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Bruxism, Occlusal Scheme, and Biomechanics of Full-Arch Implant Restorations

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Abstract

Full-arch implant-supported prosthetic rehabilitation is currently regarded as a cornerstone method for the management of complete edentulism; however, occlusal overload, particularly in patients with bruxism, remains a leading etiological factor of complications. The aim of this article is a systematic review of the current literature assessing the impact of bruxism and variants of occlusal concepts on the biomechanical behavior of total implant-supported prostheses and the development of an algorithm for clinical tactical decisions. The study design includes a structured search and critical synthesis of peer-reviewed sources from PubMed, Scopus, and Web of Science, encompassing systematic reviews, clinical studies, and finite element method (FEM) models. The obtained data indicate a high global prevalence of bruxism (approximately 22%) and demonstrate that parafunctional loads multiply increase the stress–strain state in the bone–implant–prosthesis system, pushing it beyond physiological and material tolerances. At the same time, no convincing evidence was found for the superiority of any universal occlusal scheme. The conclusions confirm the need for a personalized, risk-oriented approach. The proposed clinical algorithm, combining risk stratification with the selection of materials and design parameters of the prosthesis, represents a practical tool for reducing the frequency of biomechanical failures. The presented information will be useful to prosthodontists and implantologists, as well as researchers working in the field of occlusion and dental biomechanics.

Keywords: *Bruxism, Full-Arch on Implants, Occlusal Scheme, Biomechanics, Finite Element Method, Occlusal Overload, Rehabilitation For Edentulism, Risk Factors, Personalized Occlusion, Occlusal Splint.*

INTRODUCTION

Implant-supported full-arch fixed dental prostheses (ISFAFDPs) are currently regarded as the benchmark strategy for rehabilitating patients with complete edentulism. This modality restores esthetics and masticatory efficiency and is associated with marked improvements in patient-reported quality-of-life metrics [1]. However, despite the impressive survival of these systems, the long-term resilience of such complex prosthetic solutions remains vulnerable due to the likelihood of both mechanical and biological complications. The principal pathogenetic driver of failure is occlusal overload — the emergence of excessive forces that exceed the adaptive capacity of the bone–implant–prosthesis functional complex [2, 3].

In this context, bruxism — a parafunctional activity of the masticatory muscles with episodes of involuntary clenching and grinding — is recognized as a significant, modifiable risk factor. This activity can generate forces that multiply exceed physiological masticatory loads, thereby producing a characteristic spectrum of complications: loosening and fracture of retaining screws, implant fractures, veneer chipping, and progressive marginal bone loss around implants [5].

The relevance of the problem is corroborated by contemporary epidemiological estimates: a 2024 systematic review with meta-analysis reports a high global prevalence of bruxism — sleep bruxism (SB) occurs in 21% of the population, and awake bruxism (AB) in 23% [8]. Consequently, at least one in five patients considering implant therapy should a priori be classified as at elevated risk of parafunctional overload. This frequency reframes clinical decision-making: bruxism is no longer a rare aggravating factor but a common comorbidity requiring mandatory screening and consideration at the planning stage. Accordingly, the clinical paradigm should shift from reactive correction of consequences to proactive risk stratification and management as the standard of care.

Despite the recognized clinical significance of bruxism, a substantial gap persists in the current body of literature: there is no consensus regarding the optimal occlusal arrangement for patients with this parafunction undergoing full-arch implant-supported rehabilitation. Summary reviews consistently show that there is no compelling basis to regard any concept—whether bilateral balanced occlusion, canine guidance, or group function—as superior to the alternatives [1]. The de facto recommendations rely predominantly on empirical considerations and represent a transfer of principles developed for natural teeth or complete removable dentures. Such transposition is biomechanically inappropriate, because implants, unlike teeth, lack the periodontal ligament that provides load damping and proprioceptive control of masticatory force [3].

In the present study, the **working hypothesis** is formulated as follows: reducing the frequency of biomechanical complications in patients with bruxism undergoing full-arch implant rehabilitation is achieved not by selecting a universal occlusal scheme, but by implementing a personalized strategy. The latter should be based on a multifactorial assessment of individual risk (bruxism intensity and profile, characteristics of the opposing dentition, material and design features of the prosthesis) and should focus on constructing contacts that minimize non-axial load components and peak stresses in the critical zones of the system.

The aim of the work is to perform a systematic analysis of contemporary literature to establish the influence of bruxism and various occlusal concepts on the biomechanics of the full arch on implants and, based on the synthesis of the results obtained, to propose an algorithm for clinical decision-making.

The scientific novelty lies in a holistic consideration of the problem that integrates up-to-date epidemiological, clinical, and engineering-computational data (including finite element models) with the aim of substantiating a personalized, risk-oriented choice of occlusal design in patients with bruxism who are indicated for full-arch fixed implant-supported prostheses.

MATERIALS AND METHODS

The study relies on a systematic analysis and critical synthesis of peer-reviewed scholarly sources. The chosen strategy is interdisciplinary: to examine the stated problem comprehensively, empirical and theoretical data from clinical dentistry, biomechanics, and materials science are integrated.

The source base was formed through targeted searches in leading international bibliographic platforms — PubMed/MEDLINE, Scopus, and Web of Science. Queries were constructed on the basis of key terms and their combinations: bruxism, occlusal scheme, full-arch implants, biomechanics, finite element analysis. All works were stratified by level of evidence and degree of relevance.

The priority pool consisted of publications that defined the theoretical and analytical foundation: systematic reviews and meta-analyses, original clinical studies, high-quality narrative reviews in leading journals, as well as in silico studies employing the finite element method (FEM) to model biomechanical processes.

The auxiliary pool included dissertations and publications from databases used to account for regional specificity and to contextualize the problem.

Inclusion criteria were as follows: full-text articles; studies devoted to the biomechanics of full-arch implant-supported prostheses, the influence of occlusal schemes, and the phenomenon of bruxism. Exclusion criteria: works addressing exclusively single implants or partial prostheses (except in cases where their findings directly informed general biomechanical principles of full-arch design), as well as press releases, news items, and other materials. Application of the specified selection procedures ensured the high reliability and objectivity of the data presented.

RESULTS AND DISCUSSION

Understanding the magnitude of bruxism provides the baseline parameters for designing adequate clinical protocols. According to a systematic review with meta-analysis, the combined global prevalence of bruxism—both nocturnal and diurnal—reaches 22,22% [8]. By phenotype, based on questionnaire criteria, the frequency of sleep bruxism (SB) is 21,0%, whereas awake bruxism (AB) is 23,3% [8]. In other words, approximately every fourth inhabitant of the planet may display some form of this disorder.

Also critical is the divergence of estimates when different diagnostic approaches are used. When resorting to instrumental verification by polysomnography (PSG), the estimated prevalence of SB rises to 43,4% [8]. Such a pronounced gap indicates likely underdiagnosis when relying solely on history-based information and questionnaires and underscores the need for more objective measurement procedures in routine practice (Fig. 1).

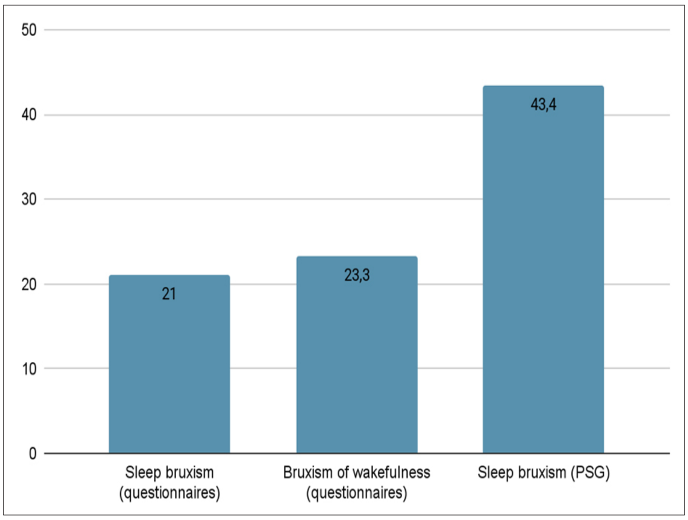

Fig.1. Global prevalence of bruxism according to 2024 data (compiled by the author based on [8]).

When considering the regional context, a substantial methodological gap becomes apparent: for Kyrgyzstan and Central Asia, up-to-date epidemiological data on bruxism have not been accumulated. The available publications predominantly refer to earlier studies, in which the range of prevalence estimates is extremely wide — from 5% to 80% [20]. Such a broad range reflects the absence of uniform diagnostic approaches in the past and renders these estimates unsuitable for contemporary clinical and organizational planning. The lack of reliable local statistics for Bishkek and the country as a whole forces clinicians to extrapolate foreign data to the local population, which potentially ignores the genetic, social, and cultural characteristics of the region.

This information deficit is not merely an accounting gap, but a significant clinical and public health problem. As a result, resource allocation, the design of preventive programs, and the development of clinical guidelines in the region rely more on assumptions than on an evidence base. The current situation poses a direct challenge to regional research institutes and universities: it is necessary to initiate modern epidemiological studies employing standardized international diagnostic criteria.

The choice of occlusal concept is among the most debated issues in the design of full-arch implant-supported prostheses. The literature traditionally distinguishes three key schemes, schematically depicted in Fig. 2.

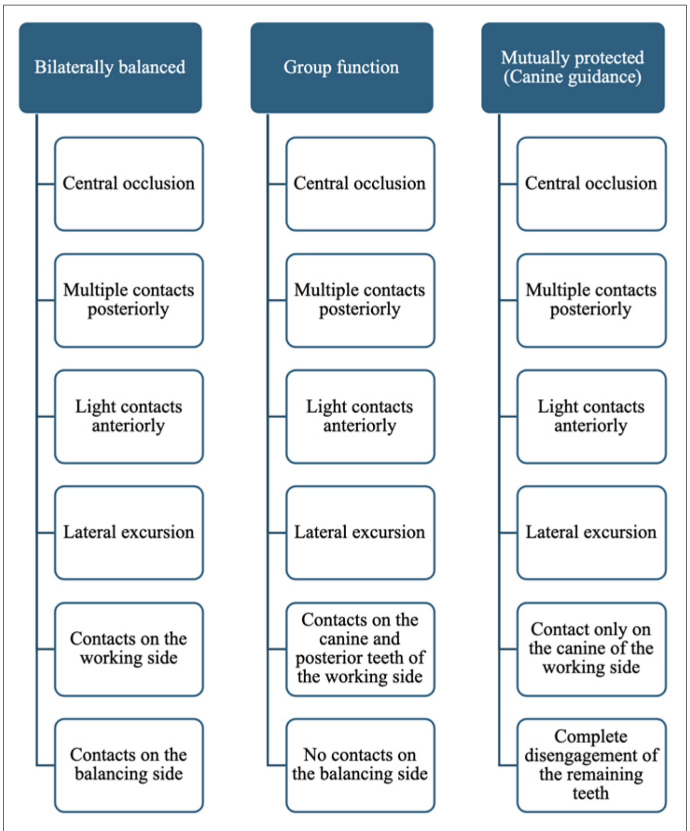

Fig.2. Schematic representation of the distribution of occlusal contacts for various concepts (compiled by the author based on [1, 4, 7, 10, 22]).

Bilaterally balanced occlusion: entails establishing multiple contacts on the working and balancing sides during laterotrusion and protrusion. Originally developed to stabilize complete removable dentures and prevent their tipping, in implantology it is relevant primarily when the antagonist of a fixed implant-supported restoration is a complete removable denture.

Group function: during lateral movements the load is distributed among the canine and several posterior teeth on the working side (premolars, sometimes the first molar), with complete elimination of contacts on the balancing side, which helps minimize non-axial forces.

Mutually protected occlusion: regarded as the most physiologic for the natural dentition. In centric occlusion the primary vertical load is borne by the posterior teeth, protecting the anterior segment from overload; during excursive movements (protrusive and lateral) the anterior teeth, chiefly the canines, guide the trajectory, providing immediate disclusion of the posterior teeth and thereby protecting them from destructive non-axial forces [1, 29].

Despite differences in theoretical paradigms, the aggregate conclusion of recent systematic reviews remains unchanged: at present there is no convincing evidence that any occlusal scheme has an advantage over others with respect to long-term survival of implants or prosthetic constructions [1, 27]. Clinical outcome is determined to a greater extent by careful orthotopic positioning of the occlusal plane, ensuring uniform load distribution in centric occlusion, and complete elimination of occlusal interferences, rather than adherence to a particular doctrine [9, 11].

A key implication follows: the choice of an occlusal scheme is not a pursuit of an abstract ideal but a pragmatic response to the biomechanics of the opposing dentition. The decision is systemic in nature and cannot be based solely on features of the prosthetic design. The aim is to establish the most stable and least traumatic occlusal environment for the entire stomatognathic system. In this context, the properties of the opposing arch (removable or fixed, with preserved or lost proprioception) become decisive. Practice-oriented recommendations derived from aggregated clinical experience suggest the following approach: when the antagonist is a complete removable denture, preference should be given to bilaterally balanced occlusion to enhance its stabilization. When the antagonist comprises natural teeth or fixed restorations (tooth-borne or implant-supported), a mutually protected occlusion or group function is rational [4, 12].

Because conducting in vivo experiments with deliberate overloading of implants is unethical and practically infeasible, the finite element method has become the leading tool for in silico modelling and analysis of stress distribution within the bone–implant–prosthesis system [21]. The use of FEM enables virtual comparison of design variants, materials, and loading regimens, providing clinically relevant information for evidence-based planning.

According to the overwhelming majority of FEM studies, under functional loading the maximum von Mises equivalent stresses are localized in the implant neck region and the adjacent cortical plate [17]. The biomechanical vulnerability of this area is explained by the fact that cortical bone is characterized by poorer vascularization and a lower remodelling potential compared with cancellous bone, and therefore adapts less effectively to peak loads [26, 28].

Simulating bruxism—that is, not only increasing the vertical force (from ≈200 N to 700–1000 N) but also adding non-axial, lateral components—leads to a sharp rise in stress. In particular, Esim E (2022) showed that under such a simulation the stress levels in the cortical bone and in the prosthetic framework exceed the strength limits of the structural materials and the physiological tolerance threshold of bone tissue, which predictably initiates microdamage and increases the risk of fatigue failure [14].

Finite element analysis consistently demonstrates the influence of key design parameters. Increasing the implant diameter reduces stress concentrations in both the cortical bone and the implant itself by redistributing force over a larger support area; this underpins the clinical strategy of selecting the maximum feasible diameter, especially in distal segments that carry the primary masticatory load [13, 14]. The framework material is also important: high-modulus systems (zirconium dioxide, cobalt–chromium alloys) provide high stiffness and efficient intra-framework force distribution but transmit higher peak stresses to the implants and bone; conversely, low-modulus materials (PEEK, composites) act as dampers, reducing peak load on bone tissue at the cost of greater deformations of the framework itself and potentially lower long-term wear resistance [12, 18]. The length of the cantilever is no less important: its increase proportionally augments the bending moment and stress on the distal implant; in patients with bruxism the cantilever should be minimized (no more than 8 mm) or eliminated altogether [4, 23].

Summary quantitative results from various FEA studies (Table 1) clearly translate these principles into measurable values and allow comparison of how material choice and loading mode affect the system's critical components. For the practicing clinician, knowing that bruxism can raise stress in cortical bone from approximately 72 MPa (a conventional norm) to more than 150 MPa (an overload zone) serves as a strong quantitative argument in favor of a more conservative, protective treatment plan.

Table 1. Summary FEM data on maximum stresses (von Mises) in system components(compiled by the author based on[17-19]).

Component	Loading conditions	Prosthesis material	Max. stress (MPa)
Cortical bone	Normal (100–200 N)	Metal-ceramic (MCER)	72.06
Cortical bone	Normal (100–200 N)	PEEK composite (PKCOM)	32.05
Cortical bone	Overload (300 N)	Titanium	≈150
Implant (All-on-4)	Molar loading	-	142.35
Implant (All-on-5)	Molar loading	-	76.50
Abutment	Normal (100–200 N)	Metal-ceramic (MCER)	81.91
Abutment	Normal (100–200 N)	Fiber-reinforced composite (FCOM)	50.80

The absence of a single universal strategy requires a shift to a systemic, risk-oriented framework for clinical decision-making. Integrating provisions of clinical guidelines with biomechanical data makes it possible to construct a holistic model for managing patients with bruxism:

Thorough diagnostics: mandatory screening for signs and symptoms of bruxism (pathologic tooth wear, hypertrophy of the masticatory muscles, chipping of restorations, patient or partner complaints of nocturnal grinding).

Biomechanically verified prosthesis design:

- Minimization of cantilevers: cantilever length should not exceed 8 mm; the ideal goal is its complete elimination.
- Increasing the number of implants: when feasible, 5–6 implants are preferable to 4 for a more uniform distribution of load.
- Use of larger-diameter implants in distal segments.

Establishment of a gentle occlusal scheme:

- Flattening of posterior cusps to reduce lateral components of force.
- Creation of freedom in centric (long centric), a small platform (1–1.5 mm) in centric occlusion that permits anterior shift without immediate disocclusion.

Selection of materials with damping properties: for the occlusal surface, it is advisable to prioritize materials that partially absorb impact energy, such as acrylic denture teeth, composites, or bilayer solutions (for example, a PEEK framework with composite veneering) [24, 25].

Mandatory use of an occlusal splint: a nocturnal protective guard (splint) is an integral component of treatment; it reduces peak parafunctional loads on the prosthesis and implants and redistributes them along the entire arch [1, 6].

The specified principles are consolidated into a single algorithm of clinical decisions. The algorithm transforms a set of recommendations into a logically structured sequence of actions, enabling the clinician to navigate complex clinical scenarios with confidence and to account for numerous interrelated variables.

At the same time, it is necessary to clearly delineate the limits of applicability and the associated risks. Finite element modeling by its nature reduces the complexity of a living system and does not reflect the dynamics of adaptive remodeling of bone tissue under functional load [3, 15, 16]. An additional limitation remains the shortage of long-term prospective clinical observations evaluating the survival of alternative design solutions in patients with instrumentally confirmed bruxism. The most significant threats in treating this cohort remain high and encompass both mechanical failures (cracks and fractures of prosthetic components) and biological complications: progressive bone loss with subsequent development of peri-implantitis and implant loss.

CONCLUSION

The conducted study demonstrates that bruxism is one of the most significant and pervasive modifiable risk factors that undermine the long-term reliability of total implant-supported prostheses. Biomechanical modeling using the finite element method consistently reveals that parafunctional activity initiates the formation of critical stress peaks within the integrated bone–implant–prosthesis system, and the amplitude of these stresses can exceed the strength limits of structural materials and the tolerance of surrounding biological tissues.

A review of current scientific publications did not find convincing evidence in favor of any single occlusal concept suitable as a universal solution for patients with bruxism. This result is consistent with the authors' hypothesis on the need to reject doctrinal schemes in favor of personalized, risk-stratified planning. The presented clinical decision-making algorithm, which combines the grading of bruxism severity with a biomechanically reasoned selection of materials and prosthetic design parameters, serves as a practical embodiment of this paradigm.

The practical value of this work lies in providing dental clinicians with a systematized view of modern evidence-based data and an operationalized tool (algorithm) for planning treatment of complex clinical situations. Mastery of key biomechanical principles and risk determinants makes it possible to design more predictable and durable prosthetic solutions, reducing the likelihood of costly and difficult-to-correct complications.

Further progress in this field requires long-term prospective clinical studies comparing the survival of different occlusal and structural strategies in patients with objectively confirmed bruxism. A promising avenue is the deepening of finite element method modeling with consideration of the temporal characteristics of loads and the patterns of bone remodeling. Finally, conducting modern epidemiological studies in regions with data deficits, including Kyrgyzstan, appears critically important for strengthening the evidence base and improving the quality of dental care at the regional level.

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