THEMATIC ABSTRACT REVIEW

Section Editor
Clark M. Stanford, DDS, PhD, MHA
University of Iowa
Iowa City, Iowa, USA

David Chvartszaid, DDS, MSc (Prostho), MSc (Perio)
University of Toronto
Toronto, Canada

Hanae Saito, DDS, MS, CCRC
University of Maryland
Baltimore, Maryland, USA

Emad Estafanous, BDS, MSD
University of Illinois Chicago
Chicago, Illinois, USA

Jan-Eirik Ellingsen, DDS, PhD
University of Oslo
Oslo, Norway

Martin Osswald, BDS, MDent
University of Alberta
Edmonton, Canada

Implant Fracture: An Update

Implant fracture is a relatively rare but serious and irreversible complication that can occur during implant placement, during function, or during implant removal. Although the specific etiology differs in each case, a consistent element is the application of force that exceeds the implant's fracture resistance. Implant fracture can be characterized as a technical or mechanical complication during function or as a surgical complication during surgical intervention. Implant fracture of a restored two-piece titanium (Ti) implant during function is a relatively well characterized and understood technical complication (Manfredini et al).[1] By contrast, non-function-related types of implant fracture are not as well documented, such as implant fracture as a surgical complication, implant fracture of specialized implant designs (eg, one-piece implants) and materials (eg, zirconia [Zr] implants), and fracture of implants with modified contours (eg, implantoplasty).

Manfredini et al[1] summarized the current state of knowledge regarding dental implant fractures in a systematic review of the literature published between 2000 and 2023. The authors identified six retrospective case-control studies meeting the inclusion criteria, and these were assessed to be at a low risk of bias. The overwhelming majority of implants in these six studies (> 99%) were two-piece Ti implants, with only one study of 170 implants focusing on one-piece Zr implants. In total, three of the six studies evaluated had a very large number of implants (> 18,000 implants each) and reported implant fracture rates between 0.2% and 0.9%. Manfredini et al[1] concluded that some factors can increase the risk of fracture, including narrow implant diameter, placement in the posterior zone, select implant designs and materials, as well as an excessive biomechanical loading through bruxism or prosthesis design (eg, cantilevers). However, not all of these factors were identified as being associated with implant fracture in each of the included studies. The authors noted the lack of standardization in reporting and heterogeneity of methodologies in the included studies as a limitation in the ability to compare and summarize the results accurately.

Yu and Qiu[2] conducted a large retrospective study focusing on fractures of Ti implants. They analyzed 2,810 patients who received 7,502 implants between 1998 and 2016 and were followed up for an average of 6.9 years (range: 2–18 years). This recent study was not included in the systematic review by Manfredini et al.[1] The overall implant fracture rate was 0.49%, and the average time from implantation to fracture was 7.2 years. This finding is similar to the 0.2% to 0.9% fracture rate reported by three large studies included in the analysis by Manfredini et al.[1] These results were also in agreement with the 0.6% fracture rate reported in the earlier work by Eckert et al,[3] which is based almost entirely on commercially pure grade 1 Ti Brånemark implants placed between 1983 and 1997. Yu and Qiu2 reported familiar results to the aforementioned studies such as the fracture susceptibility of narrow-diameter implants in the posterior zone as well as the differential fracture rates among different implant brands (ie, different implant designs and materials). Another interesting result reported by Yu and Qiu2 was the higher occurrence of fracture among implant-supported single crowns (0.85%; 30 fractured implants among 3,537 implants) compared to implant-supported splinted crowns

(0.18%; 5 fractured implants among 2,782 implants) and full-arch fixed prostheses (0.26%; 2 fractured implants among 765 implants). The surprising result of similar fracture rates reported by Yu and Qiu2 for contemporary implants of a higher Ti grade placed after 1998 and by Eckert et al3 (for commercially pure grade 1 Ti implants placed before 1998 provides indirect support for the idea that splinting may be beneficial in reducing stress on individual implants, because the Eckert et al3 patient sample included only multiunit prostheses that were supported by two or more implants.

Clinical practice and research overwhelmingly focuses on two-piece Ti implants because of their adaptability to diverse planned and unplanned intraoral scenarios. However, one-piece Ti implants are also occasionally used and may possess greater structural strength. Fujii et al[4] reported on 20 one-piece Ti implant fractures, primarily focusing on characterizing the sample of patients with fractured implants. A notable limitation of this study was the small amount of information provided on the baseline and treatment characteristics of the overall sample of patients who received one-piece Ti implants. Another notable limitation was the use of only one implant brand that was made of grade 2 Ti. Hence, the results of this study may not be representative of other one-piece implant brands or of implants made of a higher-grade Ti. Nonetheless, this is one of very few studies reporting on fractures of one-piece Ti implants.

A 2023 systematic review by Mohseni et al[5] summarized data from 25 publications that reported on 4,017 Zr implants in 2,083 patients with an average follow-up of 68.8 ± 52.5 months and revealed that a total of 26 implants fractured (0.64%). A few conclusions can be drawn from this study. First, 25 of the 26 fractures that occurred were in implant brands that are no longer commercially available. This may point to the fact that Zr implants have a rapidly developing market that has not yet matured, and differences in treatment outcomes can be expected with different generations of Zr implants. Similarly, only 4 of the 25 studies (which represented only 5% of the 4,017 implants) evaluated two-piece Zr implants. Hence, extrapolation of data from this systematic review to contemporary Zr implants is difficult, and this is particularly apparent in the case of two-piece Zr implants. Second, the fracture of one-piece Zr implants was more frequent in cases where the abutment portion of the one-piece Zr implant was prepared by a drill. This may stem from deterioration of the Zr's physical properties and an introduction of microcracking through intraoral preparation, highlighting the need to approach this step with more care.

A 2023 systematic review by Tardelli et al[6] investigated the impact of surface modifications on the fracture resistance of aged Zr implants in vitro. It concluded that, while the overall influence of surface treatment on the fracture resistance of Zr implants in the included studies was heterogenous, some studies did demonstrate decreased fracture toughness of Zr implants when subjected to select surface treatments. The third conclusion was that fractures were more frequent with narrow-diameter implants, which parallels similar observations with Ti implants.[1]

Implant fracture during placement can result from the application of excessive force during the osteotomy, especially when a lateral component of force is inadvertently applied to the implant insertion tool. This should be kept in mind as some implant manufacturers specifically recommend that implant insertion path can be modified during implant placement. The frequency of occurrence and risk factors associated with this complication are not well documented, and several frequently cited literature reviews summarizing intraoperative implant complications do not mention this complication (eg, Greenstein et al[7] and Misch and Wang[8]). The typical mode of fracture during implant placement is flowering of the implant platform. This surgical complication can be challenging to manage because flowering of the platform makes implant removal through minimally traumatic techniques (ie, without the use of a trephine) almost impossible. As is the case with other types of implant fracture, clinical experience suggests that this complication is related to clinical technique and the combination of implant design, diameter, and material composition.

Implant fracture during minimally invasive implant removal can occur during an attempt to apply a reverse torque approach. The frequency of occurrence and risk factors associated with this complication are not well documented. In general, implant fracture planes seen during implant removal are similar to those seen in implants fractured due to occlusal overloading. One fracture plane that is commonly seen when removing implants with classic designs (eg, Brånemark Mk1) is the horizontal fracture in the apical third of the implant through the bone chamber (horizontal "apical hole"). This complication is not seen with more contemporary implant designs due to the general disappearance of the apical bone chamber from the design of contemporary implants.

An implant can be weakened by inadvertent bur damage in the internal aspect of the implant during the removal of a fractured abutment screw or by purposeful modification of external implant surface topography (threads) to achieve a smoother and more maintainable surface as part of peri-implantitis management (implantoplasty). Very little is known about the frequency of occurrence, general prognosis, and probability of fracture of implants already weakened by internal aspect damage sustained during the removal

of a fractured abutment screw. Similarly, the probability of fracture of implants restored as a compromised solution secondary to another technical complication (such as restoration of an implant with a fractured or damaged connection) is unknown (eg, Hansen and Salinas[9]).

Implantoplasty aims to improve clinical outcomes of patients treated for peri-implantitis by facilitating implant maintenance and reducing the biofilm burden of contaminated implant surfaces.[10] Implantoplasty improves implant maintenance by reducing the topographic complexity of the implant surface through the reduction or elimination of implant threads as well as by reducing the biofilm burden via the removal and polishing of the contaminated implant surface. Because implantoplasty involves a reduction of implant thickness, a natural question arises: Does implantoplasty increase the risk of implant fracture? A 2019 systematic review by Stavropoulos et al[10] answered this question in the negative based on an analysis of 18 clinical publications (6 randomized controlled trials, 5 prospective case series, 4 case reports, and 3 retrospective analyses), which reported on less than 300 implants in total with a variable follow-up of 3 to 126 months.

Two recent publications attempted to provide additional insights into the fracture risk of implants that underwent implantoplasty. Goh et al[11] conducted a systematic review that included nine in vitro studies published between 2013 and 2021 with a total of 420 implants of various designs (connections, levels, and materials). A meta-analysis was not conducted due to the limited number of studies and the heterogeneity of the extracted data. Although some data demonstrated a negative impact of implantoplasty for certain factors (such as implant diameter), the overall effect of implantoplasty on implant fracture resistance showed conflicting results. The authors emphasized the likely limited applicability of the in vitro data to clinical practice due to the operator's challenging intraoral access and blood affecting visibility when performing the procedure. Hence, they caution that in vitro studies may not reflect the in vivo performance of implants following implantoplasty. Stavropoulos et al[12] assessed the impact of implantoplasty on the performance of narrow, parallel-wall implants of different designs (bone level and tissue level) and materials (Ti grade 4 and Ti-Zr alloy) from the same manufacturer with a simulated 5 mm of coronal bone loss. Dynamic loading revealed that the fracture strength of tissue-level implants was negatively affected in the context of experimental conditions. Caution must be exercised in extrapolating this result to other manufacturers and to clinical practice.

Overall, research continues to reinforce the relevance of biomechanical forces, implant design, treatment planning, and clinical execution to implant treatment outcomes, including the risk of implant fracture. From a methodologic standpoint, inconsistencies in the reporting of baseline characteristics and clinical outcomes as well as the relatively rapid changes in implant designs complicate both the interpretation of results in studies on implant fracture and the extrapolation of the published results to current clinical practice.

David Chvartszaid, DDS, MSc (Prostho), MSc (Perio), FRCDC(C)

REFERENCES

1. Manfredini M, Poli PP, Giboli L, Beretta M, Maiorana C, Pellegrini M. Clinical factors on dental implant fractures: A systematic review. Dent J (Basel) 2024;12:200.
2. 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.
3. Eckert SE, Meraw SJ, Cal E, Ow RK. Analysis of incidence and associated factors with fractured implants: A retrospective study. Int J Oral Maxillofac Implants 2000;15:662–667.
4. Fujii Y, Hatori A, Minami S, et al. Characteristics and risk factors for the fracture of one-piece implants. J Maxillofac Oral Surg 2023;22:1091–1098.
5. Mohseni P, Soufi A, Chrcanovic BR. Clinical outcomes of zirconia implants: A systematic review and meta-analysis. Clin Oral Investig 2023;28:15.
6. Tardelli JDC, Loyolla CD, Ferreira I, Kreve S, dos Reis AC. Influence of surface modifications on the fracture resistance of aged zirconia implants: A systematic review of in vitro experimental studies. J Oral Maxillofac Surg Med Pathol 2024;36:1–10.
7. Greenstein G, Cavallaro J, Romanos G, Tarnow D. Clinical recommendations for avoiding and managing surgical complications associated with implant dentistry: A review. J Periodontol 2008;79:1317–1329.
8. Misch K, Wang HL. Implant surgery complications: Etiology and treatment. Implant Dent 2008;17:159–168.
9. Hansen PA, Salinas AA. Management of a damaged implant for retention of an overdenture prosthesis and fixed single crown: Clinical reports. J Prosthodont 2018;27:376–382.
10. Stavropoulos A, Bertl K, Eren S, Gotfredsen K. Mechanical and biological complications after implantoplasty—A systematic review. Clin Oral Implants Res 2019;30:833–848.
11. Goh R, Tawse-Smith A, Atieh M, Duncan W, Ma S, Li KC. The effect of implantoplasty on dental implant fracture resistance: A systematic review. IIUM J Orofac Health Sci 2022;3:124–135.
12. Stavropoulos A, Bertl K, Isidor F, Vult von Steyern P. Implantoplasty and the risk of fracture of narrow implants with advanced bone loss: A laboratory study. Clin Oral Implants Res 2023;34:1038–1046.

Fujii Y, Hatori A, Minami S, et al. Characteristics and risk factors for the fracture of one-piece implants. J Maxillofac Oral Surg 2023;22:1091–1098.

The one-piece dental implant was originally designed to overcome the structural weaknesses of the two-piece implant. However, a fractured one-piece implant requires removal because the abutment cannot be repaired or replaced to support new prosthetic restorations. The aim of this study was to clarify the features and risk factors for fracture of the one-piece implant. This study was designed as a retrospective case series. The patients were treated for fractures of a one-piece implant at a clinic in Japan between 2012 and 2021. Fractures of the one-piece implant were diagnosed by CBCT imaging, and the association between age and duration from implant placement to fracture was analyzed by one-way ANOVA followed by the Tukey test. A total of 18 patients and 20 one-piece implants (< 39 years old: 5 patients and 6 implants; 40–59 years old: 7 patients and 7 implants; > 60 years: 6 patients and 7 implants) had fractures in their one-piece implants. Of the fractured implants, 11 had a diameter of 3 mm, and 9 had a diameter of 4 mm. The mean durations up to implant fracture were 662 days in the younger group (< 39 years old), 1,467 days in the middle group (40–59 years old), and 1,239 days in older group (> 60 years), with the duration being significantly shorter in the younger group. In addition, 83.3% of implant fractures in the younger group were in the molar region. All fractures of the one-piece implants occurred under the bone margin. Two patients had mandibular tori and one patient had bruxism. One-piece implants in younger patients located in the mandibular molar position were the most susceptible to implant fracture.

Correspondence to: yfujii@tokyo-med.ac.jp

Goh R, Tawse-Smith A, Atieh M, Duncan W, Ma S, Li KC. The effect of implantoplasty on dental implant fracture resistance: A systematic review. IIUM J Orofac Health Sci 2022;3:124–135.

An increase in dental implant placements in recent years has shown a growth in the reported cases of postoperative complications such as peri-implantitis. One of the available treatment modalities to overcome such complications is implantoplasty. Although this procedure is not new, the long-term effect of implantoplasty has not been addressed. The aim of this systematic review was to investigate the change in fracture resistance of dental implants after implantoplasty. Three electronic databases and reference lists of included studies were searched to assess the potential effect of implantoplasty on implant fracture resistance. Titles and abstracts were screened by two reviewers in parallel. The extracted information regarding implant fracture resistance was reported based on the guidelines set by the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement. A total of 56 studies were identified, of which 9 studies were included. Narrow-platform implants (< 3.75 mm) were more susceptible to fracture after implantoplasty compared to wider-platform implants (> 5 mm). Implants with an internal hexagon connection were shown to potentially have a higher risk of fracture after implantoplasty compared to other connection designs, such as external hexagon and conical connections. Other potential factors that potentially affect implant fracture resistance after implantoplasty include the crown-to-implant ratio, the implant material used, and the amount of peri-implant bone loss. Within the limitation of in vitro studies, there was no clear evidence to demonstrate the effect of implantoplasty on implant fracture resistance. Methodologic differences between the available studies did not allow for clear comparison between them. Furthermore, the limited number of clinical reports on this procedure, in combination with patient and operator variability, affect the clinical assessment of this treatment modality.

Correspondence to: andrew.tawse-smith@otago.ac.nz

Manfredini M, Poli PP, Giboli L, Beretta M, Maiorana C, Pellegrini M. Clinical factors on dental implant fractures: A systematic review. Dent J 2024;28;12:200.

Dental implant fractures pose a significant challenge to long-term treatment success. This systematic review aims to comprehensively examine the clinical factors influencing dental implant fractures (IFs). Furthermore, strategies to choose the right type of implant and prevent this complication are addressed. A systematic search was conducted across PubMed, Scopus, and Web of Science databases. The eligible studies were retrospective case-control studies, prospective cohort studies, and clinical trials. The initial search yielded 361 articles, of which 312 were excluded because they were reviews, case reports, had irrelevant information, or were written in languages other than English. This left 49 articles, with only 6 meeting the eligibility criteria for an in-depth review. They were all retrospective case-control studies that examined implant characteristics, patient demographics, surgical and prosthetic variables, biomechanical and functional factors, clinical and procedural variables, complications, and maintenance issues. The risk of bias was assessed as low using the ROBINS-I tool. Key findings suggest a correlation between implant diameter and structural resistance, with wider implants demonstrating reduced fracture risk. Additionally, posterior regions, especially molars and premolars, exhibit a greater susceptibility to IF due to increased masticatory forces. Implant design and material may considerably influence fracture risk, with conical implants and screw-retained prostheses showing a higher vulnerability to IF. Biomechanical overload, particularly in patients with bruxism, emerges as a primary contributing factor to IF. Prosthesis type significantly influences fracture incidence, with cantilever prostheses posing a higher risk due to increased stress. Peri-implant bone loss is strongly associated with IF, emphasizing the need for meticulous preoperative assessments and individualized management strategies. Future research should prioritize larger and heterogeneous populations with long-term follow-up and standardized methodologies to enhance the generalizability and comparability of findings. Randomized controlled trials and biomechanical studies under controlled conditions are also essential to elucidate the complex interactions contributing to IFs and to develop effective prevention strategies.

Additionally, integrating patient-reported outcomes may offer a comprehensive understanding of the impact of IF on quality of life.
Correspondence to: pierpaolo.poli@unimi.it

Mohseni P, Soufi A, Chrcanovic BR. Clinical outcomes of zirconia implants: A systematic review and meta-analysis. Clin Oral Investig 2023;28:15.

The aim of this study was to assess the clinical outcomes of zirconia dental implants based on an updated systematic literature review. An electronic search was performed in three databases, last updated in June 2023, and supplemented by hand searching. The eligibility criteria were clinical studies reporting patients rehabilitated with zirconia implants. The cumulative survival rate (CSR) of implants was calculated. A meta-analysis for marginal bone loss (MBL) under different follow-up times and a meta-regression assessing the relationship between mean MBL and follow-up were performed. In total, 25 studies were included (4,017 implants in 2,083 patients). Seven studies had a follow-up longer than 60 months. Overall, 172 implants failed (mean of 12.0 ± 16.1 months; min–max: 0.3–86.0). Of these, 47 were early failures, 26 were due to implant fracture, and the majority were narrow-diameter implants. The 10-year CSR was 95.1%. Implants with the coronal part prepared by drills presented statistically significant lower survival than non-prepared implants ($P < .001$). Two-piece implants presented lower survival than one-piece implants ($P = .017$). Implants discontinued from the market presented lower survival than the commercially available ones ($P < .001$). The difference in survival was not significant between implants in the maxilla and mandible ($P = .637$). The mean MBL fluctuated between 0.632 and 2.060 mm over long periods of observation up until 132 months. There was an estimated MBL increase of 0.005 mm per additional month of follow-up. Zirconia implants present high 10-year CSR and low short-term MBL.
Correspondence to: bruno.chrcanovic@mau.se

Stavropoulos A, Bertl K, Isidor F, Vult von Steyern P. Implantoplasty and the risk of fracture of narrow implants with advanced bone loss: A laboratory study. Clin Oral Implants Res 2023;34:1038–1046.

The aim of this study was to assess the impact of implantoplasty (IP) on the maximum implant failure strength of narrow-diameter implants of different type/design and material with simulated advanced bone loss. Narrow, parallel-walled implants (3.3 mm in diameter × 10 mm long) with an internal connection of different type/design (bone level [BL], tissue level [TL]) and material (titanium grade IV [Ti], titanium-zirconia alloy [TiZr]) from one specific manufacturer were used. Half of the implants were subjected to IP in their coronal 5 mm; the remaining were used as controls (7 implants per group). Dynamic loading prior to maximum load strength testing was included. During dynamic loading, the fracture rate of BL implants was low and independent of IP, while that of TL implants increased significantly with IP compared with controls ($P = .001$). The maximum implant failure strength reduction (%) due to IP was 1.3% to 25.4%, and the TiZr BL implants were least affected. Implants subjected to IP compared to those without IP as well as TL implants compared to BL implants showed a significantly lower maximum implant failure strength ($P < .002$); the effect of implant material was not significant ($P = .845$). Based on data from implants of one specific manufacturer, IP has a significant negative impact on the fracture strength of narrow implants with advanced peri-implantitis. TL implants have been more severely affected compared to BL implants and presented an increased risk for failure during normal chewing forces. In addition, this negative impact of IP on TL implants was independent of the implant material (ie, Ti or TiZr). Narrow-single TL implants with advanced horizontal bone loss (eg, 5 mm), when subjected to IP, appear to have an increased fracture risk during normal function.
Correspondence to: andreas.stavropoulos@mau.se

Tardelli JD, Loyolla CD, Ferreira I, Kreve S, dos Reis AC. Influence of surface modifications on the fracture resistance of aged zirconia implants: A systematic review of in vitro experimental studies. J Oral Maxillofac Surg Med Pathol 2024;36:1–10.

This systematic review aimed to evaluate the literature and answer the question: "Do surface-treated zirconia implants exhibit higher fracture resistance when subjected to aging than untreated ones?" This systematic review followed the PRISMA guidelines and was registered in the Open Science Framework (osf.io/ukhdz). A personalized search strategy was applied in the Embase, PubMed, Scopus, Science Direct, and Web of Science databases. Article selection was independently conducted in two steps by the reviewers. The risk of bias analysis was performed by adapting the Joanna Briggs Institute's quasi-experimental studies tool. A total of 648 articles were found in the initial search, and after excluding the duplicates, 601 were evaluated according to the title and abstract. Of these, 29 papers were selected for full-text reading, and 15 met the eligibility criteria. Concerning the risk of bias, 12 had a low risk of bias, and 3 had a moderate risk of bias. The articles included in this review were heterogeneous regarding the influence of surface treatment on the fracture resistance of zirconia implants. The literature reviewed allowed for the inference that there is a need for care in the zirconia implant development to have fracture resistance according to the parameters defined in ABNT, ASTM, or ISO standards, which help ensure the survival of zirconia implant rehabilitation.
Correspondence to: andreare73@yahoo.com.br

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.

The aim of this study was to perform an analysis of the incidence of implant body fracture and to identify possible risk factors. A long-term follow-up retrospective evaluation of 3,477 patients who received 8,588 implants from five implant systems was performed. Overall, 2,810 patients who received 7,502 implants, with an average follow-up of 6.9 years, were included in the analysis. The overall body fracture rate was 0.49% (37/7502), among which 32.4% (12/37) were implants with a reduced diameter. The estimated cumulative fracture rate was 1.24%. Fractures were observed in 2 patients with 3 Brånemark implants, 13 patients with 15 Nobel Replace implants, 8 patients with 8 Camlog implants, 8 patients with 11 Ankylos implants, and none of the patients with Thommen implants. Most fractures occurred in the molar region (29/37) and in single implant-supported restorations (30/37). The results showed significant differences between splinted and unsplinted restorations ($P = .005$) and between regular- and narrow-diameter implants ($P = .009$). Within the limitations of this retrospective analysis, a narrow-implant diameter is a potential risk factor for implant body fracture in the posterior region. Furthermore, unsplinted restorations appear to be associated with a higher rate of implant fracture.

Correspondence to: qiu_lixin@yeah.net