitis compared to healthy controls while therapeutic interventions and adjunctive treatments led to significant reductions. However, there exists variation in study methodologies and reporting standards, and no single biomarker has yet achieved universal acceptance for routine clinical use. The reviewed studies highlighted the potential utility of these markers for early diagnosis, risk prediction, and monitoring response to treatment.

Conclusion: Proinflammatory markers have considerable diagnostic and prognostic values in periodontal disease. However, future standardized longitudinal studies are needed to establish their clinical validity for routine chairside diagnosis.

Keywords: Pro-inflammatory cytokines, Biomarkers, Chronic periodontitis, Gingival crevicular fluid, MIP-1 α , IL-1 β , MMP-8.

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1. Introduction

Modern Science is testimony to the fact that biomarkers both Systemic and Oral as assessed and analyzed for early periodontal diagnosis, verify therapeutic efficacies of Periodontal therapies, and so predict future periodontal disease progression. There are broadly two rich sources of proteins, metabolites and microbiome found abundant. They are oral fluids such as Saliva, Gingival Crevicular fluid (GCF) and parts of blood such as serum and plasma.

Saliva is a serumal fluid filtered by Salivary glands and possess more than 60% of analytes. It is easily assessable, non- invasive and can be easily collected. On the other hand, GCF is site specific but tedious to collect. Both oral fluids have gained immense prominence as a source for biomarkers whether inflammatory, host derived or markers of Connective Tissue destruction.

Biomarkers are analyzed by various methods like Blood, Saliva and Gingival Crevicular Fluid (GCF) through Enzyme-linked Immunosorbent assay (ELISA), RT-PCR, Spectrophotometry, Immunofluorescence and MALDI TOF MS (Modern matrix assisted laser desorption ionization- time of flight mass spectrometry). Pro- inflammatory cytokines are the first to appear and address the antigen response by the hosts. Cytokines which were previously called Leukotrienes are an integral part of Immune response.

Macrophages along with other chronic inflammatory cells play a pivotal role. They are modulators and communicators of response to antigen attack and abuse. Many macrophages secreted or activated molecules have been studied as potential biomarker. The latest biomarker to be analyzed for pro inflammation is Macrophage inflammatory protein-1alpha (MIP- 1 α), which is secreted by Macrophages.

Pro-inflammatory markers such as macrophage inflammatory protein-1alpha (MIP-1 α), interleukin-1beta (IL-1 β), interleukin-6 (IL-6) and matrix metalloproteinase-8 (MMP-8) have been identified as clinically acceptable indicators for diagnosing periodontal disease.¹

A notable biomarker MIP-1alpha is a chemotactic chemokine produced by diverse cell types like macrophages, fibroblasts, epithelial cells, and endothelial cells. It serves multiple biological roles, including the recruitment of inflammatory cells, facilitation of wound healing, suppression of stem cells, and sustenance of effector immune responses.²

Advancements in research have pinpoint numerous salivary biomarkers associated with distinct biological phases of periodontal disease, including inflammation, collagen degradation, and bone remodeling. The vast array of evidence supporting the utilization of salivary biomarkers, along with their practical application in diagnosing and monitoring

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periodontal disease, underscores the necessity for a current systematic review to consolidate findings. Moreover, periodontitis has systemic implications for cardiovascular disease, diabetes, and adverse pregnancy outcomes. The elevated systemic levels of inflammatory biomarkers in patients with periodontitis can therefore contribute to the chronic systemic inflammatory burden associated with these comorbidities.

The need is to do a Systematic review of past 10 years of articles, scientific papers and tabloids pertaining to biomarkers as a resource of diagnosis. Furthermore, it is crucial to conduct a comprehensive review of published evidence to thoroughly confirm the diagnostic utility of salivary biomarkers before efficiently integrating saliva as a dependable and accurate diagnostic medium for periodontal disease. This Systematic review explicitly elucidates the role of pro-inflammatory cytokines in the periodontal disease.

2. Materials and Methods

This review was a systematic review that followed the guidelines for the synthesis of clinical research evidence in relation to pro-inflammatory biomarkers and their role as risk factors in chronic periodontitis. The methodology was designed based on the PICO framework for a focused, evidence-based approach. Research was carried out by hand searching and electronic searching of database records PubMed, Cochrane, and Google Scholar of past 10 years. The flow of study selection is shown schematically in Figure 1.

Inclusion Criteria included case control studies, randomized controlled trials, cohort studies, sufficient details reported on sample type, description of the assays used to detect cytokines, the results of salivary cytokines were described, only papers with a focus on oncological, oral, dental, or infectious diseases were included and both genders were included. The exclusion criteria included meta-analysis, case series, case reports, animal studies and in vitro studies, studies published in language other than English, systematic reviews, studies with only abstract available, unpublished data, comment articles and articles with incomplete data/Imprecise methodology.

2.1. Data mining techniques

Data extraction was performed using a standardized, piloted template. The following information was carefully captured for each included study: Author(s), publication year, country of origin, study design and duration,

population characteristics include number of participants, inclusion/exclusion criteria, and demographic details. Type of biological sample was also seen. Assays applied for biomarker quantification include ELISA, mass spectrometry, immunoassays, among others. List of pro-inflammatory biomarkers analyzed (such as MIP-1 α , IL-1 β , IL-6, MMP-8, TNF- α , etc.).

The emphasis of the review process was based on vital factors, including the sufficiency of control groups, justification and rationalization of sample size, clarity and transparency in methods reporting, especially in the collection and analysis of biological samples, and appropriateness and strength of statistical methods used. Besides, the review also considered potential sources of bias, such as selection, measurement, and reporting biases. Only those studies assessed to have moderate or high methodological quality based on these comprehensive criteria were retained for synthesis. This phase excluded studies with significant methodological weaknesses or those lacking clarity to ensure that conclusions from the review were reliable and scientifically valid.

After quality assessment, data from the eligible studies were synthesized by using a qualitative narrative approach. This approach was warranted because of the heterogeneity in the biological sample source, combination of biomarkers evaluated, different assay platforms, population demographics, and types of periodontal interventions evaluated. The effect size and direction of associations between specific pro-inflammatory biomarkers and periodontitis outcomes were summarized and, where possible, tabulated. Synthesis focused on key outcomes that included diagnostic accuracy and predictive value of studied biomarkers for chronic periodontitis, the relationship of individual biomarkers with disease presence, severity, and progression, and changes in the levels of these markers resulting from various periodontal treatments. Furthermore, the review sought single or combinations of markers with strong potential for routine clinical diagnostic use. Recurring patterns and trends had been underlined during synthesis, while instances of conflicting evidence were interpreted in light of differences in study populations, methodological limitations, variability in the assays used, or short follow-up periods, thus providing a balanced and comprehensive overview of the available literature.

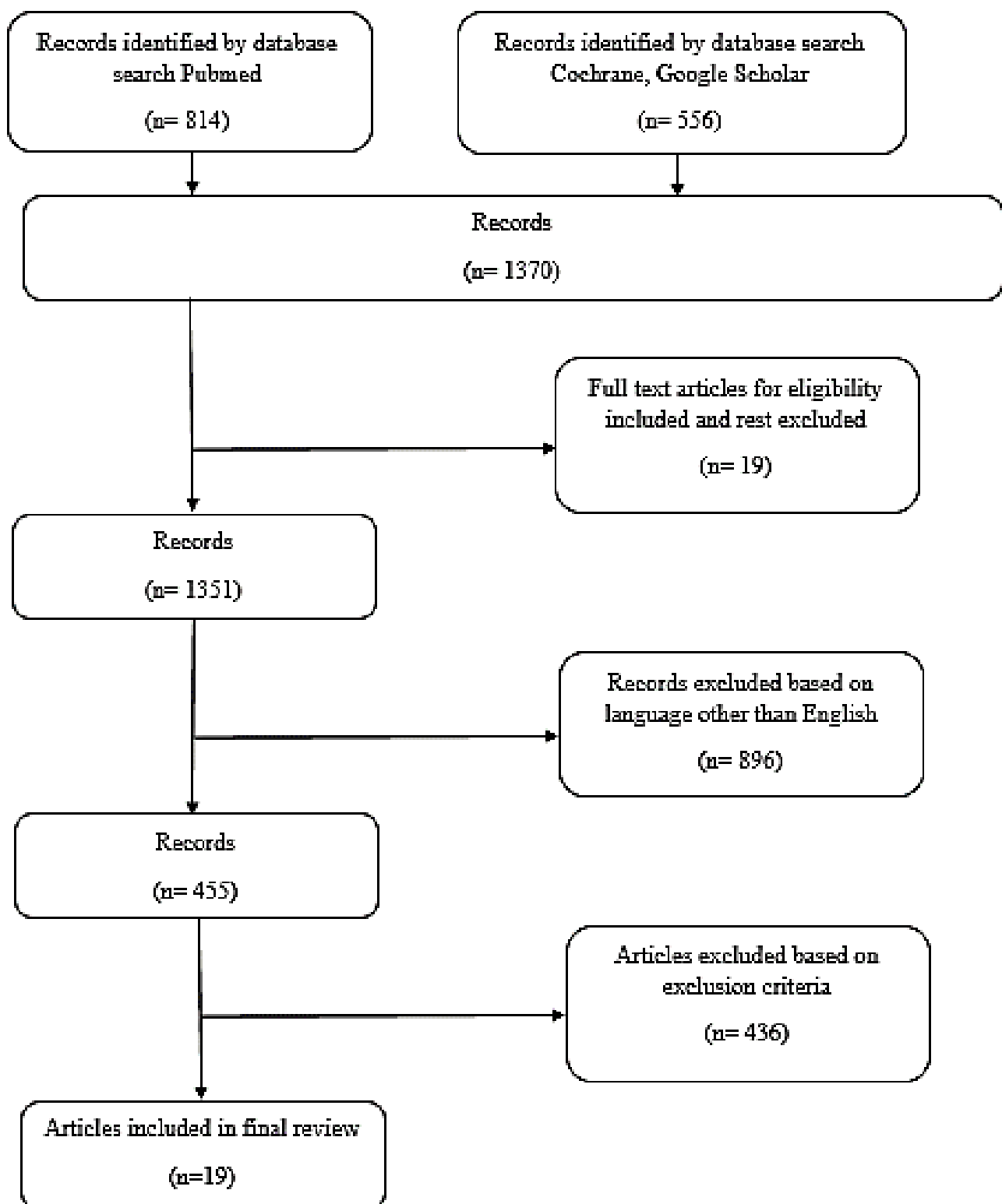


Figure 1: Methodology

Table 1. Result

S No.	Author and publication year	Number of subjects	Study design	Study duration	Biochemical parameters	Results	Country
1.	Eldessouky et al 2024 ¹	20	Twenty elderly women with chronic periodontitis were split evenly into two groups by random assignment. Patients in group II (the research group) were given soft gelatin capsules containing PUFAs to be consumed directly once daily for 12 months, as opposed to group I (the control group), who received soft gelatin capsules containing some olive oil (placebo).	12 months	AST and osteocalcin	Significant improvements in clinical indicators and a notable decrease in AST levels within the GCF were observed.	Saudi Arabia
2.	Keskin et al 2023	44	Baseline periapical exudate samples were obtained, and the patients were assigned to either control or intracanal cryotherapy group according to the final irrigation with distilled water either at room temperature or 2.5°C.	6 months	IL-8, TNF- α , PGE2 and MMP-8 levels	There was a significant decrease in IL-8, TNF- α , PGE2 and MMP-8 levels.	Turkey
3.	Moore et al 2023	76	76 patients with Stages III-IV, Grade B periodontitis were assigned to three groups: interproximal brush (IB), IB with tracking device (TD), or oral irrigator (OI).	6 weeks	IL-1 β	Results showed improvements in periodontal parameters and reduction in inflammatory markers across all groups.	USA
4.	Pilloni et al 2023	8	Eight patients 24 h post-surgery after HA application (HA group) and compared with those obtained from the same patients without HA application (no treatment; NT group).		MMP-1 protein, and TIMP1 gene expression	MMP-1 protein, and TIMP1 gene expression were significantly upregulated in the HA compared to the NT group.	Italy
5.	Aimetti et al 2023	44	Sites were randomly treated with subgingival instrumentation with or without topic DOX application.	2 weeks	(IL)-1 β , matrix-metalloproteinases (MMP)-8 and MMP-9.	The total amount of interleukin (IL)-1 β , matrix-metalloproteinases (MMP)-8 and MMP-9 in the GCF significantly decreased in the test group at T1, with relevant differences compared to controls.	Italy
6.	Persson et al 2023	30	Participating individuals with T2D were randomly assigned to a test (OBND) (n=14), or control group (n=16).	4 weeks	of IFN γ , Eotaxin IL-9, IP10, IL17a, MCP-1	Results showed reduction of serum levels of IFN γ , Eotaxin IL-9, IP10, IL17a and MCP-1, compared to the control diet.	USA
7.	Elsadek et al 2022	60	Participants were randomized in two groups: Group A – SRP + PDT (test group) and Group B – SRP alone.	6 months	(IL)-1 β and IL-6	Reduction in the IL-6 was maintained until 6 months of re-evaluation.	Saudi Arabia
8.	Alkimavičienė et al 2022	46	Forty-six patients diagnosed with periodontitis were randomised into 2 groups: 23 patients in the MINST group and 23 patients in the MINST + PACNs group received the intended treatment.	8 weeks	MMP-3	Additional use of PACNs improved MMP-3 concentration in saliva more than MINST alone.	Lithuania

Table 1. Result (continued)

S No.	Author and publication year	Number of subjects	Study design	Study duration	Biochemical parameters	Results	Country
9.	Bian et al 2021	72	The patients were randomly divided into four groups using a computer-generated table: root planing and periodontal curettage combined group (n = 18), root planning group (n = 18), periodontal curettage group (n = 18) and cleansing group (n = 18).	12 months	TNF- α and hypersensitive C-reactive protein [hs-CRP]	Levels of TNF- α and hs-CRP in the four groups decreased significantly.	China
10.	Rabelo et al 2020	60	15 patients with type 2 diabetics with generalized periodontitis, 15 patients with pre-diabetics with GP, 15 patients with normoglycemic subjects with GP, 15 patients with healthy controls.	1 month	IL-1B and IFN- γ	A significant reduction in GCF levels of several cytokines like IL-1B and IFN- γ were observed.	Brazil
11.	Martínez-Villa et al 2020	15	A total of 15 patients were finally included, with analysis of 30 histological specimens and 30 GCF samples.	8 weeks	IL-1 β , IL-6, IL-10 and IL-17a	Higher concentrations of IL-1 β and IL-6 in GCF was seen.	Spain
12.	Chen et al 2020	19	19 patients with at least one periodontitis-involved tooth in three quadrants received NSPT, and three protocols of LED light irradiation, including LED light irradiation from initial clinical assessment (T0) until the completion of scaling and root planning (T1) (LED01).	2-3 months	IL-1b and MMP-8	IL-1b and MMP-8 were reduced in all groups.	Taiwan
13.	Kasai et al 2020	13	Clinical variables were measured at four time points during initial periodontal treatment: before treatment (baseline), after supragingival scaling, after occlusal adjustment, and after scaling and root planing (SRP)	-	(IL)-10, IL-7, IL-11, and IL-12p40	Baseline interleukin (IL)-10 level in GCF was significantly higher around teeth that showed substantial improvement in periodontal epithelial surface area (PESA) after SRP than around teeth without PESA improvement. IL-3 and IL-16 levels in GCF at baseline were significantly higher around teeth with a periodontal inflamed surface area (PISA) of 0 mm ² after SRP than around teeth without PISA improvement. In addition, baseline IL-7, IL-11, and IL-12p40 levels in GCF were significantly lower around teeth with decreased mobility after occlusal adjustment than around teeth without decreased mobility.	Tokyo
14.	Chiang et al 2020	22	22 patients with 30 control teeth and 35 PTT-treated teeth were examined.	6 months	IL-1b and MMP-8	IL-1b and MMP-8 were significantly lower.	Taiwan

Table 1. Result (continued)

S No.	Author and publication year	Number of subjects	Study design	Study duration	Biochemical parameters	Results	Country
15.	Äyräväinen L et al 2018	81	Fifty-three early untreated RA (ERA) and 28 chronic RA (CRA) patients	12 months	MMP-8, TIMP-1 and IL-6	Concentrations of MMP-8 and of IL-6 in serum were elevated	Finland
16.	Bostanci et al 2017	50	15 FMF patients with generalized chronic periodontitis (FMF-CP), 15 systemically healthy patients with generalized chronic periodontitis (CP), ten systemically and periodontal healthy controls (HC), and ten periodontally healthy FMF patients (FMFHC) were enrolled in the study.	6 weeks	IL-1 β , IL-1ra, and IL-10	GCF IL-1 β and GCF IL-1ra levels were decreased in FMF-CP group. GCF IL-10 levels were increased in FMF-CP group compared to other groups.	Turkey
17.	Balci Yuce H et al 2017	53	17 CP patients with RA (RA + CP), 18 systemically healthy CP patients (CP), and 18 healthy controls (C) were included		Serum RANKL and GCF TNF- α	Serum RANKL and GCF TNF- α levels in RA patients decreased after periodontal treatment	TURKEY
18.	Acharya et al 2015	45	Forty-five subjects were divided into three groups comprising 15 subjects each as Group 1(healthy controls), Group 2 (CPD patients), and Group 3 (T2DM patients with CPD).	6 months	IL-10	IL-10 levels were elevated.	INDIA
19.	Ozgören et al 2014	32	32 subjects with chronic periodontitis were randomized into two groups: 1) phase I periodontal treatment + NSAID and 2) phase I periodontal treatment + placebo.	30 days	MMP-8 and TNF- α	Post treatment MMP-8 level in group 1 was statistically significant higher than the placebo group	TURKEY

3. Results

A total of 1370 articles were identified based on PICO including patients showing effects of Pro- inflammatory markers as a risk factor in Chronic Periodontitis. The database search was done which yielded 1351 records with full text articles, 896 records were excluded based on language other than English. From the basis of exclusion and inclusion criteria, records were removed. The total studies that were systematically reviewed came out to be 19 (Table 1).

All the selected investigations together assessed host-derived pro-inflammatory markers in GCF, saliva, and sometimes serum, with particular attention to molecules such as macrophage inflammatory protein-1 α (MIP-1 α), interleukin-1 β (IL-1 β), interleukin-6 (IL-6), matrix metalloproteinase-8 (MMP-8), tumor necrosis factor-alpha (TNF- α), prostaglandin E2 (PGE2), myeloperoxidase, and C-reactive protein (CRP).

In fact, the findings were consistent in that all studies found higher concentrations of these pro-inflammatory biomarkers in chronic periodontitis individuals compared with healthy controls. Importantly, IL-1 β , IL-6, and MMP-8 levels were increased in both saliva and GCF and strongly correlated with the presence and severity of periodontal inflammation. TNF- α , PGE2, and CRP also showed a clear positive association with disease status, further reinforcing their role as proxies of local and systemic inflammation. Additionally, the levels of CRP and hs-CRP assessed in serum were higher in patients with periodontitis, reflecting the systemic inflammatory burden associated with oral disease.

Overall, therapeutic interventions, namely nonsurgical periodontal treatments in the forms of scaling and root planning with and without adjunctive therapies, and surgical therapies significantly reduced IL-6, TNF- α , CRP, and MMP-8 biofluid levels for up to six months following the intervention. Additive improvements in biomarkers were also noted in several studies when combination therapies were employed. Panels combining IL-1 β , IL-6, and MMP-8 as a combined diagnostic tool yielded high accuracy for distinguishing chronic periodontitis from healthy states; however, their diagnostic performance varied because of population and laboratory method differences.

A subset of studies further investigated the mechanistic depth of inflammation, such as changes in LPS, gut microbiota profiles, and adipokines, as further evidence of the systemic effects of periodontal inflammation. The robust and sustained association of these pro-inflammatory markers across the body of evidence with not only the presence but also the progression and severity of chronic periodontitis was clear. Collectively, these findings underscore both the biological importance and the clinical promise of systemic and oral fluid biomarkers in enhancing diagnosis, monitoring, and overall understanding of periodontitis as part of both oral and systemic health.

4. Discussion

Periodontitis affects a subset of the population, and its progression may be continuous or episodic, necessitating effective diagnostic tools. However, current markers face

significant challenges, and no gold standard exists for diagnosing active periodontal disease. Despite numerous proposed biomarkers, none are commercially available. Chairside tests using saliva or finger stick blood could potentially assess an individual's disease risk, and routine blood tests might help diagnose and monitor periodontitis if reliable systemic biomarkers are identified. Before using any test, its impact on treatment planning must be considered. Systemic periodontal diagnostic tests are in early development, requiring further validation to ensure they become a valuable, cost-effective part of clinical practice. Stathopoulou et al reviewed potential blood and saliva biomarkers for diagnosing and monitoring periodontitis.¹³

In a study conducted by Oh H et al, it is seen that IL-1 β levels are uplifted in sites of periodontal disease and reduce following periodontal treatment.¹⁴ Supporting these findings, Nazar Majeed et al stated in the review that IL-1 β is a reliable biomarker for accurately indicating the continuation of periodontitis.¹⁵ Elsadek et al substantiated reduction in the IL-6 was maintained till 6 months of re-evaluation.¹⁶ Persson et al and Bian et al too noticed a decrease in cytokines.^{17,18}

MCP-1 is an essential cytokine responsible for the recruitment of inflammatory cells, playing a significant role in inflicting damage to the periodontium. Previous studies have shown that MCP-1 & 4 levels decrease after therapy. Therefore, they are to be considered a likely biomarker for disease strength. Acharya et al and Alkimavičienė et al conducted a study where a positive correlation was seen between cytokines and periodontitis.^{19–20}

In a recent meta-analysis, Stadler et al. observed the levels of chemokines between healthy and chronic periodontitis patients. The study found contrast in inflammatory markers between periodontal health and disease.²¹ Similar results have been shown in the study by Chen et al where IL-1b and MMP-8 levels were remarkably lower.²² Eldessouky et al and Bostanci et al also showed notable improvements in parameters of the sample.^{23–24} The results of Chiang et al were comparable showing decrease in IL-1b and MMP-8.²⁵

Martínez-Villa et al concluded in his study that the levels of GCF cytokines did not tally with the comparison group and hence further studies were needed for evidence.²⁶ Increased expression of these mediators in gingival crevicular fluid (GCF), serum, and saliva among patients with chronic periodontitis underscores their value as both local and systemic biomarkers. Elevated IL-1 β and TNF- α levels have been closely associated with enhanced collagen breakdown, osteoclastic bone resorption, and reduced tissue repair capacity. This aligns with the understanding that periodontal breakdown results from a dysregulated host immune response to microbial challenge rather than direct bacterial effects alone.

Additionally, the reviewed studies suggest that genetic polymorphisms affecting the production of key cytokines may predispose individuals to heightened inflammatory responses, thereby exacerbating periodontal destruction. Environmental and behavioral risk factors such as smoking, diabetes mellitus, and stress appear to amplify these inflammatory pathways, indicating a multifactorial interrelationship in

disease expression.

Emerging evidence also highlights the systemic implications of persistent periodontal inflammation, with elevated cytokine levels potentially contributing to the progression of atherosclerosis, diabetes, and other inflammatory disorders. This reinforces the importance of understanding and managing inflammation not only for periodontal health but also for overall systemic well-being. Future longitudinal studies and meta-analyses employing standardized markers of inflammation are needed to clarify the temporal relationship between inflammatory mediator upregulation and periodontal attachment loss. Moreover, interventions targeting pro-inflammatory pathways, including the use of host-modulatory therapies, could represent a promising adjunctive approach in the management of chronic periodontitis.

The examination of MMP-8 in GCF has been a specific biomarker for quick chair-side detection, aiding in the diagnosis of disease.²⁷ It may also serve as a valuable tool for monitoring the progression of disease. Additional enzymes examined in the GCF include myeloperoxidase, which may also serve as markers for the distinguishing and monitoring the advancement of periodontal disease.

In a study conducted by Moore et al, it is seen that Seventy-six patients with Stage III-IV, Grade B periodontitis were evaluated using different home oral hygiene methods. The results indicated improvements in periodontal parameters and reductions in inflammatory markers across all groups.⁵ Similarly, a study done by Keskin et al showed the correlation between periodontal pain and IL-1 β and PGE2 levels suggesting that these biomarkers have predictive value.⁴ These results were comparable with the study conducted by Kasai et al which replicated that the levels of some cytokines in GCF like IL-3 and IL- 16 are connected to early periodontal therapy.²⁸

A meta-analysis done by Blanco- Pinto evaluated the diagnostic accuracy of combined markers for detecting periodontitis in systemically healthy individuals. Six salivary combinations, including IL-1 β , IL-6, and MMP-8, showed high accuracy.⁶ Environmental and behavioral factors, including smoking, stress, and diet, further influence the inflammatory profile. Tobacco use enhances the release of pro-inflammatory cytokines, impairs neutrophil function, and reduces gingival blood flow, thereby worsening periodontal outcomes. Psychological stress, through cortisol-mediated immune dysregulation, enhances susceptibility to inflammation.

Arroyo et al aimed to identify salivary protein-based biomarkers for major periodontal diseases. Twelve biomarkers, including IL-1 β , ICTP, and PGE2, demonstrated high applicability, indicating their potential for clinical use in distinguishing periodontal diseases from gingivitis and healthy conditions.⁷ Oxidative stress represents another avenue linking pro-inflammatory factors with disease progression. Reactive oxygen species (ROS), generated by activated neutrophils and other immune cells during host defense, participate in bacterial killing but also inflict collateral damage on periodontal tissues. The imbalance

between oxidants and antioxidant defenses accentuates lipid peroxidation, DNA damage, and protein oxidation, reinforcing the inflammatory cascade. Current evidence suggests that antioxidant therapy, dietary modulation, and improved redox balance might serve as adjunctive approaches to mitigate tissue destruction in periodontitis.

Inflammation plays a crucial role in tumorigenesis, making the measurement of pro-inflammatory cytokines attractive for predicting local malignant transformation and monitoring treatment.

Tumor cells release cytokines which effect cells and induce cancer-related inflammation. IL-6, in particular, can cause acute inflammation with TNF- α and IL-1, inhibit dendritic cell differentiation, and promote metastasis. Studies have identified IL-6 as a prognostic marker for head and neck cancer, squamous cell carcinoma, and melanoma.²³

Hence, it is evident that data from various studies demonstrates the beneficial role of pro-inflammatory markers as a significant risk factor in chronic periodontitis. These markers can positively influence treatment outcomes when used as a diagnostic tool alongside conventional treatment method.

5. Conclusion

This systematic review aims to collect and analyze all the data available in the scientific literature pertaining to the effect of pro- inflammatory markers and its role on periodontal health and included a total of 16 studies addressing this research question. These markers pose as a crucial diagnostic tool in identifying the presence and severity of a disease in the periodontium and even other systemic conditions.¹ An overwhelming majority of studies included in this systematic review established a correlation between pro- inflammatory markers and periodontium, further evidence is required with long term follow up.

Biomarkers sourced from GCF are a valuable diagnostic tool with an ease in collection of specimens by various methods. They assist in improving treatment outcomes and tell us the past, present and future risks of periodontal disease following both surgical and non-surgical periodontal therapy. Periodontal pathogens trigger the cascade of inflammation via pathogen-associated molecular patterns that stimulate host toll-like receptors. This, in turn, leads to the release of pro-inflammatory cytokines responsible for connective tissue destruction, resorption of alveolar bone, and disturbance in tissue homeostasis. Thus, an imbalance between pro- and anti-inflammatory responses, rather than simply microbial presence, forms a central mechanism in chronic periodontitis pathophysiology.

The review also underlines that genetic predisposition and systemic factors, like diabetes mellitus, obesity, and cardiovascular diseases, can enhance pro-inflammatory signaling and, thus, aggravate periodontal destruction. This reciprocal relation between systemic inflammation and periodontal disease supports the notion of periodontitis as not just a localized oral condition but, rather, as part of a wider systemic inflammatory network. Raised systemic biomarkers, including CRP and IL-6, point to a linkage between chronic

periodontitis and increased systemic inflammatory burden, with a possible contribution to systemic disease risk.

These findings have great therapeutic implications. Traditional approaches that address only mechanical plaque control, though important, may be insufficient to manage the underlying inflammatory burden. New therapies targeting host response modulation-the use of anti-cytokine agents, sub-antimicrobial dose doxycycline, and antioxidants-show promise in controlling inflammation and preventing further tissue destruction. Such host-modulation strategies, when combined with conventional periodontal therapy, could result in improved long-term outcomes by restoring the balance between pro- and anti-inflammatory mediators.

Limitations identified across the studies include heterogeneity of assay methods, variability in cytokine quantification, and differences in study design-all factors that make it difficult to standardize diagnostic thresholds for pro-inflammatory markers. Given these limitations, the cumulative evidence from observational and interventional studies strongly supports the role of pro-inflammatory factors as both mediators and potential predictors of chronic periodontitis. It is explicitly evident that no single marker has met all the criteria required to assess the clinical state of the periodontium. Currently, various efforts are underway to develop an idealistic test, but its practical use as a chairside diagnostic tool remains indecisive. Consequently, the primary goal of periodontal research is to develop a broad spectrum of markers.

While a majority of the studies have established the positive impact biomarkers and its influence on periodontal health, a few studies failed to establish a clear association between them and thus a wider acceptance of this concept is yet to be seen. This warrants further extensive research into the matter that has the potential to validate these claims about the positive role of markers in maintaining periodontal health. This would be a valuable and highly appreciated treatment modality in treating periodontal disease that would benefit patients with periodontal disease. Further studies are necessitated to extrapolate the outcomes of gingival, salivary and blood biomarkers.

6. Source of Funding

None.

7. Conflict of Interest

None.

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Case Report

Interim fixed prosthetic rehabilitation of anterior tooth loss in a growing child with a maryland bridge: A case report

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Abstract

Objective: Management of anterior space loss in an 11-year-old male patient using a minimally invasive approach followed by rehabilitation with a Maryland bridge.

Anterior tooth loss in growing children poses a clinical challenge due to functional, aesthetic, and psychological concerns, as well as limitations imposed by ongoing growth. Definitive treatment options such as dental implants are contraindicated during this phase, and conventional fixed prostheses often require extensive tooth preparation. The Maryland bridge, a resin-bonded fixed partial denture, offers a conservative interim solution for anterior tooth replacement. This case report describes the rehabilitation of anterior tooth loss in a growing child using a Maryland bridge, demonstrating satisfactory aesthetic and functional outcomes while preserving sound tooth structure.

Conclusion: The Maryland bridge is an effective and minimally invasive interim prosthetic option for the management of anterior tooth loss in growing children. With appropriate case selection and careful clinical execution, it provides acceptable aesthetics and function while maintaining tooth structure until definitive treatment can be undertaken.

Keywords: Aesthetics, Anterior space management, Interim prosthesis, Maryland bridge.

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1. Introduction

Anterior tooth loss adversely affects mastication and speech and, more importantly, results in a pronounced aesthetic deficit that may have a significant psychological impact on patients. Rehabilitation of missing anterior teeth can be accomplished using various treatment modalities, including implant-supported prostheses, conventional fixed dental prostheses, and removable dental prostheses. However, implant-supported rehabilitation is contraindicated in a growing child.¹

In contrast to posterior teeth, anterior teeth are exposed to comparatively lower masticatory forces, thereby permitting the use of more conservative restorative approaches.² Although conventional fixed dental prostheses provide predictable functional and esthetic results, they are often considered invasive due to the extensive tooth preparation required. Previous studies have reported that tooth preparation for fixed prostheses may involve removal of approximately 63–72% of sound tooth structure, which can compromise long term tooth vitality and prognosis.¹ Consequently, resin-bonded fixed prostheses have emerged as a conservative alternative for the replacement of missing anterior teeth. These restorations require minimal preparation of adjacent abutment teeth, preserve healthy enamel, and offer a cost-effective solution while achieving satisfactory aesthetic and functional outcomes.²

2. Case Report

A 11-year-old male patient reported to the Department of Pediatric and Preventive Dentistry, the Oxford Dental College Bangalore with the chief complaint of missing teeth in the lower front region of the jaw, resulting in aesthetic concern. The medical history was non-contributory, and no systemic conditions and no history of trauma was reported. Dental history revealed loss of lower anterior teeth. Clinical examination showed a missing mandibular anterior tooth with adequate space for prosthetic rehabilitation. (Figure 1). The adjacent teeth were clinically sound, with sufficient enamel available for bonding. Radiographic evaluation revealed congenitally missing mandibular central incisors and healthy abutment teeth with no periapical pathology. (Figure 2). The patient was in the growth phase, making implant-supported rehabilitation contraindicated.

Various treatment options were discussed with the parent, including a removable partial denture, a conventional fixed partial denture, and a resin-bonded fixed partial denture. Implant-supported rehabilitation was ruled out due to the patient's age, as implant placement is contraindicated during the growth phase. Considering the conservative nature of treatment, preservation of sound tooth structure, aesthetic demands, and economic feasibility, a resin-bonded fixed partial denture (Maryland bridge) was selected as the treatment of choice.

Minimal preparation was carried out on the palatal

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surfaces of the adjacent abutment teeth, ensuring maximum enamel preservation. An impression was made, and a metal-ceramic Maryland bridge was fabricated. (Figure 3), the prosthesis was tried in to verify fit, aesthetics, and occlusion. (Figure 4). After isolation, the bridge was adhesively cemented using a resin luting cement following manufacturer's instructions. (Figure 5, 6)

The patient was reviewed after cementation and during subsequent follow-up visits. The prosthesis demonstrated satisfactory aesthetics, stability, and function. The patient and parent reported satisfaction with the outcome. No debonding or discomfort was observed during the follow-up period, and oral hygiene was maintained satisfactorily.



Figure 4: Try in wrt 31,41.



Figure 1: Pre-operative photograph, missing mandibular incisors wrt 31,41



Figure 5: Post - operative photograph.



Figure 2: OPG showing congenitally missing wrt 31,41.



Figure 6: Post- operative photograph.



Figure 3: Lingual tooth preparation wrt 32,42.

3. Discussion

Preservation of sound tooth structure remains a core principle in restorative dental practice; therefore, resin-bonded prostheses have emerged as a conservative alternative to conventional fixed partial dentures, particularly for the replacement of a single missing anterior tooth. This concept was first described by Livaditis and Thompson, who introduced electrolytic etching of the intaglio (inner) surface of a non-precious alloy framework to produce a microscopically roughened surface, thereby enhancing micromechanical retention when used with adhesive luting cements.^{3,4}

The introduction of the adhesive-retained fixed partial denture by Livaditis in 1980 marked a significant milestone in conservative tooth replacement. Retention of these restorations is primarily achieved through bonding to the

proximal and lingual enamel surfaces of intact abutment teeth.⁵ The prosthesis, consisting of a metal-ceramic pontic supported by thin metal retainers or “wings” extending onto adjacent abutment teeth, became commonly known as the Maryland bridge. Adhesive cementation of these retainers to the palatal or lingual enamel surfaces significantly reduced the need for extensive tooth preparation, thereby facilitating a minimally invasive restorative approach.³

Despite careful bonding protocols, early designs were frequently associated with bond failure at the tooth–metal interface.⁶ Efforts to enhance retention through flange design modifications aimed at increasing the bonding surface showed limited success, and loss of adhesion remained a common complication in early versions of the prosthesis.^{7,8} However, advancements in alloy selection, framework design, and surface treatment methods—including electrolytic, chemical, and air-abrasion techniques—along with improvements in adhesive composite materials, have substantially enhanced the clinical performance of resin-bonded bridges. Consequently, the Maryland bridge has demonstrated long-term clinical viability and continues to be widely used.⁶

Maryland bridges rely primarily on micromechanical retention and are typically fabricated using base metal alloys, as noble metal alloys are resistant to etching due to their passive surface characteristics.⁹

Resin-bonded fixed prostheses offer several advantages, including minimal tooth preparation without dentinal or pulpal involvement and relative ease of fabrication, making them a cost-effective restorative option. Additionally, favorable esthetic outcomes are achieved because the retainers do not extend onto the facial surfaces, thereby preserving the labial enamel of the abutment teeth. However, the preparation and bonding procedures are technique-sensitive, and improper design or tooth reduction may result in metal show-through, particularly in teeth with thin enamel in the anterior region.⁹

4. Conclusion

The Maryland bridge is a reliable and minimally invasive interim prosthetic option for the management of anterior tooth loss in growing children. With appropriate case selection and meticulous clinical execution, it offers satisfactory aesthetic

and functional outcomes while preserving sound tooth structure and allowing for future definitive rehabilitation.

5. Conflicts of Interest

No conflict of interest related to this case report.

6. Acknowledgements

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Case Report

Management of bimaxillary dentoalveolar protrusion with positive lip step using tad-supported anchorage and adjunctive platelet-rich plasma: A case report

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Abstract

Introduction: A young adult patient presented with skeletal Class I relationship (ANB within normal limits) and Angle Class I molar-canine occlusion, accompanied by positive lip step due to bimaxillary dentoalveolar protrusion.

Aim: The primary aim is to achieve a stable Class I occlusion with ideal overjet/overbite, relieve anterior crowding, correct midline deviation and facial asymmetry, and establish lip competence through dentoalveolar camouflage in this post-pubertal hyperdivergent patient and improve soft tissue profile by retracting protrusive lips, reducing 4 mm interlabial gap and positive lip step, while enhancing smile consonance and nasolabial angle.

Results: Class I molar relationship was maintained with correction of positive lip step and improvement in facial profile.

Conclusion: This case report highlights the effective treatment of bimaxillary dentoalveolar protrusion with a positive lip step in a skeletal Class I hyperdivergent adult patient using TAD-supported anchorage and adjunctive PRP.

Keywords: Positive lip step, PRP, TADS

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1. Introduction

In orthodontic diagnosis, the Korkhaus lip step analysis evaluates the sagittal position of the lower lip relative to the upper lip. A positive lip step, characterized by anterior positioning of the lower lip, is commonly associated with mandibular prominence or skeletal Class III tendencies. In contrast, patients with skeletal Class I relationships typically demonstrate a harmonious anteroposterior jaw relationship. However, in rare instances, soft-tissue discrepancies may present as a positive lip step despite underlying skeletal harmony. Such variations may arise due to factors including lip strain, bimaxillary dental protrusion, altered lip tonicity, or measurement variability.¹

This report focuses on an uncommon presentation in which a positive Korkhaus lip step was observed in a skeletal Class I patient exhibiting straight facial divergence and a straight profile. The persistence of this atypical soft-tissue profile may be attributed to hyperdivergent growth patterns or subtle vertical maxillary excess, which can permit anterior eversion of the lower lip. In these cases, overall skeletal harmony may mask underlying dental compensations. Previous studies have reported a higher prevalence of positive lip step findings in skeletal Class I patients within Asian populations (approximately 15–20%) compared with Caucasian populations (<10%).²

Mini-screw-assisted anterior retraction using sliding mechanics is a well-established and widely accepted

orthodontic treatment modality for managing skeletal Class I patients with bimaxillary protrusion. This approach facilitates posterior movement of the anterior dentition to correct dental protrusion, relieve crowding or spacing, and improve both occlusal relationships and facial esthetics. Temporary anchorage devices (TADs) provide absolute anchorage, thereby eliminating undesirable reciprocal tooth movement during anterior retraction. Their use allows controlled en-masse retraction of the anterior segment with minimal or no posterior anchorage loss, which is particularly advantageous in high-anchorage cases such as bimaxillary protrusion and hyperdivergent growth patterns.² Force application from TADs using nickel–titanium closed-coil springs or active tie-backs delivers consistent and predictable force systems, enabling bodily tooth movement and enhanced vertical control during space closure. Mini-screw-assisted retraction has demonstrated high clinical success, offering precise control over tooth movement while improving treatment efficiency and predictability. This biomechanics-driven approach significantly contributes to improvements in facial profile, smile esthetics, and functional occlusion.

In addition to biomechanical control, biological modulation was achieved through the adjunctive use of platelet-rich plasma (PRP). PRP is an autologous concentrate of platelets suspended in plasma and contains a high concentration of growth factors, including platelet-derived

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growth factor (PDGF), transforming growth factor- β (TGF- β), and vascular endothelial growth factor (VEGF). These bioactive mediators enhance angiogenesis, increase osteoclastic activity, and accelerate periodontal ligament turnover, thereby facilitating orthodontic tooth movement. Local PRP injections administered adjacent to extraction sites or within the surrounding mucosa have been shown to stimulate bone remodeling, accelerate space closure, and reduce healing time. PRP has been reported to be particularly effective during canine retraction, space closure, and en-masse anterior retraction.³ The combined use of TADs and PRP in this case incorporated both precise biomechanical control and a biologic adjunct; however, the specific contribution of PRP to treatment efficiency and outcomes cannot be determined from a single case. While TADs provide stable anchorage and controlled force delivery, PRP has been suggested to influence the regional acceleratory phenomenon (RAP); however, its effect on the rate of orthodontic tooth movement and overall treatment duration remains inconclusive in clinical settings. This combined approach may also improve periodontal response and patient comfort, making it a valuable adjunctive strategy in contemporary orthodontic practice. adjunct in the management of bimaxillary protrusion cases.⁴ PRP was used as an adjunctive biologic modality; however, its specific contribution to treatment efficiency and tissue response cannot be determined from this single case. Although PRP has been suggested to influence bone remodeling, conclusive clinical evidence in orthodontics remains limited.

2. Case Report

2.1. Diagnosis

A 19 year old female patient came with the chief complaint of a irregularly placed upper and lower front teeth since 4 years. No relevant medical, dental, or prenatal/natal/postnatal history was reported. Clinical examination revealed having straight profile and straight divergence with positive lip step. Patient had Skeletal Class I Jaw bases with retrognathic maxilla and retrognathic mandible ($ANB=1^\circ$) with Hyperdivergent growth pattern on account of J. Ratio 63%with CVMI Stage VI (Completion) with 0 % growth remaining, Patient has Angle's Class I Deweys type 2 Malocclusion, Overjet of 3 mm and an overbite of 4 mm with non-consonant smile, functionally/potentially incompetent lips, 4 mm Interlabial gap and normal nasolabial angle, Normal TMJ Bolton max. overall excess (1.85) Soft tissue analysis showed an protusive lips Upper lip to S line(Patient) = +4 mm and Lower lip to S line(Patient) = + 9mm E line- -3 mm (UPPER lip), mm + 6mm (lower lip).



Figure 1: Pretreatment extraoral and intraoral photographs

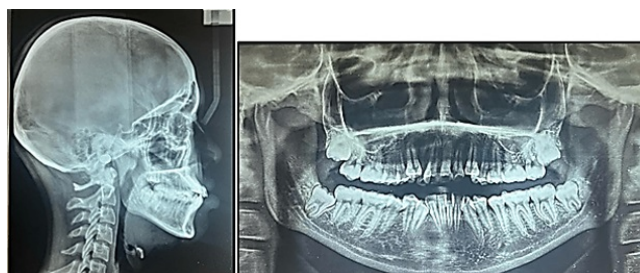


Figure 2: Pretreatment radiographs

Table 1. Pretreatment cephalometric values

Variables	Pre-treatment value
SNA	77
SNB	76
ANB	1
Wits Appraisal	-1 mm
S-N to Maxillary Plane	6
MPA	38
MMPA	35
Upper Incisor to Maxillary Plane	54
Upper Incisor to S-N Plane	120°
Lower Incisor to Mandibular Plane	95
Lower Incisor to A- Pog	7 mm
Inter- Incisal Angle	115
Lower Incisor Edge to Upper Incisor Root Centroid	-2mm
Nasolabial Angle	104
Upper Lip to E- Plane	-3 mm
Lower Lip to E- Plane	+7mm
UAFH	42 m
LAFH	58mm
AFH	101mm
PFH	64 mm
Jarabak Ratio	63%

3. Treatment Objectives

1. To correct inclination of upper teeth
2. To correct inclination of lower teeth
3. To correct positive lip step To correct midline shift
4. To achieve normal Overbite
5. To maintain Class I molar relationship.

3.1. Treatment plan

After obtaining informed consent. Phase 1 was started with bonding of upper arch with pre-activated Edgewise brackets (.022"x .028") slot. Bands were placed on all 1st permanent molars. Initial leveling and alignment were carried out

using 0.014" NiTi archwires, followed by 0.016" and 0.018" NiTi archwires. Following alignment, indicated extractions were performed and arch consolidation was achieved. For anchorage reinforcement, titanium mini screws (diameter 1.5mm, length 8mm, SK Surgical) (Figure 3) were inserted under local anesthesia in the interradicular space between the maxillary first permanent molar and second premolar at the height of mucogingival junction in (Figure 3). The implants were placed at least one week before the PRP injection to reduce the effect of mechanical stress on bone metabolism. The patient was advised to keep the micro-implant clean by gently using interdental brush



Figure 3: Mini implant placed between second premolar and 1st molar

After 1 week of implant insertion. PRP preparation was done under aseptic processing procedure by double spin technique. PRP method as described by Liou61 was used in (Figure 4).

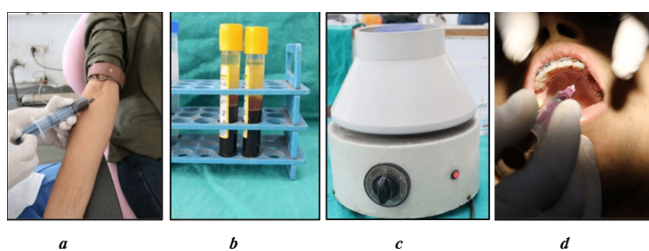


Figure 4: a) Collection of blood b) blood collected in ACD tubes c) Centrifugation d) Injecting PRP under 1000 rpm for 12 minutes-PRP was injected on distal aspect of canine

Individualised canine retraction was then started on 0.018"×0.025" SS wire using calibrated nickel-titanium closed-coil springs with 150 gm of force on each side following the injection of PRP on the intervention side.

Following segmental canine retraction, En-masse retraction of the anterior segment was carried out. Orthodontic force application from the temporary anchorage device (TAD) was discontinued, and reverse bracket bonding with respect upper right lateral incisor was done. A 0.012" nickel-titanium (NiTi) auxiliary archwire was placed in the auxiliary slot in both the maxillary and mandibular arches, while the 0.018 × 0.025-inch stainless steel working archwire was re-ligated. In the mandibular arch, an AJ Wilcock 0.018-inch stainless steel wire was continued with stop bends, and orthodontic forces were maintained on the left side. Space closure, consolidation, and finishing were completed with periodic re-ligation and controlled force adjustments until optimal alignment, root parallelism, arch coordination, and a satisfactory occlusal relationship were achieved.



Figure 5: Individual canine retraction

4. Results

Post-treatment records showed significant improvement in the facial profile, with conversion of the initial positive Korkhaus lip step into an almost straight lip step through TAD-supported anterior retraction and extraction space closure, similar to the mini-screw-assisted bimaxillary protrusion corrections reported by Lin and Liou, Villela and co-workers, and other clinicians using skeletal anchorage for full-arch retraction in Class I patients. The controlled reduction in maxillary and mandibular incisor proclination decreased lip protrusion and the interlabial gap, thereby improving sagittal lip position in line with soft-tissue changes described by investigators evaluating lip profile changes after incisor retraction. Class I molar and canine relationships were maintained, midline discrepancy was corrected, and well-aligned arches with proper overjet and overbite were achieved, reflecting the stable occlusal and esthetic outcomes commonly reported in TAD-assisted bimaxillary dentoalveolar protrusion case reports. The adjunctive use of platelet-rich plasma appeared to support smooth orthodontic tooth movement and satisfactory tissue healing. Overall, both functional and esthetic treatment objectives were successfully achieved, resulting in a stable and pleasing outcome.



Figure 6: Posttreatment extraoral and intraoral photographs

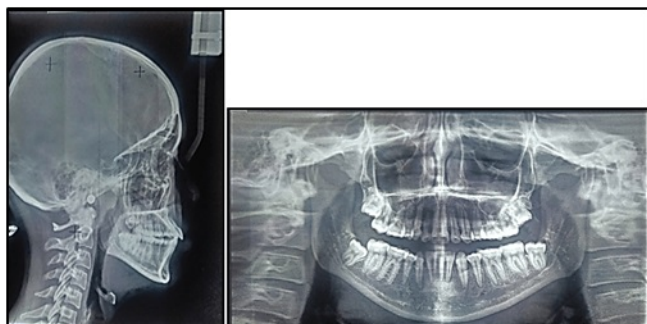


Figure 7: Posttreatment radiographs



Figure 8: Superimpositions

Table 2. Comparison between pre and Post treatment cephalometric values

Variables	Pre Treatment Value	Post Treatment Value
SNA	77	77
SNB	76	76
ANB	1	1
Wits Appraisal	-1	-1
S-N to Maxillary Plane	6	4
Mandibular Plane Angle	38	37
MMPA	35	35
Upper Incisor to Maxillary Plane	54	50
Upper Incisor to S-N Plane	120	114
Lower Incisor to Mandibular Plane	95	92
Lower Incisor to A- Pog	7	5
Inter- Incisal Angle	115	112
Lower Incisor Edge to Upper Incisor Root Centroid	-2	-1
Nasolabial Angle	104	114
Upper Lip to E- Plane	-3	-1
Lower Lip to E- Plane	7	5
UAFH	41	41
LAFH	58	58
AFH	101	99
PFH	64	63
Jarabak Ratio	63	63.6

5. Discussion

The case involves a skeletal Class I patient with significant bimaxillary dentoalveolar protrusion and a positive Korkhaus lip step—characterized by lower lip protrusion relative

to the upper lip line—despite a straight facial profile, primarily due to proclined incisors in both arches combined with a hyperdivergent growth pattern. This dental compensation caused upper and lower lip procumbency and an increased interlabial gap, creating an illusion of mild convexity without true sagittal skeletal discrepancy. An extraction-based camouflage protocol addressed the dentoalveolar component: following removal of all four first premolars, controlled anterior retraction was achieved via mini-screw-supported individualized canine-then-incisor mechanics, with temporary anchorage devices positioned between the maxillary first molar and second premolar for near-absolute anchorage, preventing posterior mesial movement. This biomechanics enabled efficient incisor repositioning, substantial lip retraction, interlabial gap reduction, and conversion of the positive Korkhaus lip step to a straight profile, aligning with outcomes reported by Lin and Liou (2020)⁵, who achieved upper incisor retraction and intrusion with miniscrew anchorage, alongside mandibular autorotation for profile enhancement. Similar soft-tissue improvements, including nasolabial angle widening and lip competency, were noted by Sharma et al. (2010)⁶ in lingual orthodontics, and more recent cases like those by Beyling F (2021)⁷ using en-masse distalization.

Adjunctively, platelet-rich plasma (PRP) was applied via Liou's (2016)⁸ submucosal injection protocol with double-spin preparation to accelerate space closure through the regional acceleratory phenomenon (RAP), enhancing osteoclastic activity. Experimental animal studies by Güleç (2017)⁹ demonstrated 1.7-fold faster tooth movement with high-concentration PRP, while Akbulut (2018)¹⁰ and Tehranchi et al. (2019)¹¹ confirmed transient acceleration in canine retraction models. However, human clinical evidence during mini-screw-assisted en-masse retraction is equivocal: Chandak and Patil (2021)¹² found no significant differences in retraction rates or anchorage control in adult Class I bimaxillary protrusion patients, despite minor postoperative discomfort. Systematic reviews by Arqub et al. (2021),¹³ and recent trials like Al-Bozaie et al. (2024)¹⁴ further highlight inconsistencies due to methodological heterogeneity, small sample sizes, and negligible overall effects in comprehensive orthodontic protocols.

6. Conclusion

This case report demonstrates the successful management of bidental protrusion associated with a positive Korkhaus lip step in a skeletal Class I hyperdivergent adult patient using extraction-based camouflage supported by temporary anchorage devices (TADs) and adjunctive platelet-rich plasma (PRP).

Mini-screw-assisted mechanics provided effective absolute anchorage, enabling controlled anterior retraction, preservation of the Class I molar relationship, correction of midline deviation, normalization of overjet and overbite, and significant improvement in facial profile. The positive lip step was successfully converted to an almost straight lip relationship, with reduction in lip protrusion and interlabial gap, resulting in enhanced lip competence and improved smile esthetics.

“Platelet-rich plasma (PRP) was used as an adjunctive biologic modality; however, its specific contribution to treatment efficiency and tissue response cannot be isolated in this single case

Overall, the combined biomechanical and biological approach proved effective in achieving stable functional occlusion and harmonious soft-tissue balance in a non-growing adult patient with bimaxillary dentoalveolar protrusion.

7. Source of Funding

None.

8. Conflict of Interest

None.

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Case Report

When earache locks the jaw: A hidden culprit of TMJ ankylosis

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Abstract

The temporomandibular joint (TMJ) is a specialized synovial articulation essential for mastication, speech, and facial expression. TMJ ankylosis, the pathological fusion of the mandibular condyle and glenoid fossa, is rare in children but can severely impair mandibular growth, facial symmetry, and oral function. Infection, particularly chronic or recurrent ear disease progressing to mastoiditis, is an uncommon cause of pediatric TMJ ankylosis. We report a 12-year-old male with a long-standing history of recurrent ear infections and chronic mastoiditis who developed progressive restriction of jaw movements, with clinical and radiographic evaluation confirming TMJ ankylosis and associated facial asymmetry. Surgical management using gap arthroplasty with distraction osteogenesis successfully restored mandibular mobility and symmetry, highlighting the importance of early recognition and timely multidisciplinary intervention to prevent long-term functional and psychosocial morbidity.

Keywords: Temporomandibular joint, TMJ ankylosis, Chronic mastoiditis, Pediatric TMJ disorder, Distraction osteogenesis, Functional rehabilitation, Secondary joint involvement.

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1. Introduction

The temporomandibular joint (TMJ) is a specialized synovial articulation that plays a vital role in mastication, speech, and coordinated mandibular movements.¹ Temporomandibular joint ankylosis is characterized by fibrous or bony fusion between the mandibular condyle and the temporal bone, resulting in progressive restriction of mandibular mobility.² The condition may be classified as true (intra-articular) or false (extra-articular) ankylosis and may present as fibrous, bony, or mixed forms.³ Although trauma is the most common etiological factor, infection remains a significant but less frequently reported cause of TMJ ankylosis.² Otolgic infections such as otitis media and mastoiditis may involve the TMJ because of its close anatomical relationship with the middle ear, external auditory canal, and mastoid air-cell system.⁴ Otitis media can rarely extend to involve the temporomandibular joint, leading to suppurative joint infection or abscess formation due to direct spread from adjacent middle ear structures.⁸ Persistent inflammatory insult to the joint may result in synovial involvement, cartilage destruction, and progressive ossification culminating in ankylosis.¹ TMJ ankylosis secondary to ear suppuration is uncommon in contemporary clinical practice but is reported more frequently in children.^{4,6} When ankylosis develops during the active growth period, it can severely impair mandibular growth, resulting in facial asymmetry, retrognathism, malocclusion, and functional disability.⁵ Experimental evidence further supports that ankylosis occurring during growth leads to abnormal

joint ossification and long-term skeletal deformity.⁷ This case report presents a rare instance of TMJ ankylosis in a 12-year-old boy secondary to chronic mastoiditis, underscoring the importance of early recognition of otogenic causes of TMJ pathology.

2. Case Report

A 12-year-old boy reported to the department with the chief complaint of progressive reduction in mouth opening over the past several years, accompanied by difficulty in chewing and deviation of the mandible during opening. The child's father recalled a severe episode of ear infection at approximately 3–4 years of age, which was managed symptomatically but without complete follow-up. No history of trauma, prolonged intubation, or systemic illness was noted. On general examination, the patient appeared well-nourished with no signs of acute infection.

Extraoral inspection revealed facial asymmetry, with flattening of the left side of face and deviation of the mandible toward the right upon opening. Maximum interincisal opening was 10mm. A prominent antegonial notch was evident on the affected side, suggestive of long-standing functional alteration and compromised mandibular growth. (Figure 1) On clinical examination, the temporomandibular joints were not palpable bilaterally, with tenderness elicited over the right TMJ region.

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Figure 1: Extraoral view showing A. Deviation of jaw towards right side of face and flattening of face over left side. B. Prominent antegonial notch over right side. C. Figure showing maximum interincisal mouth opening measured at 10 mm.

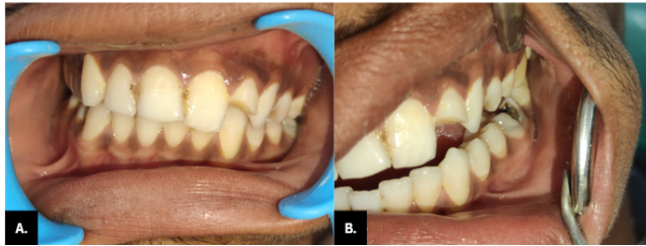


Figure 2: A. Intraoral view showing Ellis class 3 fracture with 22. B. Intraoral view showing RC-6 caries with 36.



Figure 3: A. Orthopantomogram view (OPG) showing reduced ramus height with deformed right condylar region. B. Lateral cephalogram (LC) showing reduced mandibular length and mandibular retrusion.



Figure 4: A. Coronal showing opacification of mastoid air cells on right side. B. Axial view showing opacification of mastoid air cells on right side.

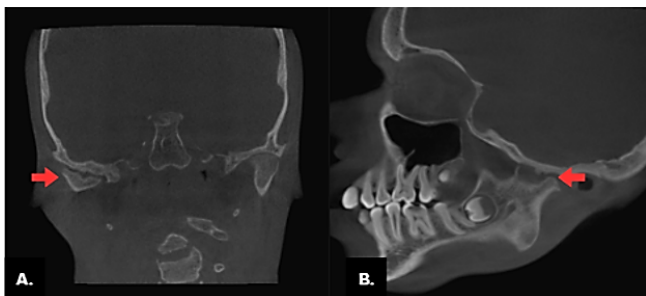


Figure 5: A. Coronal section showing irregular 'jigsaw-like' morphology of the condylar head. B. Sagittal CBCT section

showing decreased vertical height of the mandibular ramus on the right side.

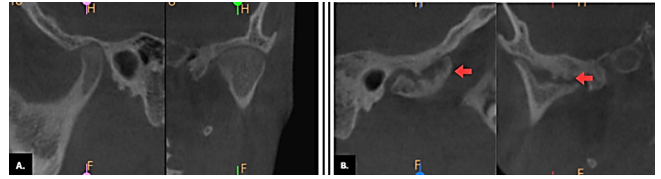


Figure 6: A. Imaging view of the TMJ demonstrating normal anatomical configuration of the left condylar head. B. Imaging view of the TMJ demonstrating altered anatomical configuration of the right condylar head with a characteristic jigsaw pattern.

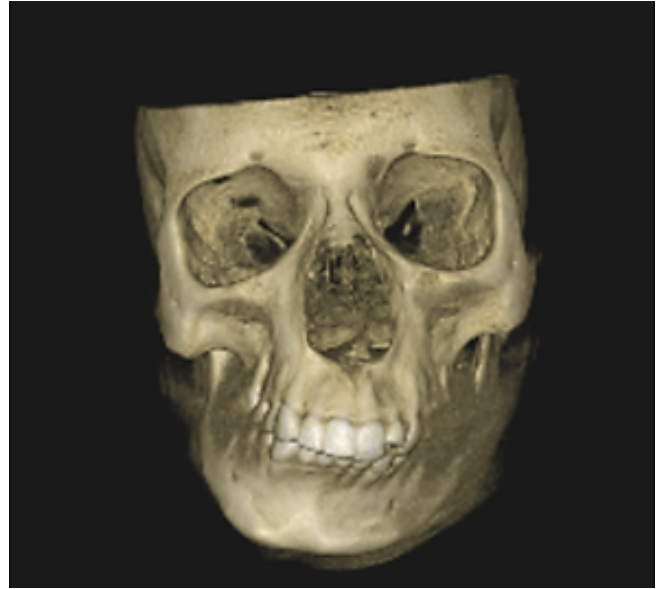


Figure 7: 3D CBCT view showing facial asymmetry over right side of jaw region

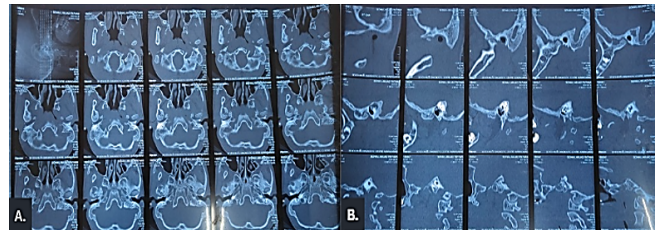


Figure 8: A. Axial view in HRCT temporal bone showing opacification of mastoid air cells. B. Sagittal views of HRCT temporal bone showing altered condylar morphology and mastoid air cells opacification.

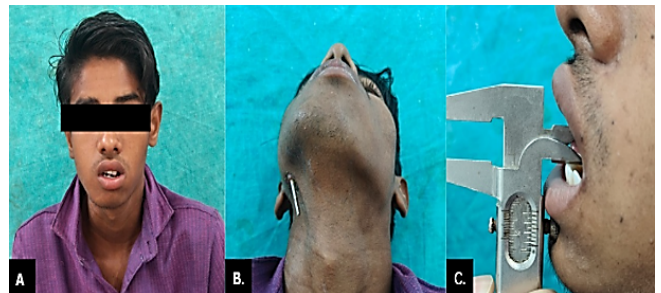


Figure 9: Post-operative follow up photos A: Frontal view showing improved facial profile. B: Submental view demonstrating reduced prominence of the antegonial notch. C: Measurement of mouth opening showing increase from 10 mm to 12 mm.

Intraoral examination revealed caries with 36 and Ellis class 3 fracture with 22. Periodontal examination revealed a fair periodontal status, with satisfactory oral hygiene and no signs of active periodontal pathology. (Figure 2) A noticeable deviation of the mandibular midline toward the right side was observed. Based on the clinical findings, a provisional diagnosis suggestive of right-sided temporomandibular joint ankylosis was made with differential diagnosis of unilateral condylar hyperplasia and post infection degenerative joint disease.

For further evaluation, radiographic investigations including orthopantomogram (OPG) and lateral cephalogram (LC) were performed. The OPG demonstrated an ill-defined, deformed right condylar region with obliteration of the joint space and reduced ramal height. The lateral cephalogram revealed mandibular retrusion, reduced mandibular length, and posterior positioning of the chin, indicating mandibular growth deficiency secondary to long-standing TMJ pathology, consistent with right temporomandibular joint ankylosis. (Figure 3)

For a detailed assessment of the joint and to determine the extent of ankylosis, a full-face cone-beam computed tomography (CBCT) scan was performed. The CBCT revealed irregular erosion and deformity of the right condylar head and glenoid fossa with loss of joint space and an intervening fibrous interface producing a characteristic “jigsaw” appearance, consistent with right TMJ fibrous ankylosis (Sawhney Type III). Associated findings included marked reduction of right ramal height (32.1 mm vs. 50.6 mm on the left), elongation of the right coronoid process, a prominent antegonial notch, and deviation of the chin to the right, indicating long-standing mandibular growth deficiency. Opacification of the right mastoid air cells was also noted, suggesting chronic mastoiditis as a possible etiological factor. (Figure 4, 5, 6, 7)

High-resolution computed tomography of the temporal bones demonstrated sclerosis and soft-tissue opacification of the mastoid air cells with extension into the middle ear cavity via the mastoid auditus and antrum, resulting in opacification of the epitympanum, mesotympanum, and hypotympanum. The ossicular chain and inner ear structures were intact, with no evidence of cholesteatoma, suggestive of chronic mastoiditis. (Figure 8)

Auditory brainstem response testing revealed that right ear peak could not be obtained till 95dBnHL and left ear peak could be obtained till 95dBnHL. Suggesting profound sensorineural hearing loss in the right ear and severe hearing loss in the left ear.

2.1. Final diagnosis

Right temporomandibular joint bony ankylosis secondary to chronic otitis media with mastoiditis

2.2. Treatment and follow-up

A staged surgical approach was planned to release the ankylotic mass, correct mandibular deficiency and facial asymmetry, and prevent re-ankylosis. Under general anesthesia, surgical release of the right TMJ was performed with excision of the ankylotic mass and

placement of interpositional material. This was followed by placement of a mandibular distractor, and distraction osteogenesis was initiated after an appropriate latency period. Gradual distraction was carried out at a controlled rate until satisfactory mandibular lengthening and facial symmetry were achieved, followed by a consolidation phase. Postoperatively, aggressive physiotherapy was instituted to maintain joint mobility. On follow-up, the patient showed significant improvement in mouth opening, mandibular function, and facial symmetry, with stable occlusion, satisfactory bone consolidation, and no evidence of recurrence. (Figure 9)

3. Discussion

Septic arthritis of the temporomandibular joint (TMJ) is an uncommon but potentially serious complication of acute otitis media (AOM) and mastoiditis in children, which can progress to ankylosis if not promptly recognized and treated.⁹ Recent pediatric studies have demonstrated that TMJ septic arthritis may arise from acute mastoiditis, with imaging frequently revealing joint effusion or adjacent abscesses, and some affected children developing ankylosis within months to years after the initial infection.^{10,12}

Early clinical diagnosis can be challenging, as signs such as preauricular swelling, pain, or trismus may be subtle or absent initially, necessitating high clinical suspicion and targeted imaging.¹⁰ Case reports emphasize that children with otogenic TMJ involvement often require a combination of antibiotic therapy and, in select cases, surgical drainage to control infection and prevent further joint damage.^{11,13}

Anatomical factors in children, such as incompletely ossified glenoid fossa and thin temporal bone partitions, may facilitate contiguous spread of infection from the mastoid to the TMJ, making the pediatric population particularly vulnerable.¹⁰ Previous studies on TMJ ankylosis secondary to ear suppuration have reported that persistent post-infectious inflammation may lead to progressive fibrous adhesion and eventual bony fusion of the temporomandibular joint.⁴ Published literature further demonstrates that TMJ infection-related pathology may present with considerable clinical variability, ranging from acute septic arthritis to delayed manifestations such as progressive limitation of mandibular movement without overt signs of active infection.^{15,17} Imaging findings reported in cases of otogenic TMJ involvement include joint effusion, early condylar surface irregularities, and inflammatory changes within the joint space, supporting the concept that structural damage may precede clinically evident ankylosis.^{16,18} Systematic reviews have highlighted the importance of early recognition of limited mouth opening, mandibular tenderness, and imaging findings to initiate timely multidisciplinary management and reduce the risk of permanent joint sequelae.^{13,14}

Given these considerations, clinicians managing pediatric mastoiditis should maintain a high index of suspicion for TMJ involvement, perform appropriate imaging studies, and coordinate care among otolaryngologists, oral and maxillofacial surgeons, dentists, and physiotherapists to prevent long-term functional impairment and growth

disturbances.^{10,12}

4. Conclusion

TMJ ankylosis is an unusual and rare complication of otitis media and mastoiditis that occurs predominantly in young children due to immature or dehiscent anatomical barriers facilitating the spread of infection. Early infection in infancy or childhood can adversely affect mandibular growth and joint function, potentially leading to significant functional and psychological disabilities if not promptly recognized and managed. Chronic otologic infections, including acute otitis media and mastoiditis, may produce secondary effects on the TMJ, with imaging sometimes revealing joint effusion or preauricular collections before ankylosis develops. Delayed recognition of otogenic TMJ involvement is a critical factor that can lead to progressive dysfunction and long-term morbidity. This case highlights the importance of interdisciplinary vigilance; persistent or recurrent ear disease should prompt clinicians to consider adjacent maxillofacial complications to ensure timely and effective management. The clinical presentation is often subtle and can be easily overlooked, emphasizing the need for comprehensive history-taking, careful clinical examination, and targeted imaging to prevent permanent joint sequelae.

5. Source of Funding

None.

6. Conflict of Interest

None.

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Case Report

The paradox of benignity and clinical aggression: An extreme odontogenic myxomaJaishri Pagare¹, Ishwari Manikrao Garad^{1*}, Nimisha Pagare²¹Dept. of Oral Medicine and Radiology, Government Dental College and Hospital, Chhatrapati Sambhajnagar, Maharashtra, India²Dept. of Periodontology, Dr. D. Y. Patil Dental College and Hospital, Pimpri Pune, Maharashtra, India**Abstract**

Odontogenic myxoma is a rare, benign but locally aggressive odontogenic tumor of ectomesenchymal origin, accounting for approximately 3–6% of all odontogenic tumors. It most commonly affects individuals in the second to fourth decades of life, with a mean age of presentation around 30–40 years and shows a slight female predilection. The mandible is more frequently involved (60–70%), particularly the posterior body and ramus, while maxillary lesions (30–40%) tend to demonstrate more aggressive behaviour due to early sinus involvement. Clinically, odontogenic myxoma presents as a slow-growing, painless jaw swelling, often reaching a considerable size before diagnosis. Radiographically, it appears as a uni or multilocular radiolucency with fine internal septations producing a characteristic honeycomb or soap-bubble pattern, along with cortical expansion and thinning. Owing to its infiltrative nature and high recurrence potential, accurate imaging is essential for management. This report describes a case of odontogenic myxoma in a 45-year-old male presenting with a large swelling of jaw with pus discharge.

Keywords: Odontogenic myxoma, Benign odontogenic tumour, Multiloculated radiolucency, Myxoid stroma, Fine needle aspiration cytology**Received:** 15-02-2026 **Accepted:** 07-04-2026 **Available Online:** 23-05-2026

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For reprints contact: reprint@ipinnovative.com**1. Introduction**

Odontogenic myxoma is an uncommon benign neoplasm of odontogenic ectomesenchymal origin that arises almost exclusively within the maxillofacial region, reflecting its close association with tooth-forming tissues such as the dental papilla, dental follicle, and periodontal ligament.^{1,2} Although histologically benign, odontogenic myxoma demonstrates locally aggressive and infiltrative behavior within cancellous bone, accounting for approximately 3–6% of all odontogenic tumors.^{1,3} The lesion most commonly affects individuals in the second to fourth decades of life, with a slight female predominance reported in several series.^{2,4} Anatomically, the mandible is more frequently involved than the maxilla; however, maxillary lesions are often considered more aggressive because of early extension into adjacent anatomical spaces such as the maxillary sinus and nasal cavity.^{3,5}

Clinically, odontogenic myxoma usually presents as a slow-growing, painless swelling, which often results in delayed diagnosis and extensive bone involvement at presentation.^{2,4} Radiographically, the lesion exhibits variable appearances ranging from well-defined unilocular radiolucencies to multilocular lesions with fine internal septations, producing characteristic honeycomb, soap-bubble, or tennis-racket patterns, along with cortical expansion, tooth displacement, and occasional root resorption.^{5,6} Histopathologically, it is composed of stellate and spindle-shaped cells dispersed in an abundant myxoid

stroma with minimal collagen content.¹ Due to its infiltrative growth pattern and notable recurrence rate following conservative treatment, accurate diagnosis supported by thorough radiologic and histopathologic evaluation is essential for appropriate surgical planning and long-term follow-up.^{3,6}

2. A Case Report

A 45-year-old male patient came to the department of oral medicine and radiology with chief complaint of large extensive swelling in the jaw region nearly since birth. The swelling was painless and associated with continuous pus discharge from 3-4 months. He was not having any systemic illness or drug history. On extraoral examination (In Figure 1) there was a large well-defined swelling extending from left infraorbital region till the hyoid bone and mediolaterally from left ear till right angle of mandible. The size of jaw swelling approx. 14 x 12 cm (SI x TR). A single punctate extraoral draining sinus noted with inferior aspect of swelling with active pus discharge noted. Facial asymmetry present due to large swelling. Reduced mouth opening till 9 mm. On palpation swelling was soft to firm to bony hard in consistency with local rise in temperature. On intraoral examination (In Figure 2) poor oral hygiene with teeth present were 18, 17, 16, 15, 14, 13, 12, 11, 21, 22, 23, 31, 32, 33, 34, 41, 42, 43, 44, 45, 46, 47, 48. Missing teeth were 24, 25, 26, 27, 28. Root piece were 41, 42, 43. Entire mandibular jaw got deviated to right side with buccolingual expansion and severe teeth displacement. Detailed examination was not

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possible due to reduced mouth opening.



Figure 1: Extraoral photographs



Figure 2: Intraoral examination



Figure 3: IOPA 34,33,32,31,41



Figure 4: Axial section

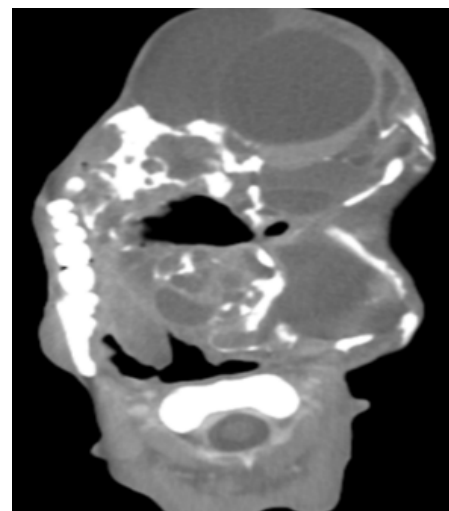


Figure 5: Axial section



Figure 6: Coronal section

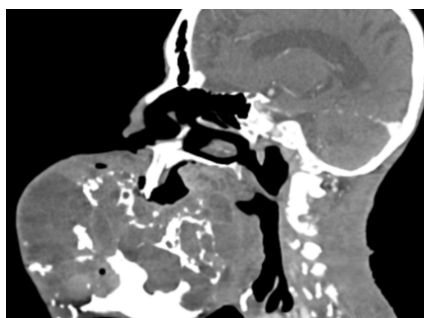


Figure 7: Sagittal section



Figure 8: Fine needle aspiration cytology

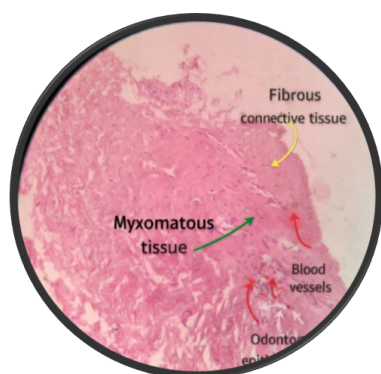


Figure 9: Histopathology slide

Radiological investigation – Initially Intraoral periapical radiograph (In Figure 3) was taken. Teeth seen were 31,32,33,34,41, they were destructed due to caries. Periapical bone shows multilocular radiolucency. Then he was sent for a Computed Tomography scan.

On CT examination (In Figure 4,5,6,7,) - A large multiloculated expansile lytic lesion measuring 16.5x12.5x14.5 cm (AP x TR x CC) is noted involving the left mandible crossing midline to involve body of right mandible. The lesion exhibits multiple internal septations within (giving soap bubble appearance), predominantly hypodense fluid content with peripheral and septal enhancement, marked cortical thinning and gross expansion of buccal and lingual cortex with extraosseous soft tissue noted. It has caused mass effect on nearby structures such as mild tracheal narrowing, superiorly it is, extending to left maxilla with resultant remodelling, displacement of left masticator space,

medially causing thinning and scalloping of lateral wall of left maxillary sinus. The lesion shows communication with oral cavity with resultant air foci within. Tongue was not seen separately from the lesion. No involvement of hard palate, left pterygoid plates, left styloid process. Features s/o benign odontogenic tumour, considering differential diagnosis as Ameloblastoma.

Patient was sent for further investigations like fine needle aspiration cytology (FNAC) and incisional biopsy for diagnosis.

FNAC (Figure 8) – On aspiration syringe with frank blood shows haemorrhagic aspirate, straw-coloured fluid (clear yellow) shows myxoid aspirate, composed of mucin-rich extracellular matrix, Hyaluronic acid, dark yellow / slightly turbid fluid represents concentrated myxoid material with old altered blood pigments.

On histopathological investigations of biopsy specimen – (Figure 9)

Microscopic examination reveals a non-encapsulated, locally invasive tumour composed of a hypocellular and abundant loose, myxoid (muroid) stroma. Within this matrix, there is a proliferation of randomly oriented stellate, spindle-shaped, and occasionally round mesenchymal cells that possess long, delicate, and often anastomosing cytoplasmic processes. The nuclei are typically small and hyperchromatic, with low mitotic activity and a lack of cellular atypia. While the stroma is primarily myxomatous, it may contain varying amounts of delicate collagen fibres and thin-walled blood vessels. Small, inactive islands or nests of odontogenic epithelium are frequently interspersed throughout the lesion but are not a mandatory feature for diagnosis. Residual bony trabeculae may also be present, reflecting the tumour's infiltrative nature as it permeates through the surrounding marrow spaces of the jaw. Final diagnosis were made as “Odontogenic Myxoma”.

Patient was admitted and prepped for surgery but got died due to systemic condition.

3. Discussion

The present case demonstrates an exceptionally rare and advanced presentation of odontogenic myxoma, primarily distinguished by its enormous size, long-standing duration since early life, midline crossing, extraosseous extension, and secondary infection. While odontogenic myxoma is known for slow but infiltrative growth, lesions of such magnitude are seldom reported in contemporary literature, largely due to earlier detection facilitated by improved access to diagnostic imaging and dental care.⁷

One of the most striking aspects of this case is the extraordinary size of the lesion, which far exceeds the average dimensions reported in most clinicopathological series. Simon et al. noted that the majority of odontogenic myxomas are diagnosed before reaching extensive proportions, as facial asymmetry and jaw expansion usually prompt patients to seek treatment earlier.⁸ The prolonged neglect in this case allowed uninterrupted tumor growth, resulting in extensive mandibular destruction, deviation of the jaw, and involvement of adjacent maxillofacial structures.

Radiologically, the lesion exhibited a multiloculated “soap-bubble” appearance with fine internal septations, marked cortical thinning, and gross expansion of both buccal and lingual cortices. Although such imaging characteristics are well documented for odontogenic myxoma, the presence of extraosseous soft-tissue extension, airway compromise, maxillary remodelling, and communication with the oral cavity is unusual and indicative of aggressive local behaviour.⁹ Kaffe et al. emphasized that cortical perforation and soft-tissue extension are relatively uncommon findings and are typically associated with long-standing or recurrent lesions.⁹

The crossing of the mandibular midline and extension into the contralateral body of the mandible further illustrates the infiltrative nature of odontogenic myxoma. This behaviour can be attributed to the tumour’s lack of encapsulation and its propensity to permeate through cancellous bone marrow spaces rather than displacing surrounding structures.¹⁰ Additionally, superior extension with scalloping of the maxillary sinus wall and remodelling of the maxilla is particularly significant, as maxillary involvement is often associated with more aggressive clinical behaviour due to anatomical proximity to vital spaces.¹¹

Secondary infection, manifested clinically as continuous pus discharge through an extraoral draining sinus, is rarely reported in odontogenic myxoma. This complication likely resulted from cortical perforation and oral cavity communication, compounded by poor oral hygiene and extensive tumour necrosis. Such features further complicated the clinical picture and contributed to functional impairment, including severe trismus and difficulty in detailed intraoral examination.

Histopathological findings in the present case were consistent with classic odontogenic myxoma, showing a hypocellular myxoid stroma containing stellate and spindle-shaped cells with long cytoplasmic processes, minimal collagen, and absence of atypia. Despite its alarming clinical and radiologic presentation, the microscopic appearance reaffirmed the benign nature of the lesion, highlighting the well-recognized discrepancy between histologic blandness and clinical aggressiveness in odontogenic myxoma.^{7,12}

From a management perspective, large odontogenic myxomas typically warrant radical surgical resection with adequate margins, as conservative approaches such as curettage are associated with high recurrence rates.^{8,11} Unfortunately, in the present case, definitive surgical intervention could not be carried out due to the patient’s deteriorating systemic condition, culminating in death. This outcome underscores the potentially life-threatening consequences of delayed diagnosis and treatment, even in histologically benign odontogenic tumors.

Overall, the sheer size, extent, secondary infection, and functional compromise observed in this case place it among the rarest and most severe presentations of odontogenic myxoma reported, reinforcing the need for early recognition

and timely intervention.

4. Conclusion

This case highlights an exceptionally rare presentation of a giant odontogenic myxoma with extensive mandibular involvement, midline crossing, extraosseous extension, and secondary infection. Despite its benign histopathological nature, the lesion exhibited aggressive local behaviour resulting in significant functional and anatomical compromise. Delayed diagnosis played a crucial role in the progression to this advanced stage. Early detection, comprehensive imaging evaluation, and timely surgical management are essential to prevent severe morbidity and mortality associated with such lesions. Long-term follow-up remains critical due to the infiltrative growth pattern and recurrence potential of odontogenic myxoma.

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None.

6. Conflict of Interest

None.

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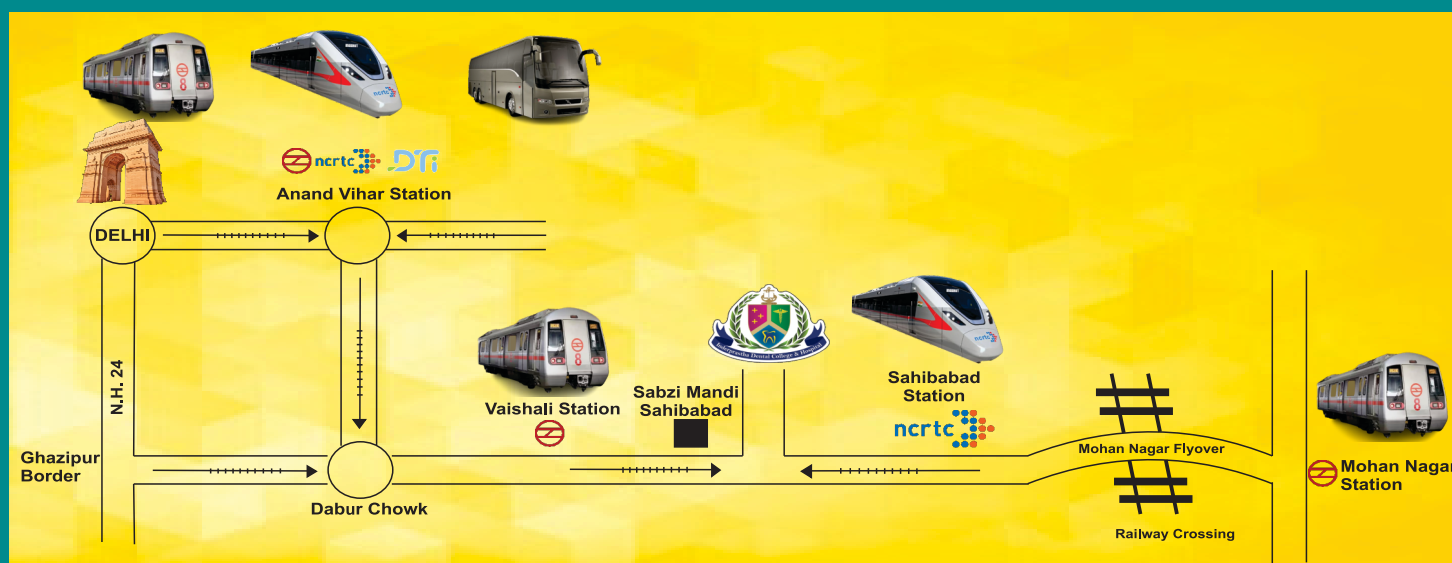
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