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Mechanical Failures and Complications of Single Implant-Supported Crown Restorations: An Overview

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ABSTRACT

Although dental implant therapy generally demonstrates a high overall success rate, various biological, mechanical, and esthetic factors can occasionally lead to implant failure. Mechanical failures are often the result of excessive or uneven forces on the implant or prosthetic components. These mechanical issues can manifest as screw loosening, fractures of the prosthetic crown or abutment, or even complete implant failure, which typically occur when the implant and its prosthetic components are unable to withstand the masticatory forces generated during normal chewing, biting, and other functional activities. To reduce the risk of these mechanical complications, careful and comprehensive planning is vital from the outset. This includes an in-depth assessment of the patient's oral health, occlusion, and functional demands. The design of the prosthetic framework should be optimized to ensure that it is capable of distributing occlusal forces evenly across the implant structure. The accuracy of implant placement is crucial as well, as deviations in position can result in improper load distribution, leading to mechanical failure. Moreover, selecting the right prosthetic materials plays a critical role in the longevity of the restoration. Materials must not only be durable and resistant to wear, but also compatible with the forces generated by the patient’s masticatory system. Equally important is the consideration of a patient’s individual force factors, which can greatly influence implant success, such as parafunctional habits and bruxism. In such cases, it may be necessary to modify treatment plans, consider splint therapy, or incorporate materials designed to withstand higher forces. These preventive measures, along with a tailored approach to each patient’s unique needs, are key to minimizing complications and enhancing the overall success rate of dental implants.

Keywords: Single implants, Crowns, Mechanical failure, Complications.

1. Introduction

As defined in the Glossary of Prosthodontic Terms, 10th edition, a dental implant is any object or material-such as an alloplastic substance or biological tissue-that is surgically inserted or grafted into the body for therapeutic, diagnostic, prosthetic, or experimental purposes (1). A significant advancement in implant dentistry was made in 1957, when Brånemark discovered that bone could integrate with titanium without eliciting a rejection response from the body (2). Since that discovery, endosseous dental implants have been widely recognized as a successful and predictable treatment modality for the rehabilitation of missing dentition (3).

The initial standardized protocol for oral rehabilitation with contemporary dental implants emphasized the placement of multiple implants in completely edentulous jaws to support full-arch fixed dental prostheses (FDP) (4). As implant technology advanced, its indications expanded to include the replacement of individual missing teeth. Schmitt and Zarb in 1993 were likely among the first to document the clinical outcomes associated with the use of dental implants for the prosthetic rehabilitation of single-tooth loss (5).

The use of implant-supported single crowns has become an established and widely accepted treatment modality for the replacement of individual missing teeth. This approach is especially indicated in clinical scenarios where adjacent teeth are sound and thus do not warrant invasive tooth preparation required for tooth-supported fixed dental prosthesis or when patients are welling to preserve the integrity of their natural dentition (6).

In addition to eliminating the need for tooth preparation, implant-supported single crowns provide several advantages over short-span tooth-supported FDPs. As they do not compromise the integrity of adjacent teeth, the risk of endodontic complications or secondary caries is significantly reduced, thereby enhancing the long-term prognosis of neighboring teeth and lowering the likelihood of abutment tooth loss (6,7). Furthermore, implant-supported restorations facilitate improved access for hygiene, allowing patients to more effectively clean the proximal surfaces of adjacent teeth (6,7). Implant-supported single crowns tend to be related to better economic outcomes, preservation of alveolar bone at the edentulous site, and improved patient psychological well-being when compared to tooth-supported prostheses (8). However, single crowns supported by implants are not impervious to technical complications or failures (9).

Implant failure is generally defined as the inability of an implant to achieve its intended functional or esthetic outcome, with the distinction between "failure" and "complication" often based on the severity and reversibility of the condition (10). Traditionally, the term “complication” has been used in the literature to describe reversible conditions that can be managed or corrected (10). However, other sources have applied the term “failure” to encompass both reversible and irreversible conditions (11,12). Therefore, for the purposes of this review, the terms “complication” and “failure” will be used interchangeably.

According to a systematic review, the failure of dental implants can be attributed to biological factors, particularly inadequacies in maintaining osseointegration, as well as mechanical factors, which include fractures of the fixture, connecting screws, and prostheses (3). Mechanical failures constitute a significant concern in implant dentistry, as they are associated with increased incidences of repair and replacement, resulting in substantial time and financial burdens, and adversely affecting patients' quality of life (13,14). Consequently, the objective of this review is to systematically examine the most prevalent mechanical failures and complications related to single implant-supported restorations, as well as to identify the risk factors contributing to implant fixture fractures.

2. Methods

A comprehensive review of the literature was conducted through an electronic search of the MEDLINE database via PubMed. The search covered studies published between January 1990 and April 2026. The search was performed using a combination of relevant keywords, including “Single”, “Dental”, “Implant”, “Prosthesis”, “Mechanical Failures”, “Complications”, “Screw Loosening”, “Screw Fracture”, “Fixture Fracture”, “Implant Fracture”, “Porcelain Chipping”, “Porcelain Fracture”, “loss of retention” and “Decementation”.

Studies were included if they reported on mechanical complications and/or failures in single implant-supported crowns, were clinical studies (randomized controlled trials, cohort studies, case-control studies, or case series), and published in English

Studies were excluded if they reported primarily on biological complications (e.g., peri-implantitis, mucositis) without mechanical outcomes, were not published in English, focused on multiple implants or full-arch prostheses, were editorials, or expert opinions without primary data and had insufficient or unclear outcome reporting.

Data were systematically extracted from the included studies, focusing on the type, frequency, and causes of mechanical complications.

3. Results and Discussion

For many years, metal-ceramic single implant-retained crowns were considered the gold standard; however, all-ceramic implant crowns have emerged as successful alternatives in contemporary practice (15). The overall 10-year survival rate for implants supporting single crowns has been reported at 95.2%, regardless of the crown material used (16). Nonetheless, at the prosthetic level, the 5-year survival rate is influenced by the choice of restorative material (Table 1) (15,17). The most commonly reported mechanical complications associated with single implant-retained crowns include screw loosening or fracture, loss of retention in cemented restorations, and chipping or fracture of the veneering ceramic.

Table 1: Five-year survival rate of different implant-supported crown materials based on published systemic reviews (15,17,18)

Crown's Material	**5-Year Survival Rate**
Metal-ceramics	98.3%
Veneered alumina	96.8%
Monolithic zirconia	96.8%
Veneered zirconia	91.6%
Monolithic lithium disilicate	91%
Hybrid ceramics	67%

3.1 Loosening or Fracture of Prosthetic or Abutment Screws

A screw joint is defined as a mechanical connection in which two distinct components are secured together by a screw (19). When torque is applied to the screw within the joint, it generates an internal force within the screw known as preload. This preload is the result of the torque applied to the screw, which induces tension along the length of the screw's shank. The tension causes the screw to stretch slightly, and upon release of the applied torque, the screw undergoes elastic recovery (20). This elastic deformation is then transferred to the two interconnected components, causing them to be pulled together and thus generating a clamping force that maintains the integrity of the joint (20). However, if the applied torque exceeds the screw's elastic limit, due to over-tightening or the application of excessive force, the screw may fail by either fracturing or loosening, thereby compromising the stability and functionality of the joint.

Screw loosening or fracture occurs more frequently with prosthetic screws than with abutment screws (13). Additionally, screw-related complications are more prevalent in single-implant restorations compared to those involving multiple units (21). Among single implant-retained crowns, screw loosening is the most common mechanical complication, with a cumulative complication rate of 8.8% over a 5-year period (16).

Among the various mechanical complications, screw loosening is a particularly significant concern for two primary reasons (13). First, it is a relatively common issue in certain implant designs, which may require frequent revisions and screw retightening (22). Second, a loose screw can often result in more severe complications, such as fatigue fracture (23). Although modern implants incorporate anti-rotational systems that considerably mitigate the risk of screw loosening (24). A thorough understanding of the underlying mechanics remains essential for developing more effective and durable designs.

A comprehensive evaluation of the literature reveals that both the design of the crown, whether screw-retained or cemented, and the type of implant-abutment connection (external or internal) play critical roles in influencing the risk of screw loosening. Studies have shown that cemented crowns on implant abutments are less susceptible to screw loosening compared to screw-retained crowns, likely due to the more stable retention achieved through cementation, which provides a more uniform distribution of forces across the restoration (25). In contrast, screw-retained crowns, while offering ease of retrieval for future maintenance, often experience higher incidences of screw loosening. Furthermore, it is recommended to limit the number of retaining screws to one, as multiple screw systems, such as those used in double screw configurations, have been associated with an increased risk of loosening (26). This is primarily due to the added complexity of distributing forces over multiple screws, which may result in uneven loading and higher stress concentrations at individual screw sites, thereby compromising the overall stability of the prosthesis (26).

Additionally, the type of implant-abutment connection significantly affects the risk of screw loosening. Implants with internal implant-abutment connections are favored over external connection systems, as internal connections provide enhanced stability and a better seal between the implant and the abutment. The internal connection reduces the likelihood of screw loosening by creating a mechanical interlock between the components (27). This is achieved through the application of torque, which pushes the abutment taper against the internal wall of the implant, resulting in friction and mechanical locking between the two parts, often referred to as the "Morse Taper" (27). This locking mechanism helps resist rotational forces and minimizes the risk of loosening under functional loading conditions. Given these factors, it is crucial to adhere to the manufacturer's recommended torque values when assembling implant restorations. These values are specifically designed to optimize the mechanical performance of the connection, ensuring that the abutment is securely fixed while minimizing the risk of screw loosening or implant damage (28).

The orientation of the prosthetic implant axis also plays a pivotal role in the stability of the screw joint. Research has demonstrated that angulation-corrected implants are associated with a higher incidence of screw loosening compared to straight implants (29). Consequently, ensuring the precise three-dimensional positioning of the implant is an essential factor in minimizing the risk of screw-related complications in screw-retained implant prostheses (29). To achieve this, the use of a surgical template developed based on a restoratively driven treatment plan is highly recommended. Such a template guarantees the correct placement of the implant in its optimal three-dimensional position. This alignment ensures that occlusal forces are applied directly along the long axis of the screw joint, thereby enhancing its stability and reducing the likelihood of mechanical failure (29).

Occlusion also plays an important role in screw loosening or fracture, depending on the type of prosthesis and the design of the opposing arch (e.g., fixed versus removable, implant versus natural teeth or dentures). The impact of occlusion on screw loosening is less significant when fixed implant prostheses oppose conventional removable dentures (30). Unfortunately, there is limited research confirming the ideal implant occlusal scheme, especially through randomized controlled trials or long-term studies. As a result, most recommendations regarding occlusal schemes and their effects on screw longevity and joint stability are based on longitudinal, empirical, or in vitro studies (31).

Repeated screw loosening may be diagnostic of an underlying occlusal issue, a poorly fitting framework, or parafunctional habit. Therefore, the most effective way to reduce the incidence of screw loosening or fracture is to maximize joint clamping forces while minimizing joint-separating forces (19). This involves managing several contributing factors, including excursive contacts which introduce lateral forces during function, off-axis centric contacts often seen in angled abutments or restorations with wide occlusal tables, increasing the risk of non-axial loading, interproximal and cantilever contacts which can lead to uneven distribution of forces and non-passive frameworks that create internal stresses due to misfit between the prosthesis and the implants (19).

It is widely accepted that achieving a perfectly passive fit is not realistic, as small discrepancies are inherent in both digital scanning and traditional impression techniques. However, regardless of the method employed, the primary aim should be to minimize any misfit to ensure that occlusal forces are directed toward the screw joint rather than the screws themselves (32).

Some researchers have proposed that 2-10% of the applied torque is lost due to the settling phenomenon (33). Since no two mating surfaces are perfectly smooth, even with accurate machining, microscopic high and low points will inevitably exist along the joint surfaces. After the initial torque is applied to the screw, these high points will gradually wear down under the influence of securing and occlusal forces, causing the abutment and implant to move closer together. This leads to a reduction in the preload on the screw and, as a result, a decrease in securing force. If the securing force diminishes below the forces acting on the joint, the screw may loosen, and ongoing functional stress could result in screw fracture (33). To counteract the settling effect and prevent premature screw loosening, it is advised to retighten the screw within 10 minutes after the initial tightening (20).

3.2 Loss of Crown Retention

Implant-supported reconstruction fabrication process requires many clinical and laboratory processes, and decisions that are related to the implant components and materials. The clinician and the technician must decide on the retention technique, such as cement or screws, at some point during the treatment planning phase. Both approaches have benefits and drawbacks, thus the clinician must decide which retention strategy is best for each patient (34).

Several systematic reviews agreed that the second most common failure in single implant supported crowns was the retention loss (35-37). In the literature, several aspects and factors that might affect the retention of single implant supported crowns were discussed. These include; abutment design and material, restorative materials, luting cements, location, bruxism and type of connection.

3.2.1 Abutment Material and Design

In a retrospective study that investigated the failure rates of different abutment materials, Wittneben et al. found that there was no significant difference between the failure rates of screw-retained implant supported crowns (ISCs) on either titanium, gold, or ceramic abutments (38).

Only few studies investigated the technical complications of implant-supported monolithic zirconia crowns on a Ti-base (39-41), while several other authors reported mechanical and technical complications of implant-supported metal-ceramic restorations (38,42-44). The height of the Ti-base and the absence of bonding between the zirconia and the Ti-base were cited as the major causes of these failures.

The height of the Ti-base was thought to be a significant consideration. Whilst one study concluded that the taller Ti-base (4 mm) had a greater retention value than the shorter Ti-base (2.5 mm) (45).

A retrospective study analyzed the loosening of cement-retained fixed implant-supported reconstructions and found that 7.7% of the single crowns on prefabricated abutments loosened, and of those on customized abutments, 0% loosened (46). Which led to the conclusion that the loosening of reconstructions placed on customized abutments can be reduced for single-crown restorations (46). Recently, another study assessed the long-term retention of various abutment types. A significant difference between the 5-year loss-of-retention rates of 12% for standardized abutments compared to 2% for customized abutments (47).

3.2.2 Restorative Materials

One study compared the complication rate for metal ceramic ISCs vs zirconia ISCs and found that metal ceramic ISCs were associated with higher complication rate (20.6%) including 5.9% overall loss of retention (including 0% for screw retained and 8.7% for cement retained), while zirconia ISCs were associated with 0% loss of retention (both screw and cement retained restorations) (48). Another study compared zirconia with gold alloy and found that restorative materials had no significant effects on loss of retention (47).

3.2.3 Luting Cement Materials

Technical and biological issues in cemented ISCs appear to be influenced by the type of cement (38,49). Either permanent or semi-permanent cements are used to attach ISCs. If peri-implantitis needs to be treated or broken ceramic veneers need to be fixed in the dental lab, semipermanent cements have been suggested for implant-supported ISCs to allow access to implant (47).

Sailer et al. found that the incidence of decementation dropped from 7.3% before 2000 to 3.1% after that year (37). The more recent rise in the use of resin cements, which are recommended for cementing all-ceramic crowns to the underlying zirconia/alumina or titanium abutments, could be one explanation for this improvement (37).

Additionally, it was noted that the choice of cement is significantly influenced by the restorative material. Because metal-ceramic crowns already have exceptional material stability, they do not require adhesive cementation to the substrate in order to gain enough strength for clinical use (37). Hence, conventional cements such glass ionomer cement or zinc phosphate are typically used to cement metal-ceramic crowns (37). Compared to metal-based crowns, ceramic crowns have a lower fracture strength, and for increased clinical strength, they must be chemically bonded to the underlying substrate (50). Resin cements provide a chemical bond between the ceramic crowns and the underlying materials, thereby reinforcing the ceramic crowns (50). It has been shown that the 5-year rate for loss of retention of ceramic crowns was only 1.1%, whereas for metal-ceramic crowns the rate for loss of retention was five times higher at 5.5%, as reported in earlier reviews (51).

Several authors have shown in the literature that bond strength and frictional resistance are increased when dual-cure resin cement and surface pretreatment are used (45,52-54). Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) crowns cemented to Ti-base abutments exhibited a greater retention strength when resin cement and self-etching adhesive were used in combination, as opposed to self-etching cement alone (54). Sandblasting the Ti-base surface improved the extraction strength of Y-TZP crowns as compared to no treatment (45). Another study has confirmed that resin-based cements have higher pull-off forces than glass ionomer cement, which in turn have higher pull-off forces than temporary cements (53).

A retrospective study evaluated the long-term retention and survival of 567 cemented implant-supported zirconia and metal-ceramic single crowns (47). Rammelsberg and Klotz found that loss of retention was observed 50 times and was predominantly solved by re-cementation (47). The incidence of retention loss after 10 years was 20% for ISCs fixed with semi-permanent cement and 8% for ISCs cemented with permanent cement (47). Cox regression analysis was used in the same study as a statistical method to evaluate the influence of potential risk factors (such as the luting cement type) on the occurrence of retention loss in implant-supported crowns (47). Loss of retention was not significantly impacted by age, sex, location (maxilla/mandible, anterior/posterior), abutment type, or framework material (zirconia/high noble metal alloy) (47). The kind of cement was the only significant risk factor for retention loss; the risk of retention loss was twice as high for semi-permanent cement as for permanent cement (47). Another study found that the aging protocol showed that temporarily cemented crowns showed a significant retention decrease, while the use of a permanent cement led to a moderate increase (55).

3.2.4 Location (Maxilla vs. Mandible/Anterior vs Posterior)

According to a finite element analysis, the maxilla had mechanical problems more frequently than the mandible (56). The forces are not perpendicular to the implant axis, because maxillary anterior implants are often more labially tilted than mandibular implants, and the maximal incisal occlusal force is directed around 12 degrees toward the frontal plane (56). The implant, abutment, and crown may experience strains as a result of these forces, which could raise the prevalence of mechanical issues, including retention loss (56).

A retrospective study evaluated implant-supported single crown failure rates and the reason for failures according to the crown location in the jaws for a 15-year follow-up period (9). A higher rate of technical problems leading to the loss of the crown occurred in the posterior region of the jaws (100% of the cases) in comparison with the anterior region (32.6% of the cases) (9). Compared to the anterior part of the jaws, the posterior region had a higher rate of crown loss and screw loosening (9). The occlusal biting load in the posterior jaw is usually about three times that of the anterior jaw, which could be an important factor to negatively affect the survival of crowns in the posterior region (57).

3.2.5 Bruxism

In a 5-year clinical retrospective study, Chitumalla et al. assessed complications in dental implants in bruxism patients and found that the most common complication seen in single crown was decementation (n=42) (58). So, it was concluded that bruxism is a parafunctional habit that affects the survival rate of dental implants and certain specific protocols in bruxism patients should be followed to prevent such complications (58).

3.2.6 Type of Connection

Moreno et al. Conducted a laboratory study to evaluate the influence of the type of implant connection on the retention of zirconia crowns cemented onto the Ti-base abutment (59). It was found that the internal connection groups performed better and attributed this finding to the improved stress distribution and stability between the abutment and implant, as well as the reduction of micro spaces at the interface of the internal connection system (59). The tight contact often called “cold welding” between the prosthetic component and the internal connection implant results in greater stability of the assembly explaining the lower percentage of cement failure (59). While the presence of micro gaps in the external connection has been attributed to the increased movement in the abutment/implant assembly, which leads to cementation failure (59).

3.3 Veneering Material Chipping or Fracture

Chipping of the veneering material is the third most common complication, with an occurrence rate of 3.5% over 5 years (16). Studies evaluating the performance of metal-ceramic and all-ceramic implant-supported prostheses with respect to overall survival rates, veneering ceramic chipping, and/or framework fractures have yielded contrasting results (16). Another systematic review found that metal-ceramic crowns significantly outperformed all-ceramic alternatives (57). Interestingly, a later systematic review by the same researcher group in 2012 reported no significant differences between the two materials (16). These results are consistent with those of another systematic review, in which the authors concluded that metal-ceramic and all-ceramic restorations demonstrate comparable clinical outcomes (58). Furthermore, a more recent systematic review could not identify any significant difference, between all-ceramic and metal-ceramic single implant-supported restorations in terms of both mechanical and biological failures (59). For bilayered zirconia restorations, ceramic veneering chipping is the most common technical complication, followed by framework fracture (35). Chipping of these restorations is mostly cohesive in nature and typically occurs near the occlusal zone adjacent to the antagonist's contact point (60).

The incidence of veneering chipping in implant-supported crowns varies greatly among studies. The rates of chipping reported for bilayered zirconia restorations range from 0% to as high as 59.7% after 5 years (64,65). A systematic review reported a 1.65% annual chipping rate for veneered all-ceramic crowns, whereas monolithic restorations showed a lower rate of 0.39%, suggesting a better durability and performance for monolithic restorations (66).

3.3.1 Factors Contributing to Veneering Material Chipping

3.3.1.1 Material Characteristics

The veneering porcelain is an inherently weak material, demonstrating a low flexural strength. In addition, the difference in thermal expansion coefficients between zirconia framework and overlaying porcelain can lead to development of residual stresses and initiation of cracks, and consequently, veneer chipping (67,68).

Hand-veneered zirconia frameworks seem to demonstrate superior resistance to chipping compared to over-pressed techniques (69). For the over-pressed restorations, porcelain chipping was reported at a higher frequency and significantly lower loads. This difference may be attributed to the difference in heat and pressure parameters between the veneering methods, which can result in variation in the porcelain's mechanical characteristics (69).

Thermal gradients that develop during the cooling process of crowns and FDPs can introduce residual stresses within the restoration, increasing the risk of chipping (68). Additionally, factors such as the incorporation of voids or flaws in the microstructure, as well as variations in the furnace firing program can further compromise the integrity of the veneering material and contribute to chipping (67).

3.3.1.2 Occlusal Forces

The occlusion or function also affects the veneering ceramic's long-term integrity (38). Dental implants lack the periodontal ligament and have a tactile sensitivity that is 8.7 times lower than that of natural teeth (70). As a result, the occlusal load on implant-retained crowns is nearly 9 times larger than that of tooth-retained crowns. Higher stress can lead to failure since veneering ceramics have relatively low fracture strength values (71).

Bruxism has been demonstrated to significantly impact not only implant failure (72), implant fractures (73), and marginal bone loss (74), but also to increase the incidence of prosthesis failure and technical complications in implant-supported restorations when compared to patients without bruxism (75,76). This condition is thought to result in excessive loading on prosthetic rehabilitations placed on implants (77), and is also recognized as a risk factor for fractures of ceramic materials (43).

In a retrospective study, two variables-male gender and probable bruxism-were identified as statistically significant risk factors for complications, as determined by the hazard ratio (HR), which quantifies the relative risk of an event occurring over time between different groups (78). However, the distribution of probable bruxism between crowns placed in male patients (37 of 145) and female patients (64 of 213) did not demonstrate statistical significance. The most prevalent complications observed were crown mobility and chipping of the ceramic material. Ceramic chipping occurred more frequently among individuals identified as probable bruxers (20 of 101) compared to non-bruxers (22 of 257), with this difference reaching statistical significance.

Although no significant disparity was noted in the prevalence of bruxism between sexes, the increased risk of crown failure observed in male patients was attributed to their generally greater maximal bite force, which is commonly associated with higher muscle mass and body size (79). Even in the absence of a bruxism diagnosis, the elevated occlusal forces observed in males may predispose them to a higher incidence of technical complications and potential implant failure (78).

3.3.1.3 Design and Thickness

Improper framework design or uneven veneer thickness can lead to weak points susceptible to fracture (80). In most cases, chipping of the veneering ceramic can be addressed chairside through intraoral adjustments using fine-grit diamond burs followed by polishing with silicone rubber polishers without the need for full replacement (80). However, while this method is effective for minor chippings, a more reliable long-term solution is to use monolithic zirconia restorations. By eliminating the veneering layer entirely, monolithic designs significantly reduce the risk of chipping, offering improved clinical behavior compared to veneered restorations (66).

3.3.2 Fracture of Bilayered and Monolithic Restorations

Zirconia framework fracture is considered relatively infrequent. Nevertheless, chipping can still occur in monolithic zirconia restorations. One possible reason for this is low-temperature degradation (LTD), a process in which the stabilized tetragonal phase of zirconia converts into the monoclinic phase under humid conditions. This transformation typically starts at the surface and gradually extends deeper into the material. Masticatory forces can accelerate this phase change by initiating it around surface micro-cracks, thereby increasing the likelihood of chipping (81).

The causes of fracture observed in several studies were related to factors other than the material itself (82). One significant factor is the framework height and design. Both in-vitro and in-vivo investigations showed that core fractures of all-ceramic FDP are influenced by connector dimensions (83). Several studies have reported oblique fracture patterns, with forces directed toward the occlusal surface, running from the midpoint of the connector to the midpoint of the pontic (63). To minimize this risk, a minimum connector cross-section of 9 mm^2 is recommended for 3-unit FDPs (67). Another contributing factor is not adhering to the manufacturer's instructions regarding material handling and design thickness. Studies have shown that more than 50% of framework fractures can be caused by such deviations (35). In addition, occlusal adjustments that lead to the exposure of the zirconia core/framework may induce or accelerate the onset of fracture (84).

The type of opposing dentition can also contribute to the fracture of both bilayered and monolithic restorations. The risk of zirconia core fractures increases when the opposing tooth is restored with ceramic material. This may be attributed to the increased wear resistance of ceramic materials (85). Furthermore, the repetitive chewing forces applied during mastication can cause surface damage over time, ultimately resulting in fatigue failure of the restoration (82).

For monolithic implant-supported zirconia single crowns, the occurrence of complications could be related to the mechanical properties of zirconia and its limited ability to absorb stress. According to the "weak link theory", failure caused by stress occurs most frequently on the most vulnerable components of the system, which can be the bonding interface, the implant supporting the prosthesis, or the antagonistic teeth/implants (86). High occlusal forces could also lead to restoration fracture. One study showed that bruxism is associated with 76.9% of observed complications and 80% of failures (86).

Another potential factor specific to implant-supported FDPs is the type of retention, which can affect the risk of core/framework fracture. Studies have shown that screw-retained crowns are at more risk of fracture than cemented single crowns (36). In implant screw-retained prostheses, fracture can result from several contributing factors. These include an inaccurate fit between the prosthesis component (zirconia ceramic and titanium abutments), insufficient prosthesis dimensions, which may lead to the accumulation of tensile stresses; and the presence of an excessively long cantilever, which increases the mechanical load on the restoration (87). Additionally, screw access holes in screw-retained implant-supported restorations have been reported to compromise the material's resistance to fracture by inducing more stresses which can lead to crack propagation and fracture (88).

3.4 Implant Fracture

One of the rare but most distressing complications is implant body fracture, a mechanical failure that leaves both patient and clinician with difficult decisions. Though infrequent, implant fractures are clinically significant because they usually mandate removal of the entire implant, often involving additional surgery, cost, and patient distress.

Studies conducted to date have indicated that implant fractures are relatively rare, with an estimated incidence of 0.2% to 1.5% (89,90). However, the clinical effects to the patient and clinician are serious because of the concurrent loss of the implant and the dental prosthesis. Implant fractures were broadly categorized into three core causes; implant design and manufacturing defects, non-passive fit of the prosthesis and biomechanical or physiological overload (91). However, clinical evidence suggests that fractures result from a complex interplay of multiple risk factors.

3.4.1 Implant Design Manufacturing Defects

Although modern manufacturing has reduced material flaws, implant design and material composition still play a crucial role (13). Titanium alloys, especially Grade IV and V, are preferred for their balance of strength and biocompatibility (92). In contrast, materials like ceramics and hydroxyapatite have proven too brittle or weak under cyclic loads, making them unsuitable for load-bearing implant bodies (93).

Geometry also matters. Smaller diameter implants, particularly in the posterior region, are more prone to fracture due to reduced resistance to bending forces (93). The moment of inertia, a measure of resistance to flexion, increases with the fourth power of radius, meaning even slight reductions in diameter significantly compromise strength (94).

Moreover, evolving implant designs have shifted from external to internal connections to improve esthetics and load distribution. However, thinner implant walls in tapered internal connections may predispose them to fatigue fractures if stressed excessively (95).

3.4.2 Non-passive Fit of the Prosthesis

A non-passive prosthetic fit can subject implants to continuous stress, eventually leading to fatigue and fracture (23). Schwarz highlighted that screw loosening, a common precursor to fracture, often begins with poor prosthetic adaptation (23). Screw mechanics are equally important. If the abutment screw is undersized or improperly torqued, preload can be insufficient. Repeated micro-movements due to occlusal forces or misfits result in metal fatigue, screw loosening, and ultimately, implant failure (13).

3.4.3 Biomechanical Overload

Among all causes, biomechanical overload from factors, like bruxism, poor prosthetic design, and cantilevers, remains the most significant (96). It was found that over 80% of long-term failures were related to fracture of the implant body due to bending overload, particularly in the posterior jaw where masticatory forces are highest (96).

The posterior maxilla and mandible are particularly vulnerable due to higher occlusal loads and, in some cases, weaker bone quality (91). It was observed that most fractures occur in these regions, with bruxism and high occlusal forces being common denominators (91,96). Bone loss, whether as a cause or consequence of fracture, further weakens implant support. Marginal resorption creates a biomechanical imbalance, amplifying stress on implant (97).

A meta-analysis examined the incidence and contributing factors of dental implant fractures by analyzing data from 69 studies, encompassing 44,521 implants, 827 cases of implant body fractures were identified, the overall incidence of implant fractures was 1.6%. Notably, the majority of these fractures (85%) were located in the premolar or molar regions, where occlusal forces are typically higher (98). Most fractures (88%) occurred in implants supporting fixed restorations (98). Interestingly, screw loosening was observed prior to fracture in over half of the cases (56%), suggesting that while it is a common precursor, other biomechanical or material-related factors also play a significant role (98). A long-term retrospective study analyzed the incidence of implant body fracture and possible risk factors associated with it. The analysis included 2,810 patients and a total of 7,502 implants, followed for an average of 6.9 years (99). It was reported that there was an implant body fracture rate of 0.49% (37 cases), with nearly one-third of these fractures (32.4%) involving reduced-diameter implants (99). The majority of fractures were located in the molar region (29 out of 37) and were most commonly associated with single implant-supported restorations (30 out of 37). Their findings suggest that narrow-diameter implants, especially when placed in the posterior jaw, carry a higher risk of fracture. They also observed that implants supporting unsplinted restorations were more prone to fracturing than those in splinted designs (99).

Table 2 and 3 represent a description of several in-vivo and in-vitro single implant supported restoration studies by study name, year of publication, sample size, variables tested and brief findings.

Table 2: Description of in-vivo single implant-supported restoration studies by study name, year of publication, sample size, variables tested and brief findings

Study	Sample size	Variables	Findings
Quirynen et al. 1992	509 implants	Implant fracture occurrence, timing after loading, implant location, prosthetic and occlusal factors	1-Five implant fractures (~1%) were reported, occurring mainly in posterior regions during the 2nd–3rd year of loading. 2-Fractures were associated with occlusal overload, improper prosthetic handling, and unfavorable implant angulation rather than biological failure.
Jemt and Pettersson 1993	70 ISCs	Restorative and postinsertion problems	1-The most frequent complication was loosening of the single tooth abutment screw.
Balshi et al. 1996	47 ISCs (22 single molar crowns supported by one implant vs 25 single molar crowns supported by two implants)	Mechanical complications	1-Off all complications, screw loosening was the most prevalent. 2-The single implant group had the most frequent loosening. 3-It was concluded that two implants provided a better mechanical situation and should be considered when the required 12-mm mesiodistal space was available.
Gargallo et al. 2008	1500 implants	Implant location, diameter, prosthesis type, cantilever presence, loading time, bruxism	1-Fractures occurred mainly in posterior regions, in fixed prostheses with cantilevers, typically within 3-4 years after loading; most patients showed bruxism.
Wittneben et al. 2014	397 fixed reconstructions (including 268 ISCs)	Mechanical/ technical complications and failures	1-The most frequent complication was ceramic chipping (20.31%) followed by occlusal screw loosening (2.57%) and loss of retention (2.06%). 2-No difference between the failure rates of screw-retained implant supported crowns (ISCs) on either titanium, gold, or ceramic abutments. 3-Implant supported prosthesis showed high survival over 10 years, but technical complications especially ceramic chipping were frequent, particularly in FDPs and patients with occlusal attrition.
Korsch and Walther 2015	408 ISCs Prefabricated abutments (n=312, including 233 ISCs) Customized computer aided abutments (n=96, including 59 ISCs)	Retention loss	It was found that 7.7% of the single crowns on prefabricated abutments loosened, and of those on customized abutments, 0% loosened. Which led to the conclusion that the loosening of reconstructions placed on customized abutments can be reduced for single-crown restorations.
Chitumalla et al. 2018	157 ISCs	Mechanical/ technical complications	Excessive occlusal overload caused in bruxism patients is the leading cause of failure such as fracture of implant, loosening of screw, fracture of screw, and fracture of porcelain.
Cheng et al. 2019	73 ISCs	Prosthetic outcomes	1-There were significantly more technical complications observed in the metal ceramic SCs than zirconia SCs. 2-The most common complication in the metal ceramic crowns group was screw loosening (14.7%), followed by loss of retention (5.9%) and ceramic fracture (2.9%). 3-The most common complication in the zirconia crowns group was screw loosening (2.9%) with 0% loss of retention or ceramic fracture.

Chrcanovic, Kisch and Larsson 2019	570 ISCs	Clinical outcomes of implant -supported single crowns and the supporting implants	1-A higher rate of technical problems had led to the loss of the crowns that occurred in the posterior region of the jaws (100% of the cases) in comparison with the anterior region (32.6% of the cases). 2-Compared to the anterior part of the jaws, the posterior region had a higher rate of crown loss and screw loosening.
Guncu et al. 2022	182 ISCs	Biologic, technical, and radiographic outcomes	It was suggested that Ti-base abutments are a feasible and affordable alternative to CAD/CAM abutments and that they can successfully support single zirconia crowns
Saponaro et al. 2022	601 ISCs	Prosthetic design, veneering strategy (monolithic vs micro-veneered), technical complications	Prosthetic design influenced complication rates, with complete-arch restorations showing the highest and single-unit restorations the lowest risk, while chipping was the most common complication occurring more frequently in micro-veneered zirconia prostheses than in monolithic designs, regardless of restoration extent
Yu et al. 2022	7502 implants	Implant system, implant diameter, implant location, prosthetic design (splinted vs unsplinted), restoration type, follow-up time	1-Implant body fracture rate was low (0.49%). Fractures occurred mainly in posterior regions and single unsplinted restorations. 2-Narrow-diameter implants showed a significantly higher fracture risk.
Larsson et al. 2023	358 ISCs	Patient factors, jaw location, crown material, fixation method, bruxism, technical complications	1-Crown survival was high (CSR 92.2% at 6–11 years). 2-Twenty crowns and seven implants failed; only one implant fracture occurred. 3-Probable bruxism and male sex were significantly associated with higher crown failure and technical complication rates, with crown mobility and ceramic chipping being the most common complications.
Rammelsberg and Klotz 2024	358 ISCs	Failure and loss of retention	1-The authors discovered a significant difference between the 5-year loss-of-retention rates of 12% for standardized abutments and 2% for customized abutments 2-The incidence of retention loss after 10 years was 20% for ISCs fixed with semi-permanent cement and 8% for ISCs cemented with permanent cement. 3-Loss of retention was not significantly impacted by age, sex, location (maxilla/ mandible, anterior/ posterior), abutment type, or framework material (zirconia/ high noble metal alloy).

Table 3: Description of in-vitro single implant supported restoration studies by study name, year of publication, sample size, variables tested and brief findings.

Study	Sample size	Variables	Findings
Norton 1997	12 implants (only abutments with no crowns)	Resistance to bending force (internal conical interface vs butt-joint interface)	1-Implants with internal implant-abutment connections are favored over external connection systems, as internal connections provide enhanced stability and a better seal between the implant and the abutment. 2-The internal connection reduces the likelihood of screw loosening by creating a mechanical interlock between the components.
Covey et al. 2000	16 ISCs	Effect of type of luting agent on the retention of the prosthetic crown	Permanent luting cement produced uniaxial retention forces approximately 3 times greater than provisional cement.
Siamos, Winkler and Boberick	40 implants (only abutments with no crowns)	Screw loosening under simulated loading conditions	1-Retightening abutment screws 10 minutes after initial torque applications should be performed routinely during abutment-implant connections.

2002			2-Increasing the torque value above 30 N-cm can be beneficial for abutment-implant stability and to decrease screw loosening.
Shin et al. 2016	40 ISCs	Effect of using double screw on the screw loosening	1-Double screw abutments in internal and external connection implants a lower removal torque loss percentage after cyclic loading than single screw abutments. 2-It was concluded that double screw was more effective in prevention of screw loosening.
Dincer Kose et al. 2017	180 implants (only abutments with no crowns)	Screw loosening and bending/ torsional moments	The preload force values manually applied to dental implant-abutment screws did not reach those recommended by the manufacturer which increased the risk of screw loosening. Therefore, the calibrated ratchet torque wrench provided by the manufacturer should be used.
Rues et al. 2017	20 ISCs	Influence of selected cements, abutment heights and aging on retention	An increase in abutment height was associated with an increase in decementation force when permanent cementation was tested. The aging protocol showed that temporarily cemented crowns showed a significant retention decrease, while use of a permanent cement led to a moderate increase.
Hotinski and Dudley 2019	14 implants (only abutments with no crowns)	Abutment screw loosening in angulation correcting implants and straight implants	The angulation-correcting implants resisted screw loosening significantly more than the straight implants because of the reduced angle of abutment screw loading.
Zahoui et al. 2020	160 ISCs	Retentive strength	The height of the Ti-base was thought to be a significant consideration. The taller Ti-base (4mm) had a greater retention value than the shorter Ti-base (2.5mm).
Bergamoa et al. 2021	80 ISCs	Influence of resin cement type and surface pretreatment on the retention of crowns to Ti-base abutments	Conventional resin cement and/or Ti-base sandblasting increased Y-TZP crown retentiveness.
Muller et al. 2021	64 ISCs	Pull-off forces with respect to abutment height and cement	Permanent cements present higher retention than semi-permanent ones, and temporary cements present the lowest values. The abutment height had a subordinate impact.
Moreno et al. 2026	160 ISCs	Retention strength of crowns	1-Mechanical aging impeded the retention force of milled zirconia crowns cemented on titanium base abutments with resin cement on 2-Morse taper implants had greater retention force compared to external hexagon implants.

4. Conclusions

Although dental implant therapy generally demonstrates a high overall success rate, various biological, mechanical, and esthetic factors can occasionally lead to implant failure. Biological complications, such as peri-implantitis, bone resorption, or soft tissue inflammation, and esthetic concerns, such as gum recession or improper crown contours, can compromise the long-term success of the implant. Additionally, mechanical failures are often the result of excessive or uneven forces on the implant or prosthetic components. These mechanical issues can manifest as screw loosening, fractures of the prosthetic crown or abutment, or even complete implant failure, which typically occur when the implant and its prosthetic components are unable to withstand the masticatory forces generated during normal chewing, biting, and other functional activities.

To reduce the risk of these mechanical complications, careful and comprehensive planning is vital from the outset. This includes an in-depth assessment of the patient's oral health, occlusion, and functional demands. The design of the prosthetic framework should be optimized to ensure it is capable of distributing occlusal forces evenly across the implant structure. The accuracy of implant placement is crucial as well, as deviations in position can result in improper load distribution, leading to mechanical failure. Moreover, selecting the right prosthetic materials plays a critical role in the longevity of the restoration. Materials must not only be durable and resistant to wear, but also compatible with the forces generated by the patient's masticatory system. For instance, choosing between materials like zirconia or porcelain will depend on the specific functional needs and esthetic requirements of the patient.

Equally important is the consideration of a patient's individual force factors, which can greatly influence implant success. For example, patients who suffer from bruxism or exhibit excessive bite forces are at a higher risk of implant-related complications. In such cases, it may be necessary to modify treatment plans, consider splint therapy, or incorporate materials designed to withstand higher forces. The distribution of occlusal load, including factors like the patient's bite alignment and jaw position, must also be thoroughly evaluated to avoid overloading any single implant or prosthetic component. Additionally, maintaining proper oral hygiene and regular follow-up appointments are essential to identify potential issues early and to ensure the long-term stability and health of both the implant and the surrounding tissues. These preventive measures, along with a tailored approach to each patient's unique needs, are key to minimizing complications and enhancing the overall success rate of dental implants.

Conflict of Interests

The authors have no conflict declared of interests to declare

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References

1. Layton DM (Ed.), Morgano SM, Muller F, Kelly JA, Nguyen CT, et al. Glossary of prosthodontic Terms 2023, 10th edition. J Prosthet Dent. 2023;130: e1-e126.
2. Gaviria L, Salcido JP, Guda T, Ong JL. Current trends in dental implants. J Korean Assoc Oral Maxillofac Surg. 2014;40:50-60.
3. Esposito M, Grusovin MG, Coulthard P, Thomsen P, Worthington HV. A 5-year follow-up comparative analysis of the efficacy of various osseointegrated dental implant systems: a systematic review of randomized controlled clinical trials. Int J Oral Maxillofac Implants. 2005;20:557-568.
4. Brånemark PI, Hansson BO, Adell R, Breine U, Lindström J, et al. Osseointegrated implants in the treatment of the edentulous jaw: Experience from a 10-year period. Scand J Plast Reconstr Surg Suppl. 1977;16:1-132.
5. Schmitt A, Zarb GA. The longitudinal clinical effectiveness of osseointegrated dental implants for single-tooth replacement. Int J Prosthodont. 1993;6:197-202.
6. Hebel K, Gajjar R, Hofstede T. Single-tooth replacement: Bridge vs. implant-supported restoration. J Can Dent Assoc. 2000;66:435-438.
7. Misch CE, Misch-Dietsh F, Silc J, Barboza E, Cianciola LJ, et al. Posterior implant single-tooth replacement and status of adjacent teeth during a 10-year period: a retrospective report. J Periodontol. 2008;79:2378-2382.
8. Scheuber S, Hicklin S, Brägger U. Implants versus short-span fixed bridges: Survival, complications, patients' benefits. Asystematic review on economic aspects. Clin Oral Implant Res. 2012;23:50-62.
9. Chrcanovic BR, Kisch J, Larsson C. Retrospective clinical evaluation of implant-supported single crowns: Mean follow-up of 15 years. Clin Oral Implants Res. 2019;30:691-701.
10. Verma A, Singh SV, 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.
11. El Askary AS, Meffert RM, Griffin T. Why do dental implants fail? Part I. Implant Dent. 1999;8:173-185.
12. El Askary AS, Meffert RM, Griffin T. Why do dental implants fail? Part II. Implant Dent. 1999;8:265-277.
13. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications with implants and implant prostheses. J Prosthet Dent. 2003;90:121-132.
14. Chee W, Jivraj S. Failures in implant dentistry. Br Dent J. 2007;202:123-129.
15. Rabel K, Spies BC, Pieralli S, Vach K, Kohal RJ. The

clinical performance of all- ceramic implant- supported single crowns: a systematic review and meta- analysis. Clin Oral Implant Res. 2018;29:196-223.

16. Jung RE, Zembic A, Pjetursson BE, Zwahlen M, Thoma DS. Systematic review of the survival rate and the incidence of biological, technical, and esthetic complications of single crowns on implants reported in longitudinal studies with a mean follow- up of 5 years. Clin Oral Implant Res. 2012;23:2-21.
17. Pjetursson BE, Valente NA, Strasding M, Zwahlen M, Liu S, et al. 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.
18. Pjetursson BE, Pitta J, Balet A, Bjarnadottir GR, Sailer I, et al. A systematic review and meta-analysis evaluating survival, failure, and complication rates of metal-ceramic, veneered, and monolithic all-ceramic tooth-supported single crowns. Int J Prosthodont. 2026;5;0:1-47.
19. McGlumphy EA, Mendel DA, Holloway JA. Implant screw mechanics. Dent Clin North Am. 1998;42:71-89.
20. Siamos G1, Winkler S, Boberick KG J. Relationship between implant preload and screw loosening on implant-supported prostheses. Oral Implantol. 2002;28:67-73.
21. Balshi TJ, Hernandez RE, Pryszlak MC, Rangert B. A comparative study of one implant versus two replacing a single molar. Int J Oral Maxillofac Implants. 1996;11:372-378.
22. Jemt T, Pettersson P. A 3-year follow-up study on single implant treatment. J Dent. 1993;21:203-208.
23. Schwarz MS. Mechanical complications of dental implants. Clin Oral Implants Res. 2000;11:156-158.
24. Theoharidou A, Petridis HP, Tzannas K, Garefis P. Abutment screw loosening in single-implant restorations: a systematic review. Int J Oral Maxillofac Implants. 2008;23:681-690.
25. Sailer I, Mühlemann S, Zwahlen M, Hämmerle CHF, Schneider D. Cemented and screw- retained implant reconstructions: A systematic review of the survival and complication rates. Clin Oral Implants Res. 2012;23:163-201.
26. Shin YG, Kim SY, Lee HK, Jeong CM, Lee SH, et al. Effect of double screw on abutment screw loosening in single-implant pros theses. Int J Prosthodont. 2016;29:445-447.
27. Norton MR. An in vitro evaluation of the strength of an internal conical interface compared to a butt joint interface in implant design. Clin Oral Implants Res 1997;8:290-298.
28. Dincer Kose O, Karataslı B, Demircan S, Kose TE, Cene E, et al. In vitro evaluation of manual torque values applied to implant-abutment complex by different clinicians and abutment screw loosening. Biomed Res Int. 2017;2017:7376261.
29. Hotinski E, Dudley J. Abutment screw loosening in angulation- correcting implants: an in vitro study. J Prosthet Dent. 2019;121:151-155.
30. Wennerberg A, Carlsson G, Jemt T. Influence of occlusal factors on treatment outcome: A study of 109 consecutive patients with mandibular implant-supported fixed prostheses opposing maxillary complete dentures. Int J Prosthodont. 2001;14:550-555.
31. Goldstein G, Goodacre C, Taylor T. Occlusal schemes for implant restorations: Best evidence consensus statement. J Prosthodont. 2021;30:84-90.
32. Sahin S, Cehreli MC. The significance of passive framework fit in implant prosthodontics: current status. Implant Dent. 2001;10:85-92.
33. Winkler S, Ring K, Ring JD, Boberick KG. Implant screw mechanics and the settling effect: An overview. J Oral Implantol. 2003;29:242-245.
34. Shadid R, Sadaqa N. A comparison between screw- and cement-retained implant prostheses: A literature review. J Oral Implantol. 2012;38:298-307.
35. Le M, Papia E, Larsson C. The clinical success of tooth- and implant-supported zirconia-based fixed dental prostheses: A systematic review. J Oral Rehabil. 2015;42:467-480.
36. Laumbacher H, Strasser T, Knüttel H, Rosentritt M. Long-term clinical performance and complications of zirconia-based tooth- and implant-supported fixed prosthodontic restorations: A summary of systematic reviews. J Dent. 2021;111:103723.
37. Sailer I, Karasan D, Todorovic A, Ligoutsikou M, Pjetursson BE. Prosthetic failures in dental implant therapy. Periodontol 2000. 2022;88:130-144.
38. Wittneben JG, Buser D, Salvi GE, Bürgin W, Hicklin S, et al. Complication and failure rates with implant-supported fixed dental prostheses and single crowns: A 10-year retrospective study. Clin Implant Dent Relat Res. 2014;16:356-364.
39. Derksen W, Tahmaseb A, Wismeijer D. A randomized clinical trial comparing the clinical fit of CAD/CAM monolithic zirconia fixed dental prostheses (FDPs) on

Ti-base abutments based on digital or conventional impression techniques: One-year follow-up. Int J Prosthodont. 2021;34:733-743.
40. Guncu MB, Aktas G, Guncu GN, Anıl D, Turkyilmaz I, et al. Clinical, technical, and radiologic outcomes of 182 implant-supported zirconia single crowns using titanium-base abutments: A retrospective study. Int J Prosthodont. 2022;35:553-559.
41. Fiore AD, Stellini E, Monaco C, Yilmaz B. Clinical outcome of monolithic zirconia on bonded or mechanically retained prefabricated titanium-base: A 4-year retrospective study. J Dent. 2024;150:105350.
42. Brägger U, Karoussis I, Persson R, Pjetursson B, Salvi G, et al. Technical and biological complications/failures with single crowns and fixed partial dentures on implants: a 10-year prospective cohort study. Clin Oral Implants Res. 2005;16:326-334.
43. Kinsel RP, Lin D. Retrospective analysis of porcelain failures of metal ceramic crowns and fixed partial dentures supported by 729 implants in 152 patients: patient-specific and implant-specific predictors of ceramic failure. J Prosthet Dent. 2009;101:388-394.
44. Yi Y, Heo SJ, Koak JY, Kim SK. Mechanical complications of implant-supported restorations with internal conical connection implants: A 14-year retrospective study. J Prosthet Dent. 2023;129:732-740.
45. Zahoui A, Bergamo ET, Marun MM, Silva KP, Coelho PG, et al. Cementation protocol for bonding zirconia crowns to titanium base CAD/CAM abutments. Int J Prosthodont. 2020;33:527-535.
46. Korsch M, Walther W. Prefabricated versus customized abutments: A retrospective analysis of loosening of cement-retained fixed implant-supported reconstructions. Int J Prosthodont. 2015;28:522-526.
47. Rammelsberg P, Klotz AL. Long-term retention and survival of cemented implant-supported zirconia and metal-ceramic single crowns: A retrospective study. Clin Oral Implants Res. 2024;35:1335-1342.
48. Cheng CW, Chien CH, Chen CJ, Papaspyridakos P. Randomized controlled clinical trial to compare posterior implant-supported modified monolithic zirconia and metal-ceramic single crowns: One-year results. J Prosthodont. 2019;28:15-21.
49. Pjetursson BE, 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 Implants Res. 2012;23:22-38.
50. Spazzin AO, Guarda GB, Oliveira-Ogliari A, Leal FB, Correr-Sobrinho L, et al. Strengthening of porcelain provided by resin cements and flowable composites. Oper Dent. 2016;41:179-188.
51. Pjetursson BE, Brägger U, Lang NP, 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 Implants Res. 2007;18:97-113.
52. Covey DA, Kent DK, St Germain HA Jr, Koka S. Effects of abutment size and luting cement type on the uniaxial retention force of implant-supported crowns. J Prosthet Dent. 2000;83:344-348.
53. Müller L, Rauch A, Reissmann DR, Schierz O. Impact of cement type and abutment height on pull-off force of zirconia reinforced lithium silicate crowns on titanium implant stock abutments: An in vitro study. BMC Oral Health. 2021;21:592.
54. TP Bergamo E, Zahoui A, Luri Amorin Ikejiri L, Marun M, Peixoto da Silva K, et al. Retention of zirconia crowns to Ti-base abutments: Effect of luting protocol, abutment treatment and autoclave sterilization. J Prosthodont Res. 2021;65:171-175.
55. Rues S, Fugina M, Rammelsberg P, Kappel S. Cemented single crown retention on dental implants: An in vitro study. Int J Prosthodont. 2017;30:133-135.
56. Hsu ML, Chen FC, Kao HC, Cheng CK. Influence of off-axis loading of an anterior maxillary implant: a 3-dimensional finite element analysis. Int J Oral Maxillofac Implants. 2007;22:301-309.
57. Flanagan D. Bite force and dental implant treatment: a short review. Med Devices (Auckl). 2017;10:141-148.
58. Chitumalla R, Halini Kumari KV, Mohapatra A, Parihar AS, Anand KS, et al. Assessment of survival rate of dental implants in patients with bruxism: a 5-year retrospective study. Contemp Clin Dent. 2018;9:S278-S282.
59. Moreno ALM, Santos DM, Melo Neto CLM, Monteiro RV, Lima CC, et al. Effect of cement, implant connection, and aging on the retention strength of zirconia crowns to Ti-base. Eur J Gen Dent. 2026 (Article published online).
60. Jung RE, Pjetursson BE, Glauser R, Zembic A, Zwahlen M, et al. A systematic review of the 5-year survival and complication rates of implant-supported single crowns. Clin Oral Implants Res. 2008;19:119-130.

61. Sailer I, Philipp A, Zembic A, Pjetursson BE, Hämmerle CH, et al. A systematic review of the performance of ceramic and metal implant abutments supporting fixed implant reconstructions. Clin Oral Implants Res. 2009;20:4-31.
62. Alqutaibi AY, Alnazzawi AA, Algabri R, Aboalrejal AN, AbdElaziz MH. Clinical performance of single implant-supported ceramic and metal-ceramic crowns: A systematic review and meta-analysis of randomized clinical trials. J Prosthet Dent. 2021;126:369-376.
63. Apte A, Sathe S, Kawade R. Evaluation of success rate of zirconia based restorations: A systematic review. J Clin Exp Dent. 2022;14:e756-e761.
64. Hosseini M, Worsaae N, Schiodt M, Gotfredsen K. A 1-year randomized controlled trial comparing zirconia versus metal-ceramic implant-supported single-tooth restorations. Eur J Oral Implantol. 2011;4:347-361.
65. Spies BC, Balmer M, Patzelt SB, Vach K, Kohal RJ. Clinical and patient-reported outcomes of a zirconia oral implant: Three-year Results of a Prospective Cohort Investigation. J Dent Res. 2015;94:1385-1391.
66. Pjetursson BE, Sailer I, Latyshev A, Rabel K, Kohal RJ, et al. A systematic review and meta-analysis evaluating the survival, the failure, and the complication rates of veneered and monolithic all-ceramic implant-supported single crowns. Clin Oral Implants Res. 2021;32:254-288.
67. Zarone F, Di Mauro MI, Spagnuolo G, Gherlone E, Sorrentino R. Fourteen-year evaluation of posterior zirconia-based three-unit fixed dental prostheses. J Dent. 2020;101:103419.
68. Shihabi S, Chrcanovic BR. Clinical outcomes of tooth-supported monolithic zirconia vs. porcelain-veneered zirconia fixed dental prosthesis, with an additional focus on the cement type: A systematic review and meta-analysis. Clin Oral Investig. 2023;27:5755-5769.
69. Baldassarri M, Zhang Y, Thompson VP, Rekow ED, Stappert CF. Reliability and failure modes of implant-supported zirconium-oxide fixed dental prostheses related to veneering techniques. J Dent. 2011;39:489-498.
70. Hämmerle CH, Wagner D, Brägger U, Lussi A, Karayiannis A, et al. Threshold of tactile sensitivity perceived with dental endosseous implants and natural teeth. Clin Oral Implants Res. 1995;6:83-90.
71. Scherrer SS, Denry IL, Wiskott HW, Belser UC. Effect of water exposure on the fracture toughness and flexure strength of a dental glass. Dent Mater. 2001;17:367-371.
72. Häggman-Henrikson B, Ali D, Aljamal M, Chrcanovic BR. Bruxism and dental implants: A systematic review and meta-analysis. J Oral Rehabil. 2024;51:202-217.
73. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A. Factors influencing the fracture of dental implants. Clin Implant Dent Relat Res. 2018;20:58-67.
74. Bredberg C, Vu C, Häggman-Henrikson B, Chrcanovic BR. Marginal bone loss around dental implants: comparison between matched groups of bruxer and non-bruxer patients: A retrospective case-control study. Clin Implant Dent Relat Res. 2023;25:124-132.
75. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A. Bruxism and dental implant treatment complications: a retrospective comparative study of 98 bruxer patients and a matched group. Clin Oral Implants Res. 2017;28:e1-e9.
76. Chrcanovic BR, Kisch J, Larsson C. Analysis of technical complications and risk factors for failure of combined tooth-implant-supported fixed dental prostheses. Clin Implant Dent Relat Res. 2020;22:523-532.
77. Lobbezoo F, Brouwers JE, Cune MS, Naeije M. Dental implants in patients with bruxing habits. J Oral Rehabil. 2006;33:152-159.
78. Larsson A, Manuh J, Chrcanovic BR. Risk factors associated with failure and technical complications of implant-supported single crowns: A retrospective study. Medicina (Kaunas). 2023;59:1603.
79. Bonakdarchian M, Askari N, Askari M. Effect of face form on maximal molar bite force with natural dentition. Arch Oral Biol. 2009;54:201-204.
80. Saponaro PC, Karasan D, Donmez MB, Johnston WM, Yilmaz B. Prosthetic complications with monolithic or micro-veneered implant-supported zirconia single-unit, multiple-unit, and complete-arch prostheses on titanium base abutments: A single center retrospective study with mean follow-up period of 72.35 months. Clin Implant Dent Relat Res. 2023;25:99-106.
81. Cattani-Lorente M, Scherrer SS, Ammann P, Jobin M, Wiskott HW. Low-temperature degradation of a Y-TZP dental ceramic. Acta Biomater. 2011;7:858-865.
82. Triwatana P, Nagaviroj N, Tulapornchai C. Clinical performance and failures of zirconia-based fixed partial dentures: A review literature. J Adv Prosthodont. 2012;4:76-83.
83. Rinke S, Wehle J, Schulz X, Bürgers R, Rödiger M. Prospective evaluation of posterior fixed zirconia dental prostheses: 10-year clinical results. Int J Prosthodont. 2018;31:35-42.

84. Zarone F, Russo S, Sorrentino R. From porcelain-fused-to-metal to zirconia: Clinical and experimental considerations. Dent Mater. 2011;27:83-96.
85. Koenig V, Vanheusden AJ, Le Goff SO, Mainjot AK. Clinical risk factors related to failures with zirconia-based restorations: An up to 9-year retrospective study. J Dent. 2013;41:1164-1174.
86. Koenig V, Wulfman C, Bekaert S, Dupont N, Le Goff S, et al. Clinical behavior of second-generation zirconia monolithic posterior restorations: Two-year results of a prospective study with Ex vivo analyses including patients with clinical signs of bruxism. J Dent. 2019;91:103229.
87. Chang JS, Ji W, Choi CH, Kim S. Catastrophic failure of a monolithic zirconia prosthesis. J Prosthet Dent. 2015;113:86-90.
88. Juica D, Marcus N, Grandon F, Sanhueza V, Wendler M. Premature failure of a screw-retained ceramic single crown: A clinical report and fractographic analysis. J Prosthet Dent. 2022;127:32-37.
89. Sánchez-Pérez A, Moya-Villaescusa MJ, Jornet-Garcia A, Gomez S. Etiology, risk factors and management of implant fractures. Med Oral Patol Oral Cir Bucal. 2010;15:e504-e508.
90. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. J Clin Periodontol. 2002;29:197-233.
91. Balshi TJ, Wolfinger GJ, Balshi SF, Nevins M, Kim DM. Thirty-two-year success of dental implants in periodontally compromised dentition. Int J Periodontics Restorative Dent. 2018;38:827-831.
92. Resnik, Randolph R, and Carl E Misch. Misch's Contemporary Implant Dentistry. Fourth edition. St. Louis: Elsevier, 2021.
93. Goodacre CJ, Kan JY, Rungcharassaeng K. Clinical complications of osseointegrated implants. J Prosthet Dent. 1999;81:537-552.
94. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Implants. 1986;1:11-25.
95. Shemtov-Yona K, Rittel D. Fatigue of dental implants: Facts and fallacies. Dent J (Basel). 2016;4:16.
96. Rangert B, Krogh PH, Langer B, van Roekel N. Bending overload and implant fracture: A retrospective clinical analysis. Int J Oral Maxillofac Implants. 1995;10:326-334.
97. Quirynen M, Naert I, van Steenberghe D. Fixture design and overload influence marginal bone loss and fixture success in the Brånemark system. Clin Oral Implants Res. 1992;3:104-111.
98. Pommer B, Bucur L, Zauza K, Tepper G, Hof M, et al. Meta-analysis of oral implant fracture incidence and related determinants. J Oral Implantol. 2014;2014:263925.
99. Yu H, Qiu L. Analysis of fractured dental implant body from five different implant systems: A long-term retrospective study. Int J Oral Maxillofac Surg. 2022;51:1355-1361.