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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]

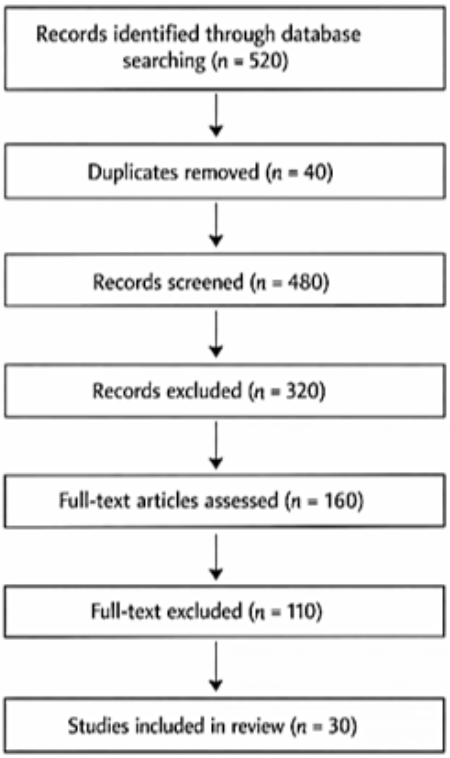

Figure 1. *PRISMA flow diagram illustrating study selection process.*

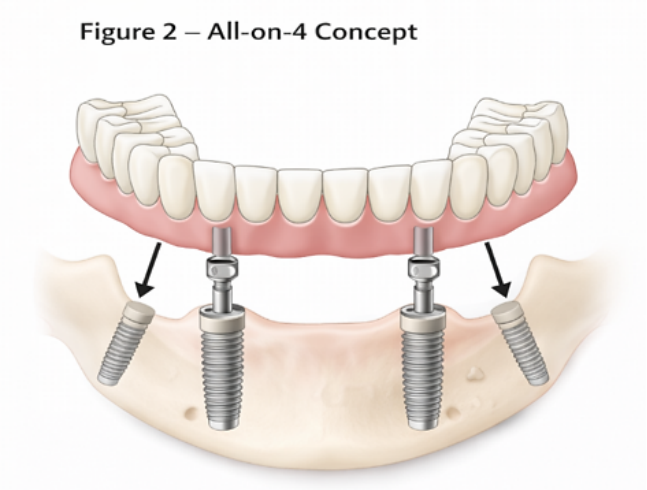

Figure 2. *Schematic representation of All-on-4 concept showing two anterior axial and two posterior tilted implants.*

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.

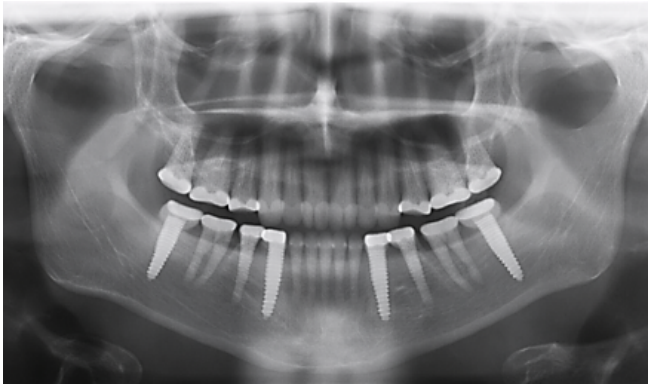

Figure 3. *Radiographic evaluation of full-arch rehabilitation using tilted implants.*

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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