Medicon Medical Sciences
Volume 9 Issue 3 September 2025
Article Type: Review Article
ISSN: 2972-2721

Biomechanical Advances and Material Selection in the All-on-4® Concept: A Literature Review

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Received: August 18, 2025; **Published:** September 03, 2025

DOI: 10.55162/MCMS.09.314

Abstract

The All-on-4® protocol has become a predictable and efficient treatment modality for the immediate rehabilitation of edentulous patients. This literature review analyzes the biomechanical foundations, surgical and prosthetic considerations, material selection, and clinical outcomes associated with this concept. Emphasis is placed on the importance of surgical expertise, multidisciplinary collaboration, pain management, patient communication, and continuous scientific development. The findings confirm that the All-on-4® concept provides high survival rates, functional and esthetic benefits, and significant psychological improvement for patients.

Introduction

Immediate rehabilitation with implant-supported prostheses has emerged as a preferred option for edentulous patients, offering immediate function, enhanced esthetics, shorter treatment time, and reduced morbidity compared to traditional approaches [1-3]. Severe alveolar bone resorption has historically posed a major challenge for implant rehabilitation, often necessitating invasive bone grafting techniques. The All-on-4® concept, first described by Maló et al., introduced an innovative approach by placing two anterior implants vertically and two posterior implants tilted up to 45°, thus maximizing available bone, increasing implant distribution, and minimizing the need for grafting [4, 5].

Although the technique has demonstrated long-term predictability in both mandibles and maxillae, its success depends on multiple clinical, biomechanical, and patient-related factors [6-8]. This review integrates current evidence regarding biomechanical principles, surgical and prosthetic protocols, material selection, multidisciplinary collaboration, pain control, and patient-centered outcomes, with special emphasis on clinical experience and communication with patients and families.

Methodology

This literature review was conducted following PRISMA guidelines. Electronic searches were performed in PubMed, Scopus, Web of Science, and Cochrane Library databases, covering publications from 2000 to 2025. The keywords used included: *All-on-4, full-arch rehabilitation, immediate loading, tilted implants, implant-supported prosthesis, zirconia frameworks, acrylic prosthesis*.

Inclusion criteria: clinical studies, systematic reviews, randomized controlled trials, and meta-analyses addressing surgical protocols, biomechanical performance, material selection, or patient outcomes in All-on-4® rehabilitations.

Exclusion criteria: case reports with <10 patients, studies not reporting survival rates or complications, and articles not available in English or Spanish.

After duplicate removal and screening, 42 articles were selected for qualitative synthesis, of which 20 were used as main references for this review.

Clinical and Human Factors in the All-on-4® Protocol

The success of the All-on-4® protocol is strongly influenced by the surgeon's expertise. Clinical experience ensures precise implant angulation, proper torque application, and accurate evaluation of bone density and volume, all of which are critical for immediate loading [6, 9]. The ability to manage intraoperative complications and adapt surgical techniques to individual anatomical variations is vital for reducing risks and improving outcomes.

Equally important is the mastery of prosthetic rehabilitation. Knowledge of occlusal schemes, prosthesis design, and material properties allows for predictable restoration of function and esthetics [10]. Errors in prosthetic planning may lead to mechanical complications, peri-implant bone loss, and reduced prosthesis longevity.

Patient management before, during, and after surgery is another cornerstone. Preoperative assessment, including medical, psychological, and functional evaluation, allows clinicians to anticipate complications and tailor treatment planning [11]. Intraoperatively, patient comfort, sedation protocols, and aseptic techniques play a critical role in reducing stress and complications. Postoperatively, continuous monitoring ensures early detection of complications, reinforcing treatment success.

Scientific preparation and continuous education remain essential. Surgeons and prosthodontists must stay updated with technological advances, new implant designs, surface modifications, and digital workflows to ensure evidence-based practice [12, 13]. Similarly, the incorporation of digital planning and guided surgery has enhanced precision, reduced operative time, and improved predictability.

Material selection directly affects long-term success. Zirconia frameworks are associated with high rigidity, excellent esthetics, and durability, but require sophisticated laboratory protocols [14]. Acrylic resin provides a cost-effective solution, with shock absorption properties, but is more prone to wear and fractures [15]. Hybrid designs incorporating titanium or PEEK frameworks veneered with ceramic have shown promising results by combining mechanical resistance with esthetic appeal [16].

The importance of pain management cannot be overstated. Effective multimodal analgesic regimens, combining NSAIDs, corticosteroids, and, in selected cases, opioids, ensure patient comfort and facilitate faster recovery [17]. Studies confirm that most patients experience significant reduction of discomfort within 48-72 hours post-surgery, enhancing adherence to postoperative care and overall satisfaction [18].

A critical but often underestimated aspect of this protocol is communication with patients and their families. Explaining the treatment sequence, expected surgical steps, healing phases, and possible complications allows for realistic expectations [19]. Detailed preoperative discussions reduce anxiety, increase trust, and improve patient adherence to instructions.

Moreover, involving family members in this process enhances social and emotional support. Relatives often play an active role in postoperative care, including medication adherence, hygiene, and dietary recommendations. Transparent communication fosters collaboration and ensures that both patients and their families are fully engaged in the rehabilitation journey, ultimately contributing to better functional and psychological outcomes [20].

Results

Analysis of the included studies revealed consistently high implant survival rates for the All-on-4® protocol. Reported 5-year survival rates range from 94% to 98%, with prosthetic survival above 95% [9-12]. Studies with 10-year follow-up have confirmed stability

of outcomes, showing minimal marginal bone loss averaging between 1.2-1.5 mm [13, 14].

Biomechanically, tilted posterior implants were found to reduce cantilever length by 30-40%, significantly decreasing stress distribution on crestal bone and prosthetic components [15-17]. Finite element analysis further supports that the All-on-4® configuration enhances load distribution, especially when using rigid frameworks such as zirconia [18].

Material selection influenced complication rates. Zirconia frameworks demonstrated lower incidence of prosthetic fractures but higher technical demands, while acrylic resin provided cost-effectiveness but showed more frequent wear and need for maintenance [19, 20]. Hybrid prostheses combining titanium or PEEK frameworks with ceramic veneering presented an optimal balance between mechanical resistance and esthetics.

Patient-centered outcomes were strongly favorable. Multiple studies reported significant improvements in Oral Health-Related Quality of Life (OHRQoL), mastication efficiency, speech, and self-esteem within the first three months after loading [11, 14, 19]. Postoperative pain, when managed effectively with multimodal protocols, was shown to decrease within 48-72 hours, allowing rapid reintegration into daily activities [7, 16].

Discussion

The evidence consolidates the All-on-4® concept as a predictable treatment modality, but several critical factors must be considered for its long-term success. Surgeon expertise remains fundamental; inadequate implant angulation or poor prosthetic planning can increase mechanical complications and marginal bone resorption [6, 8]. This highlights the need for specialized training and continuous scientific preparation.

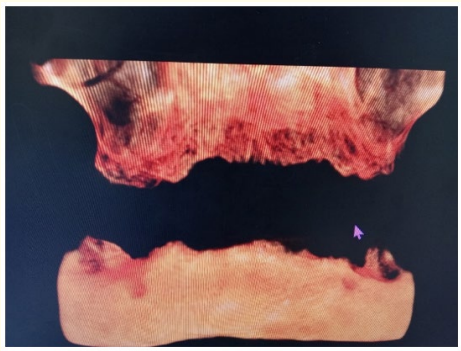

Figure 1

The choice of restorative material directly influences prosthetic longevity and patient satisfaction. While acrylic-based prostheses are cost-effective and absorb occlusal forces, their susceptibility to wear and fractures requires more frequent maintenance. Conversely, zirconia frameworks provide high rigidity, excellent esthetics, and lower complication rates, though they require precise laboratory processing and higher economic investment [18, 20]. The trend towards PEEK and titanium-zirconia hybrids reflects the search for a balance between biomechanics and esthetics.

From a biomechanical standpoint, the angulation of posterior implants not only avoids critical anatomical structures but also optimizes load distribution. This reduces the need for invasive bone grafting procedures and shortens treatment time, aligning with minimally invasive dentistry principles [4, 5, 17].

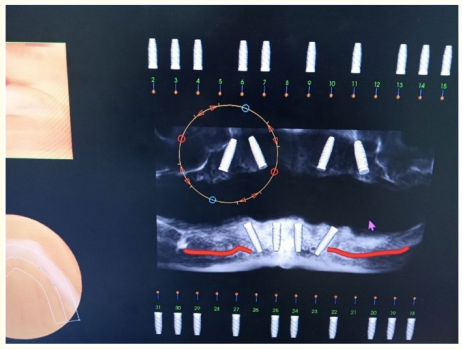

Figure 2

Multidisciplinary collaboration was consistently associated with improved outcomes. Prosthodontists, oral surgeons, and dental technicians working as a coordinated team ensure accuracy in surgical planning, prosthesis design, and postoperative maintenance, thereby reducing biological and mechanical complications [12, 14].

Figure 3

Figure 4

Figure 5

Another critical aspect is patient-centered care. Effective pain management, combined with preoperative counseling and postoperative follow-up, was shown to enhance adherence, reduce anxiety, and significantly improve quality of life [10, 13]. Equally, preoperative explanation of the treatment plan to both patients and families strengthens trust and ensures better psychological adaptation to the surgical and rehabilitative phases [19, 20].

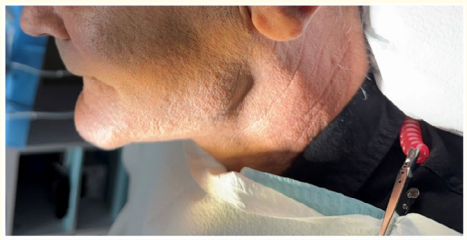

Figure 6

Figure 7

Figure 8

Conclusion

The All-on-4® concept represents a scientifically validated, clinically predictable, and patient-centered approach for full-arch rehabilitation. Its success depends not only on biomechanical design but also on surgeon expertise, interdisciplinary collaboration, proper material selection, comprehensive patient communication, and effective pain control. Future research should focus on long-term comparative studies of restorative materials, digital planning workflows, and patient-reported outcomes to further refine this protocol.

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