

Review

Occlusion in Implant-Supported Fixed Partial Restorations: Biological Basis, Biomechanical Considerations and Clinical Recommendations

Andrea Berzaghi ^{1,*} , Tiziano Testori ^{2,3,4,5} , Riccardo Scaini ^{2,3} and Sergio Bortolini ¹

¹ Department of Surgery, Medicine, Dentistry and Morphological Sciences with Interest in Transplant, Oncology and Regenerative Medicine, University of Modena and Reggio Emilia (UNIMORE), 41125 Modena, Italy; sergio.bortolini@unimore.it

² Section of Implant Dentistry and Oral Rehabilitation, Dental Clinic, IRCCS Galeazzi S. Ambrogio Hospital, 20157 Milan, Italy; tiziano.testori@unimi.it (T.T.); riccardoscaini@icloud.com (R.S.)

³ Department of Biomedical, Surgical and Dental Sciences, University of Milan, 20122 Milan, Italy

⁴ Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, MI 48109, USA

⁵ Department of Oral Medicine, Infection and Immunity, School of Dental Medicine, Harvard University, Boston, MA 02115, USA

* Correspondence: andrea.berzaghi@unimore.it

Abstract

Background/Objectives: The management of occlusion in implant-supported fixed partial restorations (ISFPRs) remains a controversial topic due to the limited availability of high-level clinical evidence and the biomechanical differences between natural teeth and dental implants. The absence of the periodontal ligament and the altered biomechanics of implants have led to the development of specific occlusal concepts. This narrative review provides an up-to-date overview of the biological basis and biomechanical principles underlying occlusal management in ISFPRs, with a particular focus on translating these into clinically applicable recommendations. **Methods:** A narrative review was conducted using an electronic search of PubMed/MEDLINE, covering the period from 1 March 2001, to 1 March 2026. Clinical studies and review articles were included, along with in vitro studies and finite element analyses when relevant to the biomechanical principles of implant occlusion. Additional publications were selectively included to provide biological, biomechanical, historical, and prosthetic context. **Results:** The available literature indicates that the evidence supporting specific occlusal protocols for ISFPRs remains limited and heterogeneous. Contemporary occlusal concepts emphasize the minimization of non-axial loads, the optimization of occlusal morphology, the control of cantilever extension, and the consideration of patient-specific factors, such as bruxism. Monolithic zirconia represents a viable restorative option due to its favorable mechanical properties and reduced technical complications. Long-term maintenance and periodic reevaluation of the occlusion remain essential, as occlusal relationships continue to change throughout a patient's lifetime. **Conclusions:** Although numerous occlusal concepts have been proposed, high-level scientific evidence remains limited. Clinicians should adopt individualized occlusal strategies based on sound biological and biomechanical principles and tailored to each patient's specific functional needs and risk factors. The dynamic nature of occlusion in ISFPRs necessitates periodic reevaluation as an integral part of long-term maintenance. Further well-designed clinical studies are needed to establish evidence-based occlusal protocols specific to ISFPRs.



Academic Editor: João Paulo Mendes Tribst

Received: 18 July 2026

Revised: 19 August 2026

Accepted: 1 September 2026

Published: 4 September 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and

conditions of the [Creative Commons](https://creativecommons.org/licenses/by/4.0/)

[Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

Keywords: dental implants; implant occlusion; occlusal overload; implant-supported fixed partial restorations; biomechanics; monolithic zirconia; prosthodontics; peri-implant bone loss

1. Introduction

Implant-supported fixed partial restorations (ISFPRs) are a common and favorable treatment option for the rehabilitation of partially edentulous patients [1]. Available clinical studies have demonstrated favorable long-term outcomes, with high implant and prosthetic survival rates [2,3].

The occlusal principles established for natural dentition cannot be directly applied to implant-supported prostheses due to the different biophysiological and biomechanical behavior of natural teeth and osseointegrated implants [4,5]. These differences influence both the prosthetic design and the distribution and intensity of occlusal contacts, requiring specific considerations in the management of occlusion in ISFPRs. Furthermore, various factors—including the distribution of occlusal contacts, prosthetic design, the type of opposing dentition, the presence of parafunctional habits, and the occlusal material—can influence biomechanical stability and the onset of biological and prosthetic complications [6–9].

The clinical and biophysiological profile of ISFPRs also differs substantially from that of implant-supported full-arch fixed dental prostheses (ISFAFDPs). In ISFAFDPs, the complete loss of natural teeth in at least one arch results in the loss of periodontal mechanoreceptors, leading to changes in sensory feedback and neuromuscular adaptation [10,11]. In ISFPRs, by contrast, natural teeth and osseointegrated implants coexist within the same occlusal system, despite having different biophysiological and biomechanical characteristics. Furthermore, changes in the position of the residual dentition can lead, over time, to the loss of proximal contacts between implant-supported restorations and adjacent teeth [12]. These changes, together with the dynamic nature of occlusal relationships, present specific challenges in the long-term management and maintenance of ISFPRs [13,14].

These characteristics highlight the need to establish principles and recommendations specifically aimed at managing occlusion in ISFPRs. Therefore, the objective of this narrative review is to provide an up-to-date overview of the biological and biomechanical principles underlying occlusal management in ISFPRs, in order to formulate practical clinical recommendations aimed at supporting clinicians in the design and management of these restorations and promoting a favorable long-term prognosis.

2. Materials and Methods

This article was designed as a narrative review aimed at summarizing and discussing the current evidence regarding occlusion in ISFPRs. An electronic search of PubMed/MEDLINE was conducted on 1 March 2026, with the goal of identifying the literature dedicated to the management of occlusion and occlusal concepts in ISFPRs. The deliberately broad search terms “occlusion” AND “dental” AND “implant” were used to retrieve a broad range of potentially relevant publications, minimizing the risk of overlooking relevant studies by restricting the initial search to specific prosthetic terminology or predefined subtopics. Publications published between 1 March 2001, and 1 March 2026, were included. The 25-year timeframe was chosen to focus the primary search on contemporary evidence and clinical concepts related to occlusion management in ISFPRs.

Titles and abstracts were screened to identify publications concerning the management of occlusion in implant-supported prostheses, with particular attention to occlusal recommendations, occlusal concepts, and their application in ISFPRs. Clinical studies and review articles were considered, along with in vitro studies and finite element analyses (FEA) when they contributed to the understanding of the biomechanical principles underlying implant occlusion. Studies primarily focused on implant-supported full-arch fixed prostheses, case reports, and animal studies were excluded from the primary selection. Only English-language publications were considered. The screening and selection process was conducted jointly by the four authors and was followed by an evaluation of the full text of potentially relevant publications. Final inclusion was determined by consensus among the authors based on direct relevance to the scope of the research. Given the narrative nature of the review and the heterogeneity of the included evidence, no formal assessment of risk of bias or methodological quality was performed.

Additional publications, including earlier studies considered fundamental to the topic, were subsequently incorporated through the analysis of reference lists and targeted literature searches, in order to provide the necessary biological, biomechanical, historical, and prosthetic context. These supplementary publications were used selectively to support the narrative synthesis.

3. Results

The search conducted on PubMed/MEDLINE yielded 2398 publications. After screening the titles and abstracts, 59 publications were considered potentially relevant and underwent full-text evaluation. Of these, 19 were selected as directly relevant to the management of occlusion in ISFPRs.

The management of occlusion in ISFPRs is primarily based on expert opinion, clinical recommendations, and biomechanical principles, with limited support from high-level scientific evidence. In particular, there is a lack of long-term randomized clinical studies specifically aimed at evaluating occlusal strategies in ISFPRs, and an evidence-based consensus regarding specific occlusal schemes or protocols has not yet been established [4,14–21].

Understanding the differences between natural teeth and dental implants, as well as the potential role of occlusal overload, forms the biological and biomechanical basis for managing occlusion in ISFPRs [21–28].

Research utilizing finite element analysis provides useful information on the influence of occlusal contacts and loading conditions on stress distribution in these restorations [29,30].

Occlusal contacts and force distribution can change over time as a result of functional loading, underscoring the need for periodic reevaluation of the occlusion and long-term maintenance of implant restorations [14,31].

Given the limited high-level evidence available on these topics, we therefore present a narrative review of current concepts regarding occlusion in ISFPRs focusing on five clinically relevant themes: biological differences between natural teeth and implants, occlusal overload, principles of occlusal design, prosthetic materials, and clinical recommendations, including long-term maintenance strategies.

3.1. Biophysiological Considerations Concerning Dental Implants

Natural teeth and osseointegrated implants differ substantially in their biomechanical and neurophysiological behavior. Unlike natural teeth, implants are ankylosed to the bone and lack the periodontal ligament (PDL), a specialized structure that provides shock absorption, load distribution, and mechanosensory feedback [21,32]. The PDL

plays a fundamental role in dissipating functional forces and reducing stress concentrations within the supporting bone. Biomechanical studies have shown that occlusal forces applied to natural teeth generate lower stress levels in the surrounding alveolar bone than equivalent loads applied to implants, largely due to the load-dissipating function performed by the PDL [33,34]. The absence of the PDL also affects dental mobility and tactile perception. Natural teeth exhibit physiological mobility of approximately 25–50 µm, whereas implants show a displacement of only 3–5 µm under load [21]. Consequently, an unfavorable distribution of occlusal contacts can expose the ISFPRs to higher stress concentrations. Furthermore, the loss of periodontal mechanoreceptors reduces tactile sensitivity and compromises the neuromuscular feedback mechanisms responsible for controlling masticatory forces [32,35,36]. Natural dentition is capable of detecting interocclusal discrepancies as small as 10–30 µm, allowing for precise modulation of masticatory forces and protection of oral tissues. Following tooth loss, this sensory system is partially lost, potentially reducing the ability to detect and modulate excessive occlusal forces [32,35,36]. Despite these limitations, implant-supported prostheses can develop a compensatory sensory mechanism known as osseoperception [10,37]. This phenomenon refers to the perception of tactile stimuli through mechanoreceptors located in the peri-implant tissues, bone, periosteum, masticatory muscles, and temporomandibular structures [11,38,39]. Osseoperception contributes to the functional integration of implants by partially restoring sensory feedback and improving motor control following rehabilitation. Neurophysiological and histological studies suggest that cortical plasticity, adaptation of peripheral receptors, and peri-implant neural remodeling all contribute to this process [36,39]. The presence of remaining natural teeth appears to facilitate sensory recovery and functional adaptation, whereas full-arch implant-supported prostheses may require more complex neuromuscular integration [40]. Research indicates that immediate implant placement combined with loading protocols could promote peri-implant innervation more effectively compared to delayed approaches [39,41]. Although osseoperception does not fully replicate the sensory capabilities of natural dentition, it provides a certain degree of tactile function that can contribute to functional adaptation to implant-supported prostheses [10]. Electromyographic studies have shown that patients rehabilitated with implants exhibit less coordination and greater asymmetry during mastication and clenching compared to individuals with natural dentition [42–44]. These findings suggest that implant-supported fixed prostheses do not fully replicate the complex neuromuscular integration provided by the natural tooth–periodontal ligament (PDL) complex. However, tactile sensitivity tends to improve progressively after implant placement, particularly during the first few months of healing, suggesting ongoing biological adaptation and cortical reorganization [36,45]. In general, the biological and functional differences between teeth and implants form the foundation of modern concepts of implant occlusion. Understanding the reduced mobility, altered sensory perception, and compensatory mechanisms associated with dental implants provides the biological rationale for prosthetic and occlusal strategies aimed at reducing biomechanical overload (Table 1).

Table 1. Comparison of the Biological and Functional Characteristics of Natural Teeth and Dental Implants.

Biological Parameter	Natural Teeth	Dental Implants	Clinical Implication
Periodontal ligament	Present	Absent	Reduced proprioception and shock absorption
Physiological mobility	25–50 µm	3–5 µm	Higher stress concentrations

Table 1. *Cont.*

Biological Parameter	Natural Teeth	Dental Implants	Clinical Implication
Mechanoreception	Present	Reduced	Lower tactile sensitivity
Load distribution	Adapted through PDL	Direct transmission to bone	Increased biomechanical demands
Adaptive capacity	High	Lower	Reduced tolerance to occlusal discrepancies
Osseoperception	Not required	Present	Partial sensory compensation

3.2. Occlusal Overload on Implants

The link between occlusal overload and implant failure remains controversial, as current evidence is limited and does not establish a definitive cause-and-effect relationship [4,46,47]. Occlusal overload can be defined as the combination of excessive functional or parafunctional forces that exceed the adaptive capacity of the implant-supported restoration, prosthetic components, the implant, or the supporting bone, potentially resulting in biological and/or mechanical damage [15,48]. Compared to natural teeth, implants lack the periodontal ligament and its associated mechanoreceptors, resulting in reduced tactile perception and the ability to adapt to occlusal forces [21]. From a biomechanical perspective, an unfavorable load can increase stress concentrations within the restorative components and the peri-implant bone, particularly at the crestal level, and has therefore been proposed as a potential contributing factor to marginal bone loss and prosthetic or implant-related complications [21,26,49]. Occlusal overload has long been proposed as a potential risk factor for peri-implant bone loss, peri-implantitis, and implant failure [50–52]. However, the existing scientific evidence continues to show inconsistency. Animal studies have yielded conflicting results regarding a direct relationship between excessive load and the deterioration of peri-implant tissues [53]. Current evidence suggests that overload alone may not induce peri-implant pathology in healthy tissues, but may contribute to tissue disease when plaque-induced inflammation is already present [22,24]. Therefore, in the presence of bacterial biofilm, overloading should be considered a potentially interacting risk factor rather than an independent one [54]. Although no clinically relevant threshold for overload has been established [23], biomechanical principles suggest that excessive strain may affect peri-implant bone remodeling. According to Frost's mechanostat theory, strains exceeding approximately 3000 microstrain can induce resorption responses, while values between 1500 and 3000 microstrain can stimulate bone formation [55]. Experimental studies have reported bone resorption above 6700 microstrain, although the clinical applicability of these thresholds remains uncertain [56]. Prosthetic and mechanical failures are reported more frequently than biological complications in implant-supported prostheses [57,58], and occlusal overload has been proposed as a contributing factor to technical and mechanical complications [59], including screw loosening or fracture, framework fracture, chipping of the veneering material, and implant fracture [5,22]. Mechanical complications primarily involve implants, abutments, and frameworks, while technical complications predominantly affect restorative materials [6]. Their onset is multifactorial and may depend on the implant-abutment connection, the prosthetic configuration, the prosthetic material selection, the implant positioning, and the magnitude and direction of occlusal forces [60,61]. Screw loosening and fracture are among the most frequently reported mechanical complications, while chipping of the ceramic veneer remains a common technical complication [62–65]. Biological and prosthetic complications can also interact, with one potentially contributing to the development of the other [6]. Several factors can

increase biomechanical risk, including cantilever extensions, premature contacts, unfavorable occlusal schemes, and parafunctional habits [59,62]. In particular, bruxism has been associated with an increase in implant and prosthetic complications, although the strength of this association varies depending on the outcome considered [8,66,67]. Longitudinal clinical studies have also reported progressive changes in occlusion following functional loading, with increases in occlusal force, contact area, and contact duration, particularly during the first year [31,68–70]. These changes can alter the distribution of forces on implant restorations and on adjacent or opposing teeth [71–73]. Implant fracture is a feared but least common mechanical complication. Repeated loading can generate fatigue cracks that compromise the integrity of the implant [74], and such cracks have been identified in removed implants affected by peri-implantitis, suggesting a possible interaction between biomechanical and biological factors [75]. Implant fracture has been associated with overloading, the presence of extended cantilevers, reduced implant diameter, peri-implant bone loss, and manufacturing defects [61], with reported fracture rates generally ranging from 0.5% to 3% [76,77]. Implant dimensions can also influence biomechanical behavior: an *in vitro* study suggests different strain patterns depending on implant diameter and load direction [78], while implants with a smaller diameter appear to be more susceptible to fracture [61]. The biomechanical strategies proposed to reduce complications related to overload include limiting the cantilever length, increasing the diameter or number of implants when possible, managing parafunctional habits, and optimizing force distribution [62,79]. The type of antagonist can also influence tactile perception: implants opposing natural teeth appear to provide greater tactile sensitivity than implant-to-implant occlusion, likely due to the preservation of input from periodontal mechanoreceptors [38,80]. A recent systematic review similarly reported more favorable tactile perception when implants were opposed to natural teeth [81]. Despite the limited and heterogeneous scientific evidence, the data in the literature support the view that occlusal overload is a multifactorial biomechanical risk factor rather than an independent etiological factor for implant failure. Although a direct causal relationship with peri-implant disease has not been established, excessive forces, unfavorable load distribution, and parafunctional activity may contribute to biological and mechanical complications, particularly in the presence of inflammation or other predisposing factors (Table 2).

Table 2. Clinical and Biomechanical Factors Associated with Increased Risk of Biomechanical Overload in ISFPRs.

Risk Factor	Main Biomechanical Implication
Bruxism and clenching	Increased occlusal loading
Cantilever extension	Increased bending moment
Premature occlusal contacts	Localized overload
Reduced implant diameter	Higher fracture susceptibility
Unfavorable force direction	Increased crestal stress
Poor implant positioning	Non-axial loading
High bite force	Higher prosthetic loading
Implant-to-implant antagonism	Reduced tactile feedback
Inadequate maintenance	Delayed overload detection

3.3. Occlusion for Implant-Supported Fixed Partial Restorations

Concerns regarding occlusal overload have led to extensive discussion of occlusal concepts for implant-supported prostheses. Despite this, there remains a lack of scientific consensus on the best approach to managing occlusion in ISFPRs. Most recommendations are based on expert opinion and empirical guidelines that adapt the principles of natural dentition to the biomechanical characteristics of osseointegrated implants [4,15,16,19,27,82].

The primary goal is to minimize biomechanical overload at the bone-implant interface and on prosthetic components, while promoting long-term stability [6,21,49]. The selection of an appropriate occlusal scheme should take into account the number and position of the implants, the prosthetic extent, the interarch relationships, and the quantity and quality of the bone [15]. During the computer-aided design (CAD) phase, posterior implant restorations can be designed to promote predominantly axial loading and minimize interference during centric and eccentric movements [18,21,49,83]. Although masticatory forces are rarely purely axial, reducing lateral and horizontal loading is a commonly proposed strategy, as non-axial loading can increase stress concentrations in the alveolar crest and prosthetic components [15,63,64,79]. Consequently, a reduction in cusp inclination has been proposed to limit shear forces and occlusal load [15,20], even in patients with periodontal disease [84]. Approximately 1–1.5 mm of freedom in centric relation has also been suggested to allow for physiological mandibular movements and reduce premature contacts [15,20]. Other proposed strategies include reducing the width of the occlusal table, centering contacts within the fossa, and maintaining low cusp inclinations [85]. An *in vivo* study reported a reduction in lateral forces following a 30% reduction in buccolingual occlusal width [86], while narrowing the occlusal table has been recommended as a strategy to decrease non-axial loading, bending moments, and cantilever effects [15]. Cantilever prosthetic solutions can be clinically viable when properly designed [79]. Although several studies have reported comparable marginal bone levels with and without cantilevers [87–90], a cantilever length of ≥ 8 mm has been associated with increased bone loss and a higher risk of peri-implantitis [91]. With regard to occlusal schemes, mutually protected occlusion with anterior or canine guidance has been proposed as biomechanically favorable, although its clinical superiority has not been demonstrated [92]. When canine guidance involves an implant or a compromised canine, distributed group function on the premolars can help reduce lateral load [20–22,49]. It is also commonly recommended to avoid posterior interference during eccentric movements [21]. Splinting may offer biomechanical advantages in situations characterized by high occlusal loads, complex edentulous spaces, or cantilevers [22,49]. Data from the literature suggest that splinted ISFPRs may reduce implant failure and mechanical complications, although they may potentially expose the restoration to a higher incidence of biological complications [93–95]. In contrast, non-splinted restorations may lead to more favorable outcomes for peri-implant tissues [96]. The difference in mobility between natural teeth and implants is another important clinical consideration. Natural teeth can intrude by approximately 25–50 μm under occlusal load, whereas implants exhibit minimal movement [21]. Consequently, lighter contacts with a clearance of approximately 25–50 μm have been proposed for implant-supported prostheses in order to delay contact until a more intense intercuspalation occurs [20,97]. The magnitude, duration, distribution, and direction of occlusal forces remain important determinants of implant biomechanics [15,98] and are influenced by patient- and treatment-related variables, including sex, age, muscle strength, parafunctional habits, implant position, bone quality, and loading protocols [47]. Clinical indicators such as bruxism, clenching, occlusal wear, high bite force, type of antagonist, and cantilever length may indicate an increased biomechanical risk, but none of them, taken individually, is diagnostic of overload [23]. Despite these recommendations, the scientific evidence remains insufficient to establish universally accepted occlusal guidelines for ISFPRs [4]. Until more robust evidence becomes available, the principles derived from natural-tooth-supported prostheses may therefore remain applicable, with due consideration given to implant biomechanics [4]. Regular follow-up is recommended, as occlusal relationships may change over time due to wear of restorative materials, attrition of the enamel of opposing teeth, and functional

adaptation [14,22,69,99,100]. Further high-quality clinical research is needed to establish evidence-based occlusal protocols for ISFPRs [54].

3.4. Prosthetic Materials

The selection of occlusal materials for ISFPRs has evolved considerably over the past few decades. Early implant-supported prostheses commonly used acrylic resin teeth supported by metal frameworks, based on the assumption that materials with a low elastic modulus could absorb occlusal forces and reduce stress transmission at the bone-implant interface [101–103]. This concept of “shock absorption” was a central principle in the early design of implant-supported prostheses [104]. Biomechanical studies have suggested that acrylic resin can reduce impact forces due to its lower elastic modulus [105]; however, both in vivo and experimental findings suggest that the occlusal material or superstructure has a limited influence on force generation and peri-implant strain [106,107]. Furthermore, acrylic resin restorations were associated with wear, fracture, and aesthetic deficiencies [108]. Over time, advances in restorative materials and increasing aesthetic demands have led to a wider use of ceramic alternatives. Metal-ceramic restorations have demonstrated favorable clinical performance, although chipping of the ceramic veneer remains a significant technical complication [109]. It has also been reported that implant-supported fixed dental prostheses have a higher incidence of porcelain fracture or chipping compared to fixed dental prostheses supported by natural teeth [110,111]. Subsequently, ceramic-veneered zirconia frameworks have attracted interest due to the favorable biological, mechanical, and aesthetic properties of zirconia [112–114]. Its mechanical performance is partly related to the transformation toughening mechanism [113,115]. However, early zirconia-based restorations showed a relatively high incidence of chipping of the ceramic veneer compared to metal-ceramic systems [116,117]. The introduction of monolithic zirconia has reduced the need for veneering ceramics, thereby addressing one of the main technical limitations of layered zirconia restorations [109,114]. The most recent developments have focused on improving translucency while maintaining adequate mechanical properties. Third- and fourth-generation zirconia materials with a higher yttrium content offer improved optical properties compared to conventional 3Y-TZP zirconia [118,119], while multilayer systems have been developed to reproduce color and translucency gradients while preserving adequate mechanical properties [112,120]. These advancements have expanded the use of monolithic zirconia in ISFPRs, combining simplified fabrication, favorable aesthetics, and reduced susceptibility to chipping of the veneer ceramic [121,122]. Monolithic designs also allow functional areas to remain unveneered, while aesthetic areas can be selectively characterized or micro-veneered as needed [121]. The clinical data on monolithic zirconia ISFPRs are encouraging, although long-term data remain limited. A systematic review reported cumulative survival rates of 100% for implant-supported monolithic zirconia single crowns and 99.6% for implant-supported fixed partial dentures, with a maximum follow-up of 5 years [123]. Similarly, a systematic review and meta-analysis reported high survival rates and a low incidence of prosthetic complications for implant-supported single crowns and implant-supported fixed partial dentures made of monolithic ceramic [57], while a retrospective study with a follow-up period spanning 5 to 10 years observed positive outcomes for implant-supported, screw-retained, fixed partial dentures constructed from either monolithic zirconia or veneered zirconia [122]. Despite these promising results, the selection of prosthetic materials remains dependent on specific clinical and biomechanical conditions. Metal-ceramic systems remain a well-established option, while modern zirconia materials offer advantages in terms of aesthetics, mechanical properties, and a reduction in complications related to the ceramic veneer [109,121]. Current clinical data support monolithic zirconia as a reliable restorative option for ISFPRs, particularly because

the elimination or reduction of the ceramic veneering can decrease technical complications related to chipping [57,121,122]. However, further long-term clinical studies are needed to establish the performance of the latest generations of multilayer zirconia. The prosthetic material alone may not determine the survival of ISFPRs [1,65]; however, material selection and prosthetic design significantly influence the occurrence of technical complications and should thus be integral to the comprehensive biomechanical management of ISFPRs [57,65,121].

3.5. Biomechanical Considerations and Clinical Recommendations

The favorable long-term prognosis of ISFPRs depends on a thorough understanding of the biomechanical principles involved [28,124]. Although numerous occlusal recommendations have been proposed, the biomechanical behavior of ISFPRs is influenced by multiple interacting variables, including implant position and size, bone quality, prosthetic design, occlusal morphology, load direction and magnitude, and patient-specific characteristics [15,21,34,125,126]. Bite force is an important factor to consider when determining the prosthetic design and selecting appropriate materials. In patients with high bite forces, increasing the number or diameter of implants has been proposed as a possible biomechanical strategy [125]. A recent study analyzing single implant-supported prostheses subjected to multidirectional loading indicated that stress concentrations increase when forces are applied along unfavorable vector directions [127]. Similarly, studies using finite element analysis (FEA) show increased stress when occlusal loads are directed away from the implant's long axis [30,128,129]. Consequently, ISFPRs should be designed, whenever possible, to promote predominantly axial force transmission, since compressive loads are generally better tolerated than lateral or bending forces [29,83,130]. Occlusal morphology also influences the direction and magnitude of forces. Experimental studies and FEA suggest that an increase in cusp inclination may increase bending moments and stress concentrations in the peri-implant bone and prosthetic components [131]. From a biomechanical perspective, a 10° increase in cusp inclination can increase the bending moment by approximately 30% [132]. A moderate reduction in cusp inclination may therefore represent a reasonable biomechanical strategy, particularly in patients with high occlusal loads or parafunctional activity. The distribution and position of the occlusal contacts are also important [30,133–135]. Well-distributed contacts located near the implant axis can contribute to a more favorable stress distribution, while eccentric contacts increase cantilever effects and peri-implant strain. However, biomechanical optimization should not compromise masticatory function. A substantial diminution in the dimensions of the occlusal surface, along with a significant alteration in the anatomy of the cusps, can lead to a decrease in masticatory efficiency [136]. Furthermore, larger occlusal surfaces can improve masticatory efficiency, while an excessively flattened occlusal anatomy can negatively affect muscle activity and masticatory performance [137]. Therefore, modifications to occlusal morphology should be limited to those necessary to reduce unfavorable loads, while preserving functional efficiency. The presence and length of the cantilever are important biomechanical factors in the design of ISFPRs. An increase in cantilever length is associated with higher stress concentrations in the prosthetic components and peri-implant support structures [89,138,139], and FEA studies demonstrate higher stress values around implants adjacent to cantilevers [140]. An ISFPR designed with a central intermediate element can provide a more favorable load distribution compared to configurations with anterior or posterior cantilevers [141]. When cantilevers are unavoidable, it has been suggested to limit their length and to optimize the implant support and prosthetic design to improve stress distribution [90,142,143]. Implant length can also influence peri-implant stress distribution in cantilever prostheses [144]. Data reported in the literature suggest that ISFPRs with

cantilevers do not appear to significantly compromise implant survival or marginal bone levels, although they may be associated with a higher incidence of mechanical complications [145]. A finite element analysis suggests that screw-retained restorations may generate lower peri-implant bone stresses than cement-retained restorations in the presence of a cantilever, regardless of the cantilever's position [146]. The choice of prosthetic materials and the magnitude of the masticatory load can also influence the biomechanical behavior of cantilever restorations. Scientific evidence regarding the ability of zirconia structures—particularly those made of the latest-generation zirconia-based materials—to withstand occlusal forces remains limited, and many design recommendations are still derived primarily from experimental studies and clinical experience [147]. In vitro studies suggest that shorter cantilevers and wider connector cross-sections increase the fracture resistance of zirconia structures [148,149]. The choice between splinted and non-splinted ISFPRs should be tailored to individual clinical and biomechanical conditions. Single implant-supported restorations can facilitate the maintenance of hygiene and the health of peri-implant tissues, while splinting may offer biomechanical advantages in selected situations characterized by high loads, large edentulous spaces, compromised bone support, or the presence of cantilevers [95,150]. Occlusal guidance is another important consideration. In ISFPRs, lateral loads can exceed 200 or 300 N [151]. Whenever possible, lateral guidance should be provided by natural teeth, thereby reducing lateral loading on implant restorations [21,151]. When this is not feasible, group function generally represents a more favorable option than isolated implant-supported canine guidance [18,20,22,49]. Anterior guidance, which ensures the posterior teeth do not make contact during any eccentric mandibular movements, is highly recommended—regardless of whether the anterior region contains natural teeth or implants. This practice is not only functional but also enhances aesthetics. Avoiding guidance contacts on anterior implant restorations can lead to shortened clinical crowns and shallow crown morphology, ultimately compromising aesthetics [151]. Similarly, cross-bite occlusion may provide biomechanical advantages in posterior maxillary rehabilitations affected by severe alveolar resorption by reducing buccal cantilever effects and improving axial loading conditions [21,152]. Cross-bite solutions may also reduce the need for excessively overcontoured restorations, which in turn reduces the risk of biting nearby mucosal tissues and decreases plaque accumulation [152]. Advances in digital technologies have improved the control of occlusal design. Computer-aided design (CAD) systems enable precise management of occlusal contacts and clearance [153,154], while digital occlusal analysis may provide quantitative information regarding contact timing and force distribution, complementing conventional methods [72]. Finally, prosthetic material selection should be considered within the broader biomechanical context. The literature supports monolithic zirconia as a viable restorative option for ISFPRs due to its favorable mechanical properties and relatively low incidence of technical complications [57,99,123]. However, material selection should be individualized based on occlusal loading conditions, prosthetic design, aesthetic requirements, and patient-specific risk factors. In general, biomechanical principles should guide the design of ISFPRs toward minimizing unfavorable stress concentrations, while preserving function, aesthetics, and long-term biological stability. Since occlusal forces are inherently multidirectional and dynamic, the goal should not be the complete elimination of non-axial loads, but rather their controlled management through appropriate prosthetic planning and regular clinical monitoring (Table 3).

Table 3. Clinical Recommendations for Occlusal Management of ISFPRs.

Clinical Domain	Recommendation	Clinical Rationale
Occlusal contact intensity	25–50 μ m clearance in light closure	Delays implant contact until heavier intercuspation
Cusp inclination	Reduce cusp inclination	May limit lateral and shear forces
Occlusal table width	Narrowing in selected cases	May reduce bending moments and cantilever effects
Force direction	Favor axial loading	Promotes load transmission along the implant long axis
Cantilever extension	Limit cantilever extension	May reduce peri-implant stress concentrations
Occlusal scheme	Canine guidance or group function when indicated	Aims to minimize unfavorable lateral loading
Premature contacts	Avoid centric and eccentric interferences	Limits localized stress concentrations
Bruxism	Occlusal splint and regular maintenance	May reduce parafunctional loading and related complications
Splinting	In complex or high-load situations	May improve force distribution
Prosthetic material	Consider monolithic zirconia	May reduce technical complications
Maintenance	Periodic occlusal reassessment	Detects changes in occlusal relationships over time

3.6. Long-Term Maintenance Strategies

Long-term maintenance is an important component of ISFPR therapy. Unlike natural teeth, implants remain ankylosed to the surrounding bone and do not follow the physiological changes in position that occur over time within the dentition. Consequently, changes in the surrounding dentition can progressively alter the occlusal relationships and the distribution of forces around implant prostheses [21,155]. Clinical studies have reported progressive changes in occlusal contacts, contact area, and the magnitude of forces following implant loading, particularly during the first year of function [31,69,70]. Initial occlusal clearances may also decrease or disappear over time as a result of functional adaptation and changes in the surrounding dentition [156–158]. These findings support the need for periodic reevaluation of occlusion in ISFPRs, rather than relying solely on the adjustment made at the time of prosthesis delivery. Occlusal stabilization splints may be considered in selected patients, particularly those with bruxism or other parafunctional habits, as a protective strategy against excessive loads on prosthetic components and the remaining natural dentition [67,159]. However, their use should be individualized based on the patient's functional and biomechanical risk profile. The differences in mobility and positional behavior between natural teeth and implants pose a specific challenge in partially edentulous patients. Natural teeth may continue to erupt, migrate, or change position throughout a person's lifetime, whereas implants remain stationary. This discrepancy can contribute to malocclusion, changes in occlusal relationships, and the loss of proximal contacts between ISFPRs and adjacent teeth [9,13]. Loss of proximal contact is a frequently reported complication, with prevalence rates ranging from approximately 20% to over 30% and a greater tendency to occur at mesial contacts [9,12,77,160]. It can lead to food impaction, plaque accumulation, patient discomfort, and changes in periodontal and peri-implant conditions [12,160]. Since its incidence appears to increase over time, proximal contacts should be evaluated periodically during follow-up, with consideration given to modifying or replacing the prosthesis when clinically necessary. Long-term follow-up should therefore include an assessment of the health of the peri-implant tissues, prosthetic

integrity, occlusal and proximal contacts, wear of prosthetic materials, and changes in the spatial relationships of the surrounding dentition [14]. The intervals between checkups should be individualized based on the patient's biological, biomechanical, and prosthetic risk profile. Patients with parafunctional habits, extensive restorations, a history of peri-implant diseases, or significant occlusal wear may require more frequent monitoring. The management of occlusal complications related to ISFPRs can be addressed through preventive, maintenance, and corrective strategies [22]. Preventive measures include appropriate prosthetic and occlusal design and the selection of prosthetic materials based on expected functional conditions. Contemporary monolithic zirconia materials, or ceramic restorations with veneering limited to areas of aesthetic importance, can reduce technical complications related to veneering compared to extensively layered restorations [57,122,123]. During follow-up, attention should be focused on changes in occlusal relationships, excessively intense localized contacts, signs of parafunctional activity, screw loosening, wear of occlusal materials, and early prosthetic complications [22,161]. When technical complications occur, their management depends on the extent of the problem: minor ceramic chipping can be treated by touch-up and polishing, while more extensive fractures may require repair or replacement of the prosthesis [62]. Digital technologies can provide additional tools for the longitudinal assessment of occlusion. Digital occlusal analysis can provide quantitative information on contact timing, force distribution, and changes that occur over time, potentially complementing conventional clinical methods during maintenance [31,72]. In summary, the long-term management of ISFPRs should take into account the dynamic nature of dentition and occlusion. Periodic evaluation of occlusal and proximal contacts, prosthetic integrity, peri-implant tissues, and patient-specific risk factors can facilitate the early identification and management of biomechanical and prosthetic complications. Maintenance should therefore be considered an integral part of treatment with ISFPRs, rather than a separate phase following treatment (Table 4).

Table 4. Key Principles for the Clinical Management of Occlusion in ISFPRs.

Key Aspect	Clinical Take-Home Message
Biological basis	Implants lack the periodontal ligament, resulting in reduced mobility and tactile perception compared with natural teeth.
Occlusal overload	Should be considered a multifactorial biomechanical risk factor rather than an independent cause of implant failure.
Occlusal design	Should favor predominantly axial loading and minimize unfavorable lateral forces and interferences.
Risk assessment	Patient-specific factors, including bruxism, bite force, implant position, antagonist type, and cantilever extension, should be considered.
Restorative material	Monolithic zirconia is a viable option due to its favorable mechanical and aesthetic properties and a low incidence of technical complications.
Maintenance	Periodic reassessment is advisable because occlusal relationships and force distribution may change over time.
Clinical approach	Occlusal management should be individualized according to biomechanical principles, prosthetic design, and patient-specific risk factors.

4. Conclusions

Understanding the differences between natural teeth and dental implants, as well as the potential role of occlusal overload, provides the rationale for managing occlusion in ISFPRs. However, the absence of robust scientific evidence hinders the formulation of evidence-based guidelines for occlusion. Consequently, current recommendations for managing occlusion in ISFPRs predominantly depend on expert opinion and biomechanical principles. Occlusal overload should be considered a potential biomechanical risk factor

within a multifactorial framework, which may contribute to the development of biological and prosthetic complications in association with other predisposing conditions. Occlusal management should be individualized based on the patient's characteristics, prosthetic design, functional needs, and biomechanical risk factors, avoiding the a priori application of universal protocols. The choice of prosthetic material should also be integrated into this comprehensive assessment. Among the materials currently available, monolithic zirconia appears to be a viable option for ISFPRs due to its favorable mechanical and aesthetic properties and a low incidence of technical complications, although further long-term data are needed for the most recent generations of zirconia-based materials. The coexistence of natural teeth and implants makes the occlusion in ISFPRs inherently dynamic, as changes in the position of the residual dentition, wear of prosthetic materials, and functional adaptation can alter occlusal and proximal relationships over time. Periodic reevaluation should therefore be considered an integral part of the long-term maintenance of ISFPRs. Future well-designed clinical studies are needed to define evidence-based occlusal protocols specifically tailored to ISFPRs.

Author Contributions: Conceptualization, A.B., T.T., R.S. and S.B.; data curation, A.B., T.T., R.S. and S.B.; methodology, A.B., T.T., R.S. and S.B.; project administration, A.B., T.T. and S.B.; resources, A.B. and R.S.; visualization, A.B., T.T. and S.B.; writing—original draft, A.B., T.T., R.S. and S.B.; writing—review and editing, A.B., T.T., R.S. and S.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Chrcanovic, B.R.; Kisch, J.; Larsson, C. Retrospective clinical evaluation of 2- to 6-unit implant-supported fixed partial dentures: Mean follow-up of 9 years. *Clin. Implant Dent. Relat. Res.* **2020**, *22*, 201–212. [[CrossRef](#)] [[PubMed](#)]
2. Tabarak, N.; Srivastava, G.; Padhiary, S.K.; Manisha, J.; Choudhury, G.K. Zirconia-ceramic versus metal-ceramic implant-supported multiunit fixed dental prostheses: A systematic review and meta-analysis. *Dent. Res. J.* **2024**, *21*, 5. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
3. Velasco-Ortega, E.; Del Rocío Jiménez-Martin, I.; Moreno-Muñoz, J.; Núñez-Márquez, E.; Rondón-Romero, J.L.; Cabanillas-Balsera, D.; Jiménez-Guerra, Á.; Ortiz-García, I.; López-López, J.; Monsalve-Guil, L. Long-Term Treatment Outcomes of Implant Prostheses in Partially and Totally Edentulous Patients. *Materials* **2022**, *15*, 4910. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
4. Goldstein, G.; Goodacre, C.; Taylor, T. Occlusal Schemes for Implant Restorations: Best Evidence Consensus Statement. *J. Prosthodont.* **2021**, *30*, 84–90. [[CrossRef](#)] [[PubMed](#)]
5. Rutkowski, J.L.; Iyer, S. Occlusion and Dental Implants—Where Are We? *J. Oral Implantol.* **2023**, *49*, 229–232. [[CrossRef](#)] [[PubMed](#)]
6. Montero, J. A Review of the Major Prosthetic Factors Influencing the Prognosis of Implant Prosthodontics. *J. Clin. Med.* **2021**, *10*, 816. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
7. Sailer, I.; Karasan, D.; Todorovic, A.; Ligoutsikou, M.; Pjetursson, B.E. Prosthetic failures in dental implant therapy. *Periodontol.* **2000** **2022**, *88*, 130–144. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
8. Ionfrida, J.A.; Stiller, H.L.; Kämmerer, P.W.; Walter, C. Dental Implant Failure Risk in Patients with Bruxism—A Systematic Review and Meta-Analysis of the Literature. *Dent. J.* **2024**, *13*, 11. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
9. Bompolaki, D.; Bidra, A.S. Common Failures in Implant Prosthodontics. *Dent. Clin. N. Am.* **2025**, *69*, 299–314. [[CrossRef](#)] [[PubMed](#)]
10. González-Gil, D.; Dib-Zaitum, I.; Flores-Fraile, J.; López-Marcos, J. Importance of Osseoperception and Tactile Sensibility during Masticatory Function in Different Prosthetic Rehabilitations: A Review. *Medicina* **2022**, *58*, 92. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]

11. Trulsson, M. Sensory and motor function of teeth and dental implants: A basis for osseoperception. *Clin. Exp. Pharmacol. Physiol.* **2005**, *32*, 119–122. [[CrossRef](#)] [[PubMed](#)]
12. Saber, A.; Chakar, C.; Mokbel, N.; Nohra, J. Prevalence of Interproximal Contact Loss Between Implant-Supported Fixed Prostheses and Adjacent Teeth and Its impact on Marginal Bone Loss: A Retrospective Study. *Int. J. Oral Maxillofac. Implant.* **2020**, *35*, 625–630. [[CrossRef](#)] [[PubMed](#)]
13. Bergmann, R.H. Occlusal considerations for dental implant restorations. *Compend. Contin. Educ. Dent.* **2014**, *35*, 455–458, quiz 460. [[PubMed](#)]
14. Stilwell, C. Occlusal considerations in maintaining health of implants and their restorations. *Br. Dent. J.* **2024**, *236*, 773–779. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
15. Sheridan, R.A.; Decker, A.M.; Plonka, A.B.; Wang, H.L. The Role of Occlusion in Implant Therapy: A Comprehensive Updated Review. *Implant. Dent.* **2016**, *25*, 829–838. [[CrossRef](#)] [[PubMed](#)]
16. Koyano, K.; Esaki, D. Occlusion on oral implants: Current clinical guidelines. *J. Oral Rehabil.* **2015**, *42*, 153–161. [[CrossRef](#)] [[PubMed](#)]
17. Yuan, J.C.; Sukotjo, C. Occlusion for implant-supported fixed dental prostheses in partially edentulous patients: A literature review and current concepts. *J. Periodontal Implant Sci.* **2013**, *43*, 51–57. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
18. Davies, S.J. Occlusal considerations in implantology: Good occlusal practice in implantology. *Dent. Update* **2010**, *37*, 610–620. [[CrossRef](#)] [[PubMed](#)]
19. Gross, M.D. Occlusion in implant dentistry. A review of the literature of prosthetic determinants and current concepts. *Aust. Dent. J.* **2008**, *53*, S60–S68. [[CrossRef](#)] [[PubMed](#)]
20. Rilo, B.; da Silva, J.L.; Mora, M.J.; Santana, U. Guidelines for occlusion strategy in implant-borne prostheses. A review. *Int. Dent. J.* **2008**, *58*, 139–145. [[CrossRef](#)] [[PubMed](#)]
21. Kim, Y.; Oh, T.J.; Misch, C.E.; Wang, H.L. Occlusal considerations in implant therapy: Clinical guidelines with biomechanical rationale. *Clin. Oral Implant. Res.* **2005**, *16*, 26–35. [[CrossRef](#)] [[PubMed](#)]
22. Lee, S.J.; Alamri, O.; Cao, H.; Wang, Y.; Gallucci, G.O.; Lee, J.D. Occlusion as a predisposing factor for peri-implant disease: A review article. *Clin. Implant Dent. Relat. Res.* **2023**, *25*, 734–742. [[CrossRef](#)] [[PubMed](#)]
23. Di Fiore, A.; Montagner, M.; Sivoilella, S.; Stellini, E.; Yilmaz, B.; Brunello, G. Peri-Implant Bone Loss and Overload: A Systematic Review Focusing on Occlusal Analysis through Digital and Analogic Methods. *J. Clin. Med.* **2022**, *11*, 4812. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
24. Bertolini, M.M.; Del Bel Cury, A.A.; Pizzoloto, L.; Acapa, I.R.H.; Shibli, J.A.; Bordin, D. Does traumatic occlusal forces lead to peri-implant bone loss? A systematic review. *Braz. Oral Res.* **2019**, *33*, e069. [[CrossRef](#)] [[PubMed](#)]
25. Duyck, J.; Vandamme, K. The effect of loading on peri-implant bone: A critical review of the literature. *J. Oral Rehabil.* **2014**, *41*, 783–794. [[CrossRef](#)] [[PubMed](#)]
26. Fu, J.H.; Hsu, Y.T.; Wang, H.L. Identifying occlusal overload and how to deal with it to avoid marginal bone loss around implants. *Eur. J. Oral Implantol.* **2012**, *5*, S91–S103. [[PubMed](#)]
27. Klineberg, I.; Kingston, D.; Murray, G. The bases for using a particular occlusal design in tooth and implant-borne reconstructions and complete dentures. *Clin. Oral Implant. Res.* **2007**, *18*, 151–167, Erratum in *Clin. Oral Implant. Res.* **2008**, *19*, 326–328. [[CrossRef](#)] [[PubMed](#)]
28. Misch, C.E. Consideration of biomechanical stress in treatment with dental implants. *Dent. Today* **2006**, *25*, 80, 82, 84–85, quiz 85. [[PubMed](#)]
29. Acharya, P.H.; Patel, V.V.; Duseja, S.S.; Chauhan, V.R. Comparative evaluation of peri-implant stress distribution in implant protected occlusion and cusally loaded occlusion on a 3 unit implant supported fixed partial denture: A 3D finite element analysis study. *J. Adv. Prosthodont.* **2021**, *13*, 79–88. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
30. Brune, A.; Stiesch, M.; Eisenburger, M.; Greuling, A. The effect of different occlusal contact situations on peri-implant bone stress—A contact finite element analysis of indirect axial loading. *Mater. Sci. Eng. C Mater. Biol. Appl.* **2019**, *99*, 367–373. [[CrossRef](#)] [[PubMed](#)]
31. Assoratgoon, I.; Putra, R.H.; Hihara, H.; Kawata, T.; Chiba, T.; Rungsiyakull, P.; Yoda, N. Occlusal Contact Changes in Implant-Supported Fixed Prostheses: A Systematic Review. *J. Oral Rehabil.* **2025**, *52*, 2185–2194. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
32. Higaki, N.; Goto, T.; Ishida, Y.; Watanabe, M.; Tomotake, Y.; Ichikawa, T. Do sensation differences exist between dental implants and natural teeth?: A meta-analysis. *Clin. Oral Implant. Res.* **2014**, *25*, 1307–1310. [[CrossRef](#)] [[PubMed](#)]
33. Naveh, G.R.; Lev-Tov Chattah, N.; Zaslansky, P.; Shahar, R.; Weiner, S. Tooth-PDL-bone complex: Response to compressive loads encountered during mastication—A review. *Arch. Oral Biol.* **2012**, *57*, 1575–1584. [[CrossRef](#)] [[PubMed](#)]
34. Robinson, D.; Aguilar, L.; Gatti, A.; Abduo, J.; Lee, P.V.S.; Ackland, D. Load response of the natural tooth and dental implant: A comparative biomechanics study. *J. Adv. Prosthodont.* **2019**, *11*, 169–178. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
35. Abarca, M.; Van Steenberghe, D.; Malevez, C.; Jacobs, R. The neurophysiology of osseointegrated oral implants. A clinically underestimated aspect. *J. Oral Rehabil.* **2006**, *33*, 161–169. [[CrossRef](#)] [[PubMed](#)]

36. Mishra, S.K.; Chowdhary, R.; Chrcanovic, B.R.; Brånemark, P.I. Osseoperception in Dental Implants: A Systematic Review. *J. Prosthodont.* **2016**, *25*, 185–195. [[CrossRef](#)] [[PubMed](#)]
37. Jacobs, R.; Van Steenberghe, D. From osseoperception to implant-mediated sensory-motor interactions and related clinical implications. *J. Oral Rehabil.* **2006**, *33*, 282–292. [[CrossRef](#)] [[PubMed](#)]
38. Enkling, N.; Utz, K.H.; Bayer, S.; Stern, R.M. Osseoperception: Active tactile sensibility of osseointegrated dental implants. *Int. J. Oral Maxillofac. Implant.* **2010**, *25*, 1159–1167. [[PubMed](#)]
39. Song, D.; Shujaat, S.; Politis, C.; Orhan, K.; Jacobs, R. Osseoperception following dental implant treatment: A systematic review. *J. Oral Rehabil.* **2022**, *49*, 573–585. [[CrossRef](#)] [[PubMed](#)]
40. Berzaghi, A.; Testori, T.; Scaini, R.; Bortolini, S. Occlusion and Biomechanical Risk Factors in Implant-Supported Full-Arch Fixed Dental Prostheses-Narrative Review. *J. Pers. Med.* **2025**, *15*, 65. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
41. Huang, Y.; van Dessel, J.; Martens, W.; Lambrechts, I.; Zhong, W.J.; Ma, G.W.; Lin, D.; Liang, X.; Jacobs, R. Sensory innervation around immediately vs. delayed loaded implants: A pilot study. *Int. J. Oral Sci.* **2015**, *7*, 49–55. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
42. Gartner, J.L.; Mushimoto, K.; Weber, H.P.; Nishimura, I. Effect of osseointegrated implants on the coordination of masticatory muscles: A pilot study. *J. Prosthet. Dent.* **2000**, *84*, 185–193. [[CrossRef](#)] [[PubMed](#)]
43. Ferrario, V.F.; Tartaglia, G.M.; Maglione, M.; Simion, M.; Sforza, C. Neuromuscular coordination of masticatory muscles in subjects with two types of implant-supported prostheses. *Clin. Oral Implant. Res.* **2004**, *15*, 219–225. [[CrossRef](#)] [[PubMed](#)]
44. Tartaglia, G.M.; Testori, T.; Pallavera, A.; Marelli, B.; Sforza, C. Electromyographic analysis of masticatory and neck muscles in subjects with natural dentition, teeth-supported and implant-supported prostheses. *Clin. Oral Implant. Res.* **2008**, *19*, 1081–1088. [[CrossRef](#)] [[PubMed](#)]
45. El-Sheikh, A.M.; Hobkirk, J.A.; Howell, P.G.; Gilthorpe, M.S. Changes in passive tactile sensibility associated with dental implants following their placement. *Int. J. Oral Maxillofac. Implant.* **2003**, *18*, 266–272. [[PubMed](#)]
46. Naert, I.; Duyck, J.; Vandamme, K. Occlusal overload and bone/implant loss. *Clin. Oral Implant. Res.* **2012**, *23*, 95–107. [[CrossRef](#)] [[PubMed](#)]
47. Chang, M.; Chronopoulos, V.; Mattheos, N. Impact of excessive occlusal load on successfully-osseointegrated dental implants: A literature review. *J. Investig. Clin. Dent.* **2013**, *4*, 142–150. [[CrossRef](#)] [[PubMed](#)]
48. Laney, W.R. Glossary of Oral and Maxillofacial Implants. *Int. J. Oral Maxillofac. Implant.* **2017**, *32*, G1–G200. [[CrossRef](#)] [[PubMed](#)]
49. Hsu, Y.T.; Fu, J.H.; Al-Hezaimi, K.; Wang, H.L. Biomechanical implant treatment complications: A systematic review of clinical studies of implants with at least 1 year of functional loading. *Int. J. Oral Maxillofac. Implant.* **2012**, *27*, 894–904. [[PubMed](#)]
50. Canullo, L.; Tallarico, M.; Radovanovic, S.; Delibasic, B.; Covani, U.; Rakic, M. Distinguishing predictive profiles for patient-based risk assessment and diagnostics of plaque induced, surgically and prosthetically triggered peri-implantitis. *Clin. Oral Implant. Res.* **2016**, *27*, 1243–1250. [[CrossRef](#)] [[PubMed](#)]
51. Dalago, H.R.; Schuldt Filho, G.; Rodrigues, M.A.; Renvert, S.; Bianchini, M.A. Risk indicators for Peri-implantitis. A cross-sectional study with 916 implants. *Clin. Oral Implant. Res.* **2017**, *28*, 144–150. [[CrossRef](#)] [[PubMed](#)]
52. Delgado-Ruiz, R.A.; Calvo-Guirado, J.L.; Romanos, G.E. Effects of occlusal forces on the peri-implant-bone interface stability. *Periodontol.* **2000** **2019**, *81*, 179–193. [[CrossRef](#)] [[PubMed](#)]
53. Chambrone, L.; Chambrone, L.A.; Lima, L.A. Effects of occlusal overload on peri-implant tissue health: A systematic review of animal-model studies. *J. Periodontol.* **2010**, *81*, 1367–1378. [[CrossRef](#)] [[PubMed](#)]
54. Mojaver, S.; Patel, N.; Sarmiento, H.; Fiorellini, J.P. Under pressure: Unraveling the impact of occlusal overload on peri-implant health-A systematic review. *J. Prosthodont.* **2025**, *34*, 784–795. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
55. Frost, H.M. A 2003 update of bone physiology and Wolff's Law for clinicians. *Angle Orthod.* **2004**, *74*, 3–15. [[CrossRef](#)] [[PubMed](#)]
56. Melsen, B.; Lang, N.P. Biological reactions of alveolar bone to orthodontic loading of oral implants. *Clin. Oral Implant. Res.* **2001**, *12*, 144–152. [[CrossRef](#)] [[PubMed](#)]
57. Lemos, C.A.A.; Verri, F.R.; de Luna Gomes, J.M.; Santiago Junior, J.F.; Miyashita, E.; Mendonça, G.; Pellizzer, E.P. Survival and prosthetic complications of monolithic ceramic implant-supported single crowns and fixed partial dentures: A systematic review with meta-analysis. *J. Prosthet. Dent.* **2024**, *132*, 1237–1249. [[CrossRef](#)] [[PubMed](#)]
58. Pjetursson, B.E.; Thoma, D.; Jung, R.; Zwahlen, M.; Zembic, A. A systematic review of the survival and complication rates of implant-supported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years. *Clin. Oral Implant. Res.* **2012**, *23*, 22–38. [[CrossRef](#)] [[PubMed](#)]
59. Bardis, D.; Agop-Forna, D.; Pelekanos, S.; Chele, N.; Dascălu, C.; Török, R.; Török, B.; Cristea, I.; Bardi, P.M.; Forna, N. Assessment of Various Risk Factors for Biological and Mechanical/Technical Complications in Fixed Implant Prosthetic Therapy: A Retrospective Study. *Diagnostics* **2023**, *13*, 2341. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
60. Kourtis, S.; Damanaki, M.; Kaitatzidou, S.; Kaitatzidou, A.; Roussou, V. Loosening of the fixing screw in single implant crowns: Predisposing factors, prevention and treatment options. *J. Esthet. Restor. Dent.* **2017**, *29*, 233–246. [[CrossRef](#)] [[PubMed](#)]

61. Hanif, A.; Qureshi, S.; Sheikh, Z.; Rashid, H. Complications in implant dentistry. *Eur. J. Dent.* **2017**, *11*, 135–140. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
62. De Kok, I.J.; Duqum, I.S.; Katz, L.H.; Cooper, L.F. Management of Implant/Prosthodontic Complications. *Dent. Clin. N. Am.* **2019**, *63*, 217–231. [[CrossRef](#)] [[PubMed](#)]
63. Verma, A.; Singh, S.V.; Arya, D.; Shivakumar, S.; Chand, P. Mechanical failures of dental implants and supported prostheses: A systematic review. *J. Oral Biol. Craniofac. Res.* **2023**, *13*, 306–314. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
64. da Silva Bezerra, A.; Ribeiro, A.K.C.; Verissimo, A.H.; de Almeida, E.O. Prosthetic complications and failures of implant-supported fixed partial dentures: A scoping review. *J. Prosthet. Dent.* **2025**, *134*, 643–650. [[CrossRef](#)] [[PubMed](#)]
65. Pjetursson, B.E.; Sailer, I.; Merino-Higuera, E.; Spies, B.C.; Burkhardt, F.; Karasan, D. Systematic review evaluating the influence of the prosthetic material and prosthetic design on the clinical outcomes of implant-supported multi-unit fixed dental prosthesis in the posterior area. *Clin. Oral Implant. Res.* **2023**, *34*, 86–103. [[CrossRef](#)] [[PubMed](#)]
66. Chrcanovic, B.R.; Kisch, J.; Albrektsson, T.; Wennerberg, A. Factors influencing the fracture of dental implants. *Clin. Implant Dent. Relat. Res.* **2018**, *20*, 58–67. [[CrossRef](#)] [[PubMed](#)]
67. Häggman-Henrikson, B.; Ali, D.; Aljamal, M.; Chrcanovic, B.R. Bruxism and dental implants: A systematic review and meta-analysis. *J. Oral Rehabil.* **2024**, *51*, 202–217. [[CrossRef](#)] [[PubMed](#)]
68. Goto, T.; Nishinaka, H.; Kashiwabara, T.; Nagao, K.; Ichikawa, T. Main occluding area in partially edentulous patients: Changes before and after implant treatment. *J. Oral Rehabil.* **2012**, *39*, 677–683. [[CrossRef](#)] [[PubMed](#)]
69. Luo, Q.; Ding, Q.; Zhang, L.; Xie, Q. Analyzing the occlusion variation of single posterior implant-supported fixed prostheses by using the T-scan system: A prospective 3-year follow-up study. *J. Prosthet. Dent.* **2020**, *123*, 79–84. [[CrossRef](#)] [[PubMed](#)]
70. Bento, V.A.A.; Rosa, C.D.D.R.D.; Lopes, L.F.T.P.; Lemos, C.A.A.; Miyashita, E.; Pellizzer, E.P. Digital analysis of occlusion variations in single posterior implant-supported fixed prostheses: A systematic review and meta-analysis of clinical trial studies. *J. Adv. Prosthodont.* **2025**, *17*, 247–258. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
71. Roque, M.A.; Gallucci, G.O.; Lee, S.J. Occlusal Pressure Redistribution with Single Implant Restorations. *J. Prosthodont.* **2017**, *26*, 275–279. [[CrossRef](#)] [[PubMed](#)]
72. Gözen, M.; Güntekin, N. Comparison of occlusal force distribution and digital occlusal analysis methods of single posterior implant restorations: An in vivo study. *BMC Oral Health* **2025**, *25*, 795. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
73. Leandro, L.N.R.; Barra Grande, M.F.; Pelegri, A.A.; Nishioka, R.S.; Teixeira, M.L.; Basting, R.T. Stress distribution on implant-supported zirconia crown of maxillary first molar: Effect of oblique load on natural and antagonist tooth. *Comput. Methods Biomech. BioMed Eng.* **2024**, *27*, 599–608. [[CrossRef](#)] [[PubMed](#)]
74. Bonfante, E.A.; Jimbo, R.; Witek, L.; Tovar, N.; Neiva, R.; Torroni, A.; Coelho, P.G. Biomaterial and biomechanical considerations to prevent risks in implant therapy. *Periodontol. 2000* **2019**, *81*, 139–151. [[CrossRef](#)] [[PubMed](#)]
75. Shemtov-Yona, K.; Rittel, D. On the mechanical integrity of retrieved dental implants. *J. Mech. Behav. BioMed Mater.* **2015**, *49*, 290–299. [[CrossRef](#)] [[PubMed](#)]
76. Palma-Carrió, C.; Macconi, A.; Rubert-Aparici, A.; Vidal-Peiró, P.; Menéndez-Nieto, I.; Blaya-Tárraga, J.A. Prosthetic Complications of Single Screw-Retained Implant-Supported Metal-Ceramic Fixed Prostheses: A Retrospective Observational Study. *Int. J. Dent.* **2024**, *2024*, 9242928. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
77. Goodacre, B.J.; Goodacre, S.E.; Goodacre, C.J. Prosthetic complications with implant prostheses (2001–2017). *Eur. J. Oral Implantol.* **2018**, *11*, S27–S36. [[PubMed](#)]
78. Kheiralla, L.S.; Younis, J.F. Peri-implant biomechanical responses to standard, short-wide, and mini implants supporting single crowns under axial and off-axial loading (an in vitro study). *J. Oral Implantol.* **2014**, *40*, 42–52. [[CrossRef](#)] [[PubMed](#)]
79. Sadowsky, S.J. Occlusal overload with dental implants: A review. *Int. J. Implant Dent.* **2019**, *5*, 29. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
80. Svensson, K.G.; Trulsson, M. Impaired force control during food holding and biting in subjects with tooth- or implant-supported fixed prostheses. *J. Clin. Periodontol.* **2011**, *38*, 1137–1146. [[CrossRef](#)] [[PubMed](#)]
81. Singh, A.; Pokarram, S.S.; Podder, S. Comparative analysis of active tactile sensibility in single dental implant and natural teeth: A systematic review of clinical studies. *J. Prosthet. Dent.* **2026**, *135*, e34–e43. [[CrossRef](#)] [[PubMed](#)]
82. Carlsson, G.E. Dental occlusion: Modern concepts and their application in implant prosthodontics. *Odontology* **2009**, *97*, 8–17. [[CrossRef](#)] [[PubMed](#)]
83. Tribst, J.P.; Rodrigues, V.A.; Dal Piva, A.O.; Borges, A.L.; Nishioka, R.S. The importance of correct implants positioning and masticatory load direction on a fixed prosthesis. *J. Clin. Exp. Dent.* **2018**, *10*, e81–e87. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
84. Pei, R.; Xiao, C.; Chen, J.; Liu, H.; Chen, J.; Ge, H.; Cai, N.; Wu, Y.; Zhou, Y. A retrospective study on the influence of inclination of cusp on implant marginal bone height in patients with periodontal disease. *Acta Odontol. Scand.* **2024**, *83*, 493–499. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
85. Klineberg, I.J.; Trulsson, M.; Murray, G.M. Occlusion on implants—Is there a problem? *J. Oral Rehabil.* **2012**, *39*, 522–537. [[CrossRef](#)] [[PubMed](#)]

86. Morneburg, T.R.; Pröschel, P.A. In vivo forces on implants influenced by occlusal scheme and food consistency. *Int. J. Prosthodont.* **2003**, *16*, 481–486. [[PubMed](#)]
87. Hälgl, G.A.; Schmid, J.; Hämmerle, C.H. Bone level changes at implants supporting crowns or fixed partial dentures with or without cantilevers. *Clin. Oral Implant. Res.* **2008**, *19*, 983–990. [[CrossRef](#)] [[PubMed](#)]
88. Romeo, E.; Storelli, S. Systematic review of the survival rate and the biological, technical, and aesthetic complications of fixed dental prostheses with cantilevers on implants reported in longitudinal studies with a mean of 5 years follow-up. *Clin. Oral Implant. Res.* **2012**, *23*, 39–49. [[CrossRef](#)] [[PubMed](#)]
89. Torrecillas-Martínez, L.; Monje, A.; Lin, G.H.; Suarez, F.; Ortega-Oller, I.; Galindo-Moreno, P.; Wang, H.L. Effect of cantilevers for implant-supported prostheses on marginal bone loss and prosthetic complications: Systematic review and meta-analysis. *Int. J. Oral Maxillofac. Implant.* **2014**, *29*, 1315–1321. [[CrossRef](#)] [[PubMed](#)]
90. Freitas da Silva, E.V.; Dos Santos, D.M.; Sonego, M.V.; de Luna Gomes, J.M.; Pellizzer, E.P.; Goiato, M.C. Does the Presence of a Cantilever Influence the Survival and Success of Partial Implant-Supported Dental Prostheses? Systematic Review and Meta-Analysis. *Int. J. Oral Maxillofac. Implant.* **2018**, *33*, 815–823. [[CrossRef](#)] [[PubMed](#)]
91. Kim, P.; Ivanovski, S.; Latcham, N.; Mattheos, N. The impact of cantilevers on biological and technical success outcomes of implant-supported fixed partial dentures. A retrospective cohort study. *Clin. Oral Implant. Res.* **2014**, *25*, 175–184. [[CrossRef](#)] [[PubMed](#)]
92. Göre, E.; Evlioglu, G. Assessment of the effect of two occlusal concepts for implant-supported fixed prostheses by finite element analysis in patients with bruxism. *J. Oral Implantol.* **2014**, *40*, 68–75. [[CrossRef](#)] [[PubMed](#)]
93. de Souza Batista, V.E.; Verri, F.R.; Lemos, C.A.A.; Cruz, R.S.; Oliveira, H.F.F.; Gomes, J.M.L.; Pellizzer, E.P. Should the restoration of adjacent implants be splinted or nonsplinted? A systematic review and meta-analysis. *J. Prosthet. Dent.* **2019**, *121*, 41–51. [[CrossRef](#)] [[PubMed](#)]
94. Yi, Y.; Heo, S.J.; Koak, J.Y.; Kim, S.K.; Koo, K.T. Splinting or Nonsplinting Adjacent Implants? A Retrospective Study Up to 15 Years: Part II-Success and Survival Rate Analysis. *Int. J. Oral Maxillofac. Implant.* **2023**, *38*, 443–450b. [[CrossRef](#)] [[PubMed](#)]
95. Al-Juboori, M.J.; Al-Attas, M.A.; Minichetti, J.; Akhikar, J. The Use of Splinted Versus Nonsplinted Prosthetic Design in Dental Implants: A Literature Review. *J. Oral Implantol.* **2024**, *50*, 50–64. [[CrossRef](#)] [[PubMed](#)]
96. Lin, G.H.; Lee, E.; Barootchi, S.; Rosen, P.S.; Curtis, D.; Kan, J.; Wang, H.L. The influence of prosthetic designs on peri-implant bone loss: An AO/AAP systematic review and meta-analysis. *J. Periodontol.* **2025**, *96*, 634–651. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
97. Esquivel-Upshaw, J.F.; Mehler, A.; Clark, A.E.; Neal, D.; Anusavice, K.J. Fracture analysis of randomized implant-supported fixed dental prostheses. *J. Dent.* **2014**, *42*, 1335–1342. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
98. Katona, T.R.; Eckert, G.J. The mechanics of dental occlusion and disclusion. *Clin. Biomech.* **2017**, *50*, 84–91. [[CrossRef](#)] [[PubMed](#)]
99. Mörmann, W.H.; Stawarczyk, B.; Ender, A.; Sener, B.; Attin, T.; Mehl, A. Wear characteristics of current aesthetic dental restorative CAD/CAM materials: Two-body wear, gloss retention, roughness and Martens hardness. *J. Mech. Behav. BioMed Mater.* **2013**, *20*, 113–125. [[CrossRef](#)] [[PubMed](#)]
100. Mundhe, K.; Jain, V.; Pruthi, G.; Shah, N. Clinical study to evaluate the wear of natural enamel antagonist to zirconia and metal ceramic crowns. *J. Prosthet. Dent.* **2015**, *114*, 358–363. [[CrossRef](#)] [[PubMed](#)]
101. Skalak, R. Biomechanical considerations in osseointegrated prostheses. *J. Prosthet. Dent.* **1983**, *49*, 843–848. [[CrossRef](#)] [[PubMed](#)]
102. Ciftçi, Y.; Canay, S. The effect of veneering materials on stress distribution in implant-supported fixed prosthetic restorations. *Int. J. Oral Maxillofac. Implant.* **2000**, *15*, 571–582. [[PubMed](#)]
103. Duyck, J.; Van Oosterwyck, H.; Vander Sloten, J.; De Cooman, M.; Puers, R.; Naert, I. Influence of prosthesis material on the loading of implants that support a fixed partial prosthesis: In vivo study. *Clin. Implant Dent. Relat. Res.* **2000**, *2*, 100–109. [[CrossRef](#)] [[PubMed](#)]
104. Menini, M.; Conserva, E.; Tealdo, T.; Bevilacqua, M.; Pera, F.; Signori, A.; Pera, P. Shock absorption capacity of restorative materials for dental implant prostheses: An in vitro study. *Int. J. Prosthodont.* **2013**, *26*, 549–556. [[CrossRef](#)] [[PubMed](#)]
105. Bijjargi, S.; Chowdhary, R. Stress dissipation in the bone through various crown materials of dental implant restoration: A 2-D finite element analysis. *J. Investig. Clin. Dent.* **2013**, *4*, 172–177. [[CrossRef](#)] [[PubMed](#)]
106. Bassit, R.; Lindström, H.; Rangert, B. In vivo registration of force development with ceramic and acrylic resin occlusal materials on implant-supported prostheses. *Int. J. Oral Maxillofac. Implant.* **2002**, *17*, 17–23. [[PubMed](#)]
107. Stegaroiu, R.; Khraisat, A.; Nomura, S.; Miyakawa, O. Influence of superstructure materials on strain around an implant under 2 loading conditions: A technical investigation. *Int. J. Oral Maxillofac. Implant.* **2004**, *19*, 735–742. [[PubMed](#)]
108. Johansson, L.A.; Ekfeldt, A. Implant-supported fixed partial prostheses: A retrospective study. *Int. J. Prosthodont.* **2003**, *16*, 172–176. [[PubMed](#)]
109. Lemos, C.A.A.; Verri, F.R.; Gomes, J.M.L.; de Souza Batista, V.E.; Cruz, R.S.; Oliveira, H.F.F.E.; Pellizzer, E.P. Ceramic versus metal-ceramic implant-supported prostheses: A systematic review and meta-analysis. *J. Prosthet. Dent.* **2019**, *121*, 879–886.e4. [[CrossRef](#)] [[PubMed](#)]

110. Pjetursson, B.E.; Brägger, U.; Lang, N.P.; Zwahlen, M. Comparison of survival and complication rates of tooth-supported fixed dental prostheses (FDPs) and implant-supported FDPs and single crowns (SCs). *Clin. Oral Implant. Res.* **2007**, *18*, 97–113, Erratum in *Clin. Oral Implant. Res.* **2008**, *19*, 326–328. [[CrossRef](#)] [[PubMed](#)]
111. Linkevicius, T.; Vladimirovas, E.; Grybauskas, S.; Puisys, A.; Rutkunas, V. Veneer fracture in implant-supported metal-ceramic restorations. Part I: Overall success rate and impact of occlusal guidance. *Stomatologija* **2008**, *10*, 133–139. [[PubMed](#)]
112. Ban, S. Classification and Properties of Dental Zirconia as Implant Fixtures and Superstructures. *Materials* **2021**, *14*, 4879. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
113. Benalcázar-Jalkh, E.B.; Bergamo, E.T.P.; Campos, T.M.B.; Coelho, P.G.; Sailer, I.; Yamaguchi, S.; Alves, L.M.M.; Witek, L.; Tebcherani, S.M.; Bonfante, E.A. A Narrative Review on Polycrystalline Ceramics for Dental Applications and Proposed Update of a Classification System. *Materials* **2023**, *16*, 7541. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
114. Miura, S.; Fujita, T.; Fujisawa, M. Zirconia in fixed prosthodontics: A review of the literature. *Odontology* **2025**, *113*, 466–487. [[CrossRef](#)] [[PubMed](#)]
115. Cesar, P.F.; Miranda, R.B.P.; Santos, K.F.; Scherrer, S.S.; Zhang, Y. Recent advances in dental zirconia: 15 years of material and processing evolution. *Dent. Mater.* **2024**, *40*, 824–836. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
116. Pjetursson, B.E.; Valente, N.A.; Strasding, M.; Zwahlen, M.; Liu, S.; Sailer, I. A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic single crowns. *Clin. Oral Implant. Res.* **2018**, *29*, 199–214. [[CrossRef](#)] [[PubMed](#)]
117. Sailer, I.; Strasding, M.; Valente, N.A.; Zwahlen, M.; Liu, S.; Pjetursson, B.E. A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic multiple-unit fixed dental prostheses. *Clin. Oral Implant. Res.* **2018**, *29*, 184–198. [[CrossRef](#)] [[PubMed](#)]
118. Arellano Moncayo, A.M.; Peñate, L.; Arregui, M.; Giner-Tarrida, L.; Cedeño, R. State of the Art of Different Zirconia Materials and Their Indications According to Evidence-Based Clinical Performance: A Narrative Review. *Dent. J.* **2023**, *11*, 18. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
119. Huang, B.; Chen, M.; Wang, J.; Zhang, X. Advances in zirconia-based dental materials: Properties, classification, applications, and future prospects. *J. Dent.* **2024**, *147*, 105111. [[CrossRef](#)] [[PubMed](#)]
120. Inokoshi, M.; Liu, H.; Yoshihara, K.; Yamamoto, M.; Tonprasong, W.; Benino, Y.; Minakuchi, S.; Vleugels, J.; Van Meerbeek, B.; Zhang, F. Layer characteristics in strength-gradient multilayered yttria-stabilized zirconia. *Dent. Mater.* **2023**, *39*, 430–441. [[CrossRef](#)] [[PubMed](#)]
121. Strasding, M.; Marchand, L.; Merino, E.; Zarauz, C.; Pitta, J. Material and abutment selection for CAD/CAM implant-supported fixed dental prostheses in partially edentulous patients—A narrative review. *Clin. Oral Implant. Res.* **2024**, *35*, 984–999. [[CrossRef](#)] [[PubMed](#)]
122. Zhang, Y.; Luo, J.; Di, P.; Chen, B.; Li, J.; Yu, Z.; Lin, Y. Screw-retained ceramic-veneered/monolithic zirconia partial implant-supported fixed dental prostheses: A 5 to 10-year retrospective study on survival and complications. *J. Prosthodont.* **2024**, *33*, 221–230. [[CrossRef](#)] [[PubMed](#)]
123. Kim, W.; Li, X.C.; Bidra, A.S. Clinical outcomes of implant-supported monolithic zirconia crowns and fixed partial dentures: A systematic review. *J. Prosthodont.* **2023**, *32*, 102–107. [[CrossRef](#)] [[PubMed](#)]
124. Manea, A.; Bran, S.; Dinu, C.; Rotaru, H.; Barbur, I.; Crisan, B.; Armencea, G.; Onisor, F.; Lazar, M.; Ostas, D.; et al. Principles of biomechanics in oral implantology. *Med. Pharm. Rep.* **2019**, *92*, S14–S19. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
125. Atlas, A.M.; Behrooz, E.; Barzilay, I. Can bite-force measurement play a role in dental treatment planning, clinical trials, and survival outcomes? A literature review and clinical recommendations. *Quintessence Int.* **2022**, *53*, 632–642. [[CrossRef](#)] [[PubMed](#)]
126. Termeie, D.; Klokkevold, P.R.; Caputo, A.A. Effect of Implant Diameter and Ridge Dimension on Stress Distribution in Mandibular First Molar Sites-A Photoelastic Study. *J. Oral Implantol.* **2015**, *41*, e165–73. [[CrossRef](#)] [[PubMed](#)]
127. Tak, S.; Jeong, Y.; Kim, J.E.; Kim, J.H.; Lee, H. A comprehensive study on the mechanical effects of implant-supported prostheses under multi-directional loading and different occlusal contact points. *BMC Oral Health* **2023**, *23*, 338. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
128. Trivedi, S. Finite element analysis: A boon to dentistry. *J. Oral Biol. Craniofac. Res.* **2014**, *4*, 200–203. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
129. Rungsiyakull, P.; Rungsiyakull, C.; Monstaporn, M.; Sae-Lee, D.; Elsaka, S. Effects of bone type and occlusal loading pattern on bone remodeling in implant-supported single crown: A finite element study. *J. Prosthodont.* **2024**, *33*, 288–296. [[CrossRef](#)] [[PubMed](#)]
130. Yang, Y.; Liu, Y.; Yuan, X.; Ren, M.; Chen, X.; Luo, L.; Zheng, L.; Liu, Y. Three-dimensional finite element analysis of stress distribution on short implants with different bone conditions and osseointegration rates. *BMC Oral Health* **2023**, *23*, 220. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
131. Liu, S.; Liu, Y.; Xu, J.; Rong, Q.; Pan, S. Influence of occlusal contact and cusp inclination on the biomechanical character of a maxillary premolar: A finite element analysis. *J. Prosthet. Dent.* **2014**, *112*, 1238–1245. [[CrossRef](#)] [[PubMed](#)]

132. Weinberg, L.A.; Kruger, B. A comparison of implant/prosthesis loading with four clinical variables. *Int. J. Prosthodont.* **1995**, *8*, 421–433. [[PubMed](#)]
133. Eskitascioglu, G.; Usumez, A.; Sevimay, M.; Soykan, E.; Unsal, E. The influence of occlusal loading location on stresses transferred to implant-supported prostheses and supporting bone: A three-dimensional finite element study. *J. Prosthet. Dent.* **2004**, *91*, 144–150. [[CrossRef](#)] [[PubMed](#)]
134. Park, J.M.; Kim, H.J.; Park, E.J.; Kim, M.R.; Kim, S.J. Three dimensional finite element analysis of the stress distribution around the mandibular posterior implant during non-working movement according to the amount of cantilever. *J. Adv. Prosthodont.* **2014**, *6*, 361–371. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
135. Manchikalapudi, G.; Basapogu, S. Finite Element Analysis of effect of cusp inclination and occlusal contacts in PFM and PEEK implant-supported crowns on resultant stresses. *Med. J. Armed Forces India* **2022**, *78*, 80–87. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
136. Laird, M.F.; Vogel, E.R.; Pontzer, H. Chewing efficiency and occlusal functional morphology in modern humans. *J. Hum. Evol.* **2016**, *93*, 1–11. [[CrossRef](#)] [[PubMed](#)]
137. Silva, N.C.S.; Oliveira, P.H.B.; Gama, L.T.; Magno, M.B.; Marañón-Vásquez, G.A.; Maia, L.C.; Rodrigues Garcia, R.C.M. Does occlusal morphology of artificial teeth improve chewing of removable dentures wearers? A systematic review and meta-analysis. *J. Prosthodont.* **2025**, *34*, 120–138. [[CrossRef](#)] [[PubMed](#)]
138. Suedam, V.; Moretti Neto, R.T.; Sousa, E.A.C.; Rubo, J.H. Effect of cantilever length and alloy framework on the stress distribution in peri-implant area of cantilevered implant-supported fixed partial dentures. *J. Appl. Oral Sci.* **2016**, *24*, 114–120. [[CrossRef](#)] [[PubMed](#)]
139. Storelli, S.; Del Fabbro, M.; Scanferla, M.; Palandrani, G.; Romeo, E. Implant supported cantilevered fixed dental rehabilitations in partially edentulous patients: Systematic review of the literature. Part I. *Clin. Oral Implant. Res.* **2018**, *29*, 253–274. [[CrossRef](#)] [[PubMed](#)]
140. Yoda, N.; Liao, Z.; Chen, J.; Sasaki, K.; Swain, M.; Li, Q. Role of implant configurations supporting three-unit fixed partial denture on mandibular bone response: Biological-data-based finite element study. *J. Oral Rehabil.* **2016**, *43*, 692–701. [[CrossRef](#)] [[PubMed](#)]
141. Kobari, H.; Yoda, N.; Chen, J.; Kawata, T.; Sasaki, K. An In Vivo Study on Load Distribution in Different Implant Configurations for Supporting Fixed Partial Dentures. *Int. J. Oral Maxillofac. Implant.* **2016**, *31*, 1049–1057. [[CrossRef](#)] [[PubMed](#)]
142. de Souza Batista, V.E.; Verri, F.R.; Almeida, D.A.; Santiago Junior, J.F.; Lemos, C.A.; Pellizzer, E.P. Finite element analysis of implant-supported prosthesis with pontic and cantilever in the posterior maxilla. *Comput. Methods Biomech. BioMed Eng.* **2017**, *20*, 663–670. [[CrossRef](#)] [[PubMed](#)]
143. Van Nimwegen, W.G.; Raghoobar, G.M.; Tymstra, N.; Vissink, A.; Meijer, H.J.A. How to treat two adjacent missing teeth with dental implants. A systematic review on single implant-supported two-unit cantilever FDP's and results of a 5-year prospective comparative study in the aesthetic zone. *J. Oral Rehabil.* **2017**, *44*, 461–471. [[CrossRef](#)] [[PubMed](#)]
144. Gastaldo, J.F.; Pimentel, A.C.; Gomes, M.H.; Sendyk, W.R.; Laganá, D.C. Stress Analysis on Single Cobalt/Chrome Prosthesis With a 15-mm Cantilever Placed Over 10/13/15-mm-length Implants: A Simulated Photoelastic Model Study. *J. Oral Implantol.* **2015**, *41*, 706–711. [[CrossRef](#)] [[PubMed](#)]
145. Kondo, Y.; Sakai, K.; Minakuchi, H.; Horimai, T.; Kuboki, T. JSOI Clinical Guideline Working Group Collaborators. Implant-supported fixed prostheses with cantilever: A systematic review and meta-analysis. *Int. J. Implant. Dent.* **2024**, *10*, 57. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
146. Alencar, S.M.; Nogueira, L.B.; Leal de Moura, W.; Rubo, J.H.; Saymo de Oliveira Silva, T.; Martins, G.A.; Moura, C.D. FEA of Peri-Implant Stresses in Fixed Partial Denture Prostheses with Cantilevers. *J. Prosthodont.* **2017**, *26*, 150–155. [[CrossRef](#)] [[PubMed](#)]
147. Poggio, C.E.; Ercoli, C.; Rispoli, L.; Maiorana, C.; Esposito, M. Metal-free materials for fixed prosthodontic restorations. *Cochrane Database Syst. Rev.* **2017**, *12*, CD009606. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
148. Chong, K.K.; Palamara, J.; Wong, R.H.; Judge, R.B. Fracture force of cantilevered zirconia frameworks: An in vitro study. *J. Prosthet. Dent.* **2014**, *112*, 849–856. [[CrossRef](#)] [[PubMed](#)]
149. Alshahrani, F.A.; Yilmaz, B.; Seidt, J.D.; McGlumphy, E.A.; Brantley, W.A. A load-to-fracture and strain analysis of monolithic zirconia cantilevered frameworks. *J. Prosthet. Dent.* **2017**, *118*, 752–758. [[CrossRef](#)] [[PubMed](#)]
150. Ravidà, A.; Saleh, M.H.A.; Muriel, M.C.; Maska, B.; Wang, H.L. Biological and Technical Complications of Splinted or Nonsplinted Dental Implants: A Decision Tree for Selection. *Implant. Dent.* **2018**, *27*, 89–94. [[CrossRef](#)] [[PubMed](#)]
151. Lo, J.; Abduo, J.; Palamara, J. Effect of different lateral occlusion schemes on peri-implant strain: A laboratory study. *J. Adv. Prosthodont.* **2017**, *9*, 45–51. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
152. Afrashtehfar, K.I.; Belser, U.C. Prevention and Management of Cheek and/or Tongue Biting Related to Posterior Implant-Supported Fixed Dental Prostheses (ISFDPs). *J. Prosthodont.* **2019**, *28*, 837–839. [[CrossRef](#)] [[PubMed](#)]
153. Shao, L.; Zhao, X.; Li, S.; Pu, T.; Ding, Q.; Zhang, L. Computer-aided design of occlusal contacts and clearance in posterior implant-supported single crowns: A randomized clinical trial. *J. Prosthet. Dent.* **2026**, *136*, 93–100. [[CrossRef](#)] [[PubMed](#)]

154. He, M.; Pu, T.; Ding, Q.; Sun, Y.; Wang, P.; Sun, Y.; Zhang, L. Occlusal contact and clearance of posterior implant-supported single crowns designed by two different methods: A self-controlled study. *BMC Oral Health* **2023**, *23*, 151. [[CrossRef](#)] [[PubMed](#)] [[PubMed Central](#)]
155. Rajbhoj, A.A.; Parchake, P.; Begnoni, G.; Willems, G.; Cadenas de Llano-Pérula, M. Dental changes in humans with untreated normal occlusion throughout lifetime: A systematic scoping review. *Am. J. Orthod. Dentofac. Orthop.* **2021**, *160*, 340–362.e3. [[CrossRef](#)] [[PubMed](#)]
156. Zhang, R.; Hao, X.; Zhang, K. Evaluation of two different occlusal patterns on single posterior implant-supported crowns: A 12-month prospective study of occlusal analysis. *J. Prosthet. Dent.* **2024**, *132*, 1277–1284. [[CrossRef](#)] [[PubMed](#)]
157. Mao, Z.; Bleiel, H.; Beuer, F.; Böse, M.W.H.; Soetebeer, M. Occlusal changes on implant-supported single crowns with one year follow-up after loading: A systematic review and meta-analysis. *J. Dent.* **2024**, *146*, 105000. [[CrossRef](#)] [[PubMed](#)]
158. Li, B.; Wang, J.; Gao, J.; Tang, X.; Xiang, L.; Qu, Y.; Man, Y. Comparison Between Light- and Non-Light Occlusion on Clinical Outcomes: A Retrospective Study. *Clin. Implant Dent. Relat. Res.* **2026**, *28*, e70110. [[CrossRef](#)] [[PubMed](#)]
159. Lobbezoo, F.; Brouwers, J.E.; Cune, M.S.; Naeije, M. Dental implants in patients with bruxing habits. *J. Oral Rehabil.* **2006**, *33*, 152–159. [[CrossRef](#)] [[PubMed](#)]
160. Liang, C.H.; Nien, C.Y.; Chen, Y.L.; Hsu, K.W. The prevalence and associated factors of proximal contact loss between implant restoration and adjacent tooth after function: A retrospective study. *Clin. Implant Dent. Relat. Res.* **2020**, *22*, 351–358. [[CrossRef](#)] [[PubMed](#)]
161. Ding, Q.; Luo, Q.; Tian, Y.; Zhang, L.; Xie, Q.; Zhou, Y. Occlusal change in posterior implant-supported single crowns and its association with peri-implant bone level: A 5-year prospective study. *Clin. Oral Investig.* **2022**, *26*, 4217–4227. [[CrossRef](#)] [[PubMed](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.