

IMPLANT-SUPPORTED ALL-ON-4 PROSTHESES – PRINCIPLES OF FABRICATION-A NARRATIVE REVIEW

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ABSTRACT

Full-arch rehabilitation of edentulous patients remains one of the major challenges in contemporary prosthodontics. Over the last two decades, the All-on-4 concept has emerged as a predictable alternative to conventional removable prostheses and extensive implant-supported rehabilitation protocols requiring multiple implants or bone grafting procedures. The concept relies on four strategically placed implants, including two axially positioned anterior implants and two tilted posterior implants, allowing increased anteroposterior spread and reduction of distal cantilevers.

The purpose of this narrative review is to analyze and synthesize recent evidence regarding the principles involved in the fabrication of implant-supported full-arch prostheses within the All-on-4 concept. Seven recent publications addressing biomechanical considerations, prosthetic planning, digital workflows, restorative materials and peri-implant health were reviewed.

Current literature demonstrates that long-term success depends on several key factors, including prosthetically driven implant placement, cantilever control, optimization of anteroposterior spread, passive framework fit, appropriate restorative material selection and maintenance of peri-implant health. The integration of digital technologies and artificial intelligence-based design optimization has further enhanced treatment accuracy and predictability.

Keywords: All-on-4, implant-supported prosthesis, full-arch rehabilitation, prosthodontics, digital workflow, peri-implant health.

1. INTRODUCTION

Complete edentulism remains a major oral health problem worldwide, particularly among the elderly population. Total tooth loss is associated with significant functional and psychosocial consequences, including reduced masticatory efficiency, impaired speech, compromised facial aesthetics, and a decreased quality of life. Furthermore, the progressive resorption of the alveolar ridges is an inevitable consequence of edentulism, making long-term prosthetic rehabilitation increasingly challenging.

For decades, conventional complete dentures represented the standard therapeutic option for fully edentulous patients. However, numerous studies have demonstrated the limitations of these restorations, particularly in the mandible, where retention and stability are often inadequate. The development of oral implantology has enabled the introduction of therapeutic solutions capable of significantly improving both function and patient comfort.

In this context, the All-on-4 concept was introduced as a simplified approach for the

complete rehabilitation of edentulous arches. The fundamental principle of this technique consists of using four strategically positioned dental implants to support a fixed full-arch prosthesis. Two implants are placed axially in the anterior region, whereas the posterior implants are inserted at an angulation of approximately 30–45 degrees. This configuration allows the avoidance of important anatomical structures, such as the maxillary sinuses and the mandibular canal, while increasing the anteroposterior spread of the restoration.

The advantages of the All-on-4 concept include a reduced need for bone augmentation procedures, shorter treatment duration, the possibility of immediate loading, and lower costs compared with rehabilitations supported by a greater number of implants. Owing to these benefits, the technique has gained widespread acceptance and is now extensively used in contemporary clinical practice.

Nevertheless, the long-term success of All-on-4 restorations is not determined solely by implant osseointegration. The prosthetic phase plays a crucial role in the distribution of functional forces, the prevention of mechanical and biological complications, and the maintenance of peri-implant health. In recent years, researchers have increasingly focused on optimizing prosthetic design and integrating digital technologies into the treatment workflow.

Computer-aided design and computer-aided manufacturing (CAD/CAM), intraoral scanning, cone-beam computed tomography (CBCT), and artificial intelligence algorithms currently enable the fabrication of restorations with a high degree of accuracy and predictability. These developments have led to the emergence of new therapeutic paradigms aimed at treatment personalization

and the reduction of clinical complications.

Therefore, a thorough understanding of the principles governing the design and fabrication of implant-supported prostheses within the All-on-4 concept is essential for achieving stable and long-lasting clinical outcomes.

2. MATERIALS AND METHODS

The present study represents a narrative review of the recent literature concerning the principles involved in the fabrication of fixed full-arch implant-supported restorations within the All-on-4 concept.

Seven articles published in 2024 were analyzed and selected based on their relevance to the topic. The included publications comprised clinical studies, finite element biomechanical analyses, narrative reviews, and investigations focused on digital workflows and computational optimization of prosthetic restorations.

The review focused on the following key areas:

- Prosthetically driven treatment planning;
- Biomechanical considerations of full-arch restorations;
- The influence of distal cantilevers;
- Selection of restorative materials;
- Integration of digital technologies;
- Peri-implant health and long-term maintenance;
- Current trends and future developments of the All-on-4 concept.

The data extracted from the selected literature were synthesized and integrated into a critical analysis of the principles considered essential for the long-term success of All-on-4 restorations.

3. RESULTS

The analysis of the seven publications included in the present review demonstrated that current research on implant-supported full-arch fixed restorations is primarily focused on the biomechanical optimization of the All-on-4 concept, the integration of digital technologies, and the improvement of restoration longevity through the control of biological and mechanical factors. Although each study addressed a specific aspect of treatment, their findings converge on the notion that successful outcomes depend on an interdisciplinary approach in which prosthetic planning, implant surgery, and digital technology are integrated into a comprehensive therapeutic protocol.

3.1. Analysis of the Study by Martins et al.

Martins and colleagues described a fully digital workflow for the rehabilitation of completely edentulous patients using the All-on-4 concept [1]. The authors demonstrated that the combined use of cone-beam computed tomography (CBCT), intraoral scanning, and CAD/CAM technology enables the fabrication of restorations with enhanced precision while reducing the number of clinical and laboratory procedures.

One of the main advantages identified was the ability to accurately transfer virtual planning into the clinical phase. Furthermore, the digital workflow allows virtual assessment of the available prosthetic space and facilitates the fabrication of frameworks with superior fit and adaptation.

The authors concluded that the complete integration of digital technologies can contribute to reduced treatment time, improved communication between clinician

and dental technician, and increased predictability of definitive restorations.

3.2. Rehabilitation of the Edentulous Maxilla Using the All-on-4 Concept

The article published in the *International Dental Journal* evaluated the applicability of the All-on-4 concept for the rehabilitation of the completely edentulous maxilla [2].

The authors highlighted that the maxilla presents anatomical challenges that often limit the placement of implants in conventional posterior positions. Maxillary sinus pneumatization and post-extraction bone resorption reduce the available bone volume and frequently necessitate reconstructive procedures.

By using tilted posterior implants, the All-on-4 concept allows clinicians to avoid the maxillary sinuses while increasing the anteroposterior spread of the restoration. This strategy reduces the need for bone augmentation procedures and facilitates immediate loading in appropriately selected cases.

The authors reported high implant and prosthesis survival rates, confirming the predictability of the concept for the treatment of the edentulous maxilla.

3.3. Biomechanical Analysis of All-on-4 Restorations

The study conducted by Alenezi and colleagues [3] employed three-dimensional finite element analysis (FEA) to evaluate the biomechanical behavior of different prosthetic configurations.

The results demonstrated that stress distribution is directly influenced by:

- Distal cantilever length;

- Position of the posterior implants;
- Direction of occlusal forces;
- Anteroposterior spread;
- Type of functional loading.

The authors observed that excessive distal extensions resulted in stress concentration around the terminal implants and prosthetic components. This phenomenon may contribute to mechanical complications such as screw loosening, framework fracture, and marginal bone loss.

Based on their findings, the authors recommended minimizing cantilever length and optimizing posterior implant positioning to reduce biomechanical stresses.

3.4. Artificial Intelligence and Personalized Prosthetic Design

Chen and colleagues [4] investigated the potential application of artificial intelligence algorithms for optimizing the design of All-on-4 restorations.

The proposed model utilized machine-learning techniques to identify structural configurations capable of minimizing areas of high stress concentration. Compared with conventional design methods, restorations generated through optimization algorithms demonstrated a more homogeneous distribution of functional loads.

These findings suggest that artificial intelligence may represent an important step forward in the development of digital implant dentistry and personalized prosthetic rehabilitation.

3.5. The Importance of Prosthodontically Driven Planning

The review conducted by Nulty [5] analyzed the influence of prosthetic planning on

implant treatment success.

The author emphasized that implant positioning should be determined according to the final prosthetic restoration rather than solely based on bone availability. The concept of *prosthodontically driven implant placement* facilitates favorable emergence profiles, improved esthetics, and a reduction in long-term complications.

The study concluded that surgical guides and digital planning should be considered the standard of care in contemporary implant dentistry.

3.6. Prosthetic Design and Peri-Implant Health

Janda and Mattheos [6] evaluated the relationship between prosthetic design and peri-implant tissue health.

The authors identified several factors influencing biofilm accumulation and the development of peri-implant inflammation:

- Emergence profile;
- Restoration contour;
- Accessibility for oral hygiene procedures;
- Type of prosthetic components;
- Framework adaptation.

Restorations characterized by excessively convex emergence profiles and areas difficult to clean were associated with an increased risk of peri-implantitis.

3.7. Contemporary Full-Arch Restoration Techniques

Froimovici and colleagues [7] reviewed contemporary techniques used in implant-supported full-arch fixed restorations.

The authors highlighted the advantages of

CAD/CAM-manufactured restorations and proposed modifications to conventional treatment protocols aimed at improving restoration longevity.

Their recommendations included:

- The use of frameworks with optimal passive fit;
- Reduction of distal cantilever extensions;
- Individualization of prosthetic design;

4. DISCUSSIONS

4.1. The Role of Prosthetic Planning in the Success of the All-on-4 Concept

In contemporary implant dentistry, prosthetic planning is considered the central element of treatment, serving as the starting point for all subsequent clinical stages. In the past, implant positioning was determined primarily by the available bone volume, while the prosthetic restoration was adapted afterward to the surgically created conditions. The development of the concept of *prosthodontically driven implant placement* has transformed this paradigm, making the final restoration the primary reference point for treatment planning.

Within the All-on-4 concept, the importance of prosthetic planning is amplified by the limited number of implants used to support a complete arch restoration. Each implant plays a major biomechanical role, and its position directly influences force distribution, prosthesis stability, and peri-implant tissue health. Therefore, implant placement should be determined according to the design of the future restoration, intermaxillary relationships, and individual esthetic requirements.

Recent literature demonstrates that digital planning enables simultaneous evaluation of the available bone volume, implant positioning, and definitive prosthesis design. Specialized software facilitates simulation of the final outcome and identification of potential limitations before surgery. This approach reduces the risk of unfavorable emergence profiles, hygiene difficulties, and excessive biomechanical loading.

Another major advantage of prosthetic planning is the possibility of fabricating surgical guides. These devices allow accurate transfer of the virtual treatment plan to the surgical field and contribute to reducing positioning errors. Furthermore, guided surgery facilitates implant placement in locations that optimize both biomechanical support and accessibility for oral hygiene procedures.

Consequently, prosthetic planning should not be regarded as a secondary stage of treatment but rather as the element that coordinates the entire therapeutic process. The success of All-on-4 restorations is directly dependent on the quality of treatment planning and on the clinician's ability to integrate biological, functional, and esthetic requirements into a coherent treatment strategy.

4.2. Biomechanical Considerations of All-on-4 Prostheses

Biomechanics represents one of the most extensively investigated aspects of implant-supported full-arch restorations. Unlike natural teeth, dental implants lack a periodontal ligament and therefore do not possess its capacity to absorb and distribute occlusal forces. Consequently, functional loads are transmitted almost entirely to the peri-implant bone and prosthetic components.

The All-on-4 concept utilizes only four implants to support an entire dental arch, making force distribution a critical factor. Recent biomechanical studies have demonstrated that stresses generated during mastication are influenced by numerous variables, including implant position, anteroposterior spread, distal cantilever length, restorative material, and occlusal scheme.

The distal cantilever is considered one of the most significant biomechanical factors affecting restoration success. Excessive distal extensions create lever-arm effects that increase stresses on terminal implants and prosthetic screws. These forces may result in component loosening, framework fracture, and marginal bone loss.

Posterior implant angulation is one of the defining characteristics of the All-on-4 concept. Tilting the posterior implants increases the anteroposterior spread while reducing distal cantilever length. This biomechanical strategy promotes a more favorable distribution of functional loads and enhances prosthetic stability.

The framework material also influences the biomechanical behavior of the system. Rigid frameworks distribute forces differently compared with those possessing greater flexibility. Material selection should therefore be based on patient-specific clinical conditions and anticipated functional demands.

The occlusal scheme represents another critical factor. Premature contacts and occlusal interferences may generate localized overload and accelerate the development of complications. For this reason, occlusal equilibration and regular follow-up examinations are essential components of treatment.

4.3. Impact of Digital Workflows on Full-Arch Restorations

Digitalization represents one of the most important transformations in modern implant dentistry. The integration of digital technologies into the planning and fabrication of All-on-4 restorations has profoundly changed both clinical and laboratory procedures.

The digital workflow begins with data acquisition through intraoral scanning and cone-beam computed tomography (CBCT). These data are integrated into a virtual environment that allows simultaneous assessment of bone anatomy and prosthetic requirements. As a result, clinicians can virtually design implant positions and prosthetic contours before surgical intervention.

Compared with conventional methods, digital technologies offer numerous advantages. The accuracy of digital impressions eliminates errors associated with conventional impression materials and enables faithful reproduction of the clinical situation. Furthermore, CAD/CAM systems facilitate the fabrication of frameworks with superior adaptation and reduce the variability associated with traditional laboratory procedures.

A particularly important advantage is the possibility of virtually evaluating framework passivity and available prosthetic space. This contributes to reducing mechanical complications and optimizing restoration design.

The development of artificial intelligence algorithms represents a new stage in the evolution of digital implant dentistry. Structural optimization models allow simulation of force distribution and

identification of prosthetic configurations with superior biomechanical performance. In the future, these technologies may enable complete customization of restorations according to the anatomical and functional characteristics of individual patients.

4.4. Selection of Restorative Materials

The selection of materials for All-on-4 restorations should be based on a balance between biomechanical, esthetic, and economic considerations. Advances in dental materials have led to the development of restorative options capable of providing superior performance compared with traditional solutions.

Polymethyl methacrylate (PMMA) remains widely used for provisional restorations due to its low cost and ease of modification. However, its limited mechanical strength makes it less suitable for long-term definitive restorations.

Hybrid restorations consisting of a titanium framework veneered with acrylic resin remain among the most commonly used clinical solutions. These restorations offer a favorable balance between strength, cost-effectiveness, and repairability. In addition, the metallic framework contributes to uniform force distribution and reduces the risk of fracture.

Monolithic zirconia has gained increasing popularity due to its high mechanical strength and excellent esthetic properties. Zirconia restorations exhibit color stability and wear resistance, making them a preferred option for definitive prostheses. Nevertheless, the increased rigidity of zirconia requires careful framework design to prevent excessive stress concentration.

The selection of restorative materials should

be individualized for each patient and should consider functional demands, esthetic expectations, available prosthetic space, and long-term maintenance requirements.

4.5. Peri-Implant Health and Long-Term Maintenance

The maintenance of peri-implant tissue health is one of the essential prerequisites for the long-term success of All-on-4 restorations. Even when a restoration exhibits favorable biomechanics and accurate adaptation, biofilm accumulation may lead to biological complications.

Peri-implantitis is among the leading causes of late implant failure. Current literature indicates that prosthetic design directly influences the patient's ability to maintain effective oral hygiene. Restorations with excessively convex contours and difficult-to-clean areas promote plaque accumulation and soft tissue inflammation.

The emergence profile should be designed to facilitate access for oral hygiene instruments and to support effective biofilm control. Furthermore, the space between the restoration and the peri-implant mucosa should be individually adjusted to provide both esthetic support and adequate access for cleaning.

Regular professional maintenance is indispensable for monitoring the condition of both the implants and the prosthetic restoration. Periodic examinations enable the early detection of biological and mechanical complications and contribute to extending the functional lifespan of the prosthesis.

Patient education is a fundamental component of treatment success. Patients should receive detailed instructions regarding hygiene procedures specific to fixed full-arch

restorations and should be enrolled in an individualized maintenance program.

5. CONCLUSION

The All-on-4 concept is currently regarded as one of the most extensively documented and predictable implant-prosthetic treatment modalities for the rehabilitation of completely edentulous patients. The analysis of recent literature demonstrates that the long-term success of fixed full-arch restorations depends not only on implant osseointegration but also on the harmonious integration of surgical, prosthetic, biomechanical, and biological principles [1,5].

The reviewed evidence highlights that prosthetically driven treatment planning constitutes the foundation of contemporary implant therapy. Implant positioning in relation to the final restoration allows optimization of function, esthetics, and oral hygiene accessibility, while simultaneously reducing the incidence of mechanical and biological complications [5]. Moreover, the use of surgical guides and digital technologies facilitates the accurate transfer of the treatment plan and enhances the predictability of clinical outcomes [1].

From a biomechanical perspective, controlling distal cantilever length and maximizing the anteroposterior spread are essential factors for achieving favorable distribution of occlusal forces. Finite element analysis studies have demonstrated that excessive distal extensions increase stress concentrations around terminal implants and prosthetic components, thereby predisposing the restoration to mechanical complications [3]. The angulation of posterior implants remains one of the key advantages of the All-on-4 concept, as it reduces lever-arm effects

and improves the biomechanical behavior of the restoration [2,3].

The selection of restorative materials should be individualized according to the patient's functional and esthetic requirements. Hybrid restorations supported by titanium frameworks continue to provide predictable clinical outcomes, whereas monolithic zirconia has emerged as a highly effective option for definitive restorations due to its superior mechanical strength and long-term stability [7]. Nevertheless, the increased rigidity of zirconia necessitates careful framework design to prevent excessive stress concentration and mechanical overload [4,7].

Peri-implant health represents a critical determinant of long-term treatment success. Current evidence emphasizes that prosthetic design must facilitate effective oral hygiene and biofilm control. Unfavorable emergence profiles and excessively convex contours have been associated with an increased risk of peri-implant inflammation and marginal bone loss [6]. Consequently, restoration design should simultaneously address functional, esthetic, and biological objectives.

The integration of complete digital workflows based on cone-beam computed tomography (CBCT), intraoral scanning, and CAD/CAM systems represents one of the most significant developments in modern implant dentistry [1]. These technologies reduce clinical and laboratory errors, improve framework adaptation, and increase the overall efficiency of the therapeutic process.

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