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CLINICAL RESEARCH

Retrospective analysis of dental implant fracture following loading: A retrospective clinical study

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ABSTRACT

Statement of problem. Fracture of an osseointegrated implant (FOI) is a rare complication that occurs primarily after loading and may lead to other complications including failure or fracture of the implant-supported prosthesis. Risk factors for FOI are not well understood.

Purpose. The purpose of this retrospective clinical study was to determine the frequency of occurrence of FOI among participants treated with dental implants in an academic setting and to identify and analyze the possible risk indicators and contributing factors.

Material and methods. A retrospective analysis was performed using dental records of participants who received dental implant treatment at the Faculty of Dentistry, University of Toronto, from January 1979 until January 2020, and experienced post-loading FOI. A systematic search of the dental records was conducted, and clinical situations with FOI were identified. Data related to patient factors, implant factors, and prosthesis factors were collected from the identified clinical situations with FOI. The data were analyzed to determine the incidence of FOI. A descriptive analysis was used to identify the possible risk indicators for FOI.

Results. A total of 7712 implants had been placed at the Faculty of Dentistry, University of Toronto, from January 1979 until January 2020. During the 41-year period, a total of 27 fractured implants were identified. The incidence of FOI following loading was 0.35%. Overall, the mean ±standard deviation time between loading and occurrence of implant fracture was 10.6 ±7 years. Implant fractures occurred in 23 different study participants; 16 men, and 7 women, with a mean ±standard deviation age of 65.4 ±8.0 years at the time of FOI. Factors associated with implant fracture include narrow-diameter implants (≤3.75 mm), implants placed in posterior mandible (molar or premolar regions), presence of a long cantilever, and unfavorable implant design (such as the Tri-Channel design). Among the 27 fractured implants, 19 were removed, 6 were buried, and 2 were adjusted or smoothed and restored with a new prosthesis.

Conclusions. The incidence rate of FOI was very low, but might have been increased by an increased presence of predisposing risk factors. (J Prosthet Dent 2025;134:143-150)

Dental implants have become a popular treatment option with high survival and success rates.[1] However, dental implants and implant-supported prostheses can experience complications including implant loss.[2] Implant complications can be categorized into biological (such as, failure of osseointegration, severe infection) or mechanical (such as, screw loosening, screw fracture, implant fracture).[3,4] One of the most severe mechanical complications is implant fracture. Implant fracture can occur at the time of surgical implant placement as a surgical complication secondary to high insertion torque or as a mechanical complication following prosthesis loading.[5]

Fracture of an osseointegrated implant (FOI) is a relatively rare mechanical

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Clinical Implications

Understanding factors associated with FOI can lead to better planning and execution of the implant treatment and improved patient outcomes.

complication with an estimated incidence of 0.2 to 1.5%.[5,6] Several factors have been reported as a possible cause for the FOI,[7–9] that either result in elevated forces being transmitted to the implant(s) or result in the reduced ability of the implant(s) to withstand these forces.[10,11] These factors have been classified into 4 major categories: manufacturing factors (such as, materials used in implant production, general implant shape, implant design, and connection type)[12–14]; biomechanical factors (such as number of implants, implant distribution, prosthetic design, and length of the cantilever)[8,15,16]; iatrogenic factors (such as cross-threading of the internal threads, improper treatment planning and prosthesis design, and improper occlusion)[10,17]; and patient factors (such as masticatory forces, and parafunctional activities).[17–20] The management of FOI is challenging and may include additional surgery, prosthesis modification, or new prosthesis fabrication.[19,21,22]

Clinical studies on FOI are somewhat limited (Table 1); hence, its etiology has been imperfectly understood.[19,23,24] Understanding risk factors for FOI would be beneficial in preventing its occurrence and may lead to better planning and execution of the implant treatment as well as improved patient outcomes.[19,22]

Therefore, the objective of this retrospective clinical study was to determine the incidence of FOI among participants treated with dental implants in an academic setting and to identify its risk indicators. This research hypothesis was that FOI was influenced by factors that included implant diameter, implant location, prosthesis design, and patient-specific characteristics. By identifying these risk indicators, this study aimed to improve treatment planning and enhance long-term implant success.

MATERIAL AND METHODS

This retrospective clinical study used the dental records of participants who received dental implants and experienced implant fracture at the Faculty of Dentistry, University of Toronto and had been approved by the Research Ethics Boards (protocol No. 40222). The Faculty of Dentistry at the University of Toronto has been providing dental implant-supported prostheses since 1979, which provides access to one of the longest follow-ups of implant treatment in the world. Patients provided with implant-supported prostheses have been recalled on a regular basis. The inclusion criteria were adult participants ≥18 years old who received dental implant(s), experienced an FOI, and had dental records and radiographs available. The exclusion criteria were adult participants who received dental implant(s) and either did not experience an FOI or experienced implant fracture before loading.

The dental records of all patients provided with dental implants at the Faculty of Dentistry, University of Toronto, from January 1979 until January 2020 were accessed through a dental database (axiUm; Exan Enterprises Inc). A systematic search was conducted of the dental records using keywords within the daily appointment notes for implant complications, implant fracture, and implant failure, as well as using the treatment codes for implant placement, implant removal, and implant failure available in the dental records (Fig. 1). Reports were generated and reviewed to identify all incidents of fractured implant. Paper charts were reviewed to obtain more details when needed for implant treatments before 2007. Extracted data from the dental records were de-identified by using the coded identifier list and reviewed. To understand the risk

Table 1. Studies reporting dental implant fractures. All studies had retrospective design

Study	Study Year	Maximum Duration of Follow-up (Years)	Population (P: participants; I: Implants)	Implant Fractures Number (%)	Identified Risk Factors or Indicators
Balshi[19]	1996	5	P: N/A I: 4045	8 (0.2%)	posterior position, overload, misfit, cantilever, parafunction
Eckert et al[23]	2000	15	P: N/A I: 4937	28 (0.6%)	partially edentulous restorations (1.5%), pure titanium, 3.75 mm diameter implants
Gargallo-Albiol et al[24]	2008	18	P: N/A I: 1500	21 (1.4%)	diameter of 3.75 mm (one 4 mm), men, cantilever, molar or premolar regions, 3–4 years after loading
Tabrizi et al[29]	2017	12	P: N/A I: 18 700	37 (0.002%)	tapered implants, screw-retained prostheses, molar and premolar areas
Stoichkov et al[9]	2018	10	P: 101 I: 218	5 (2.3%)	bruxism, inappropriate occlusion, single crowns
Chrcanovic et al[7]	2018	14	P: 2670 I: 10 099	44 (0.44%)	grade of titanium, implant diameter, implant length, cantilever, bruxism
Lee et al[20]	2019	12	P: 101 I: 218	5 (2.3%)	narrow implants, absence of microthreads

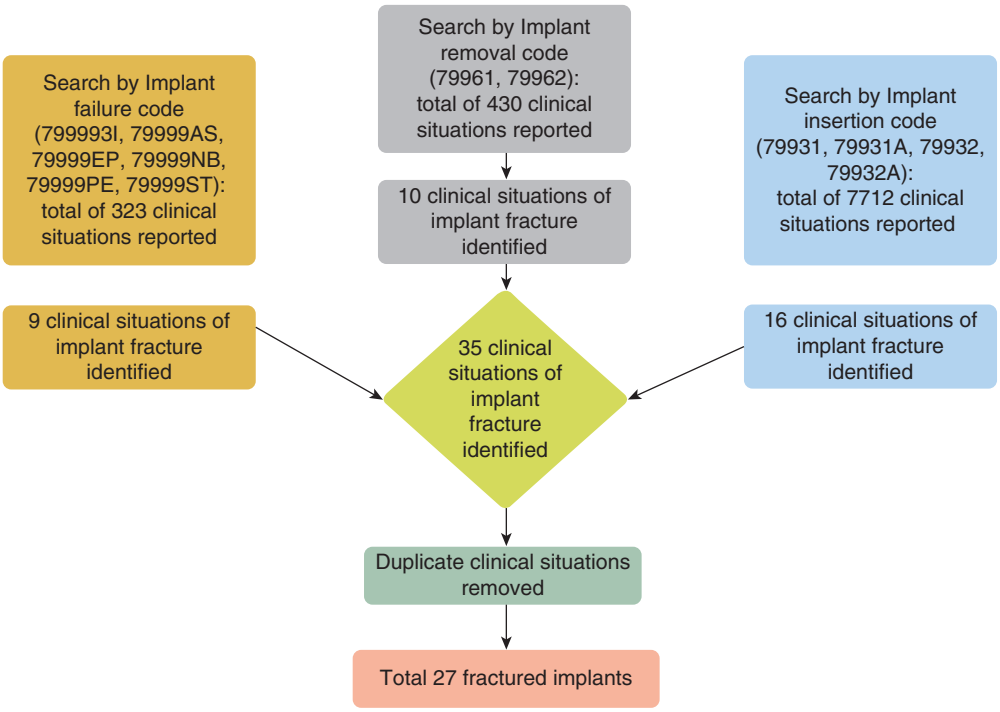

Figure 1. Flow chart of clinical situations identification.

indicators for implant fracture, data on patient factors, implant factors, and prosthesis factors were collected from the dental records.

The data were analyzed to determine the frequency of occurrence of implant fracture, duration of prosthetic service before implant fracture, percentage of fractured implants based on implant location, percentage of fractured implants based on sex, and the presence or absence of cantilevers. Descriptive analysis was used to identify risk factors in relation to implant fracture.

RESULTS

A total of 7712 implants in 3418 patients were placed at the Faculty of Dentistry, University of Toronto, from January 1979 until January 2020. More implants were placed in women (4247 implants in 1927 participants) than in men (3465 implants in 1491 participants), in the maxilla (4293 implants, 56%) than the mandible (3419 implants, 44%), and in the posterior region (5615 implants, 73%), than in the anterior region (2097 implants, 27%). Over the years, several implant brands and products were placed including Brånemark (MK II and MK III), Nobel BioCare (Nobel Replace, Nobel replace conical connection and Nobel Active), Straumann (Bone Level and Tissue Level), Zimmer Biomet (Osseotite and T3), Astra (Osseospeed TX, Osseospeed EV), and Sybron Implant (Endopore).

From the total of 7712 inserted implants, 430 implants were reported as removed, and 323 implants were reported as failed. Finally, a total of 27 clinical situations of FOI were identified (Fig. 1), representing an incidence rate of 0.35%. Overall, the mean time between loading and occurrence of implant fracture was 10.6 ±7 years (range: 1 to 25 years, median: 8 years, IQR: 14) (Table 2).

Implant fractures occurred in 23 different participants (16 men, 7 women), of whom 19 had 1 fractured implant, and 4 had 2 fractured implants. The mean age of the participants at the time of implant fracture was 65.4 ±8.0 years. A total of 22 implants fractured in participants whose parafunction was controlled with a nightguard appliance, 2 implants fractured in participants whose parafunction was not controlled, and 3 implants fractured implants in participants without parafunction (Table 2).

The fractured implants belonged to 6 brands: Brånemark; Titanium with machined surface (15 implants), Astra Osseospeed EV; Titanium with fluoride-modified titanium oxide surface (6 implants), Zimmer Biomet Osseotite; Titanium with a dual acid-etched surface (2 implants), Nobel Biocare Replace; Titanium with oxidized surface (2 implants), Straumann Bone Level; Titanium with SLA surface (1 implant), and Straumann Tissue Level; Titanium with SLA surface (1 implant). The implant-abutment connection was found to be an external hexagon connection in 16 implants and an internal connection in 11 implants (6 with Conical Seal Design, 2 with Tri-Channel Connection, 1 with CrossFit Connection, 1 with synOcta Connection, and 1 with Certain Internal Connection). The mean ±standard

Table 2. Distribution of placed implants and fractured implants according to characteristics

Implant Characteristics	Number	Percentage
Total Number of Fractured Implants	27	
Mean age (years)	65.40 ±8.0 (40 –82 years)	
Sex		
Men	18	67%
Women	9	33%
Parafunction		
No	3	11%
Yes, controlled	22	81%
Yes, not controlled	2	7%
Implant Diameter		
3.3 mm	1	4%
3.5 mm	8	30%
3.75 mm	7	26%
4.0 mm	3	11%
4.1 mm	1	4%
4.5 mm	3	11%
4.8 mm	1	4%
5.0 mm	1	4%
5.5 mm	2	7%
Implant Location		
Anterior Maxilla	2	7%
Posterior Maxilla	8	30%
Anterior Mandible	4	15%
Posterior Mandible	14	52%
Implant Brand		
Branemark MK II	4	15%
Branemark MK III	11	41%
Nobel Biocare Replace	2	7%
Straumann Bone Level	1	4%
Straumann Tissue Leve	1	4%
Zimmer Biomet Osseotite	2	7%
Astra Osseospeed EV	6	22%
Implant-Abutment Connection		
external hexagon	16	59%
Conical Seal Design	6	22%
Tri-Channel Connection	2	7%
CrossFit Connection	1	4%
synOcta Connection	1	4%
Certain Internal Connection	1	4%
Type of Prosthesis		
single crown	10	37%
fixed dental prosthesis (complete arch)	8	30%
fixed dental prosthesis (multi-unit, partial edentulism)	6	22%
Removable dental prosthesis	3	11%
Preceding Mechanical Complications		0%
screw loosening	7	26%
prosthesis fracture	4	15%
screw fracture	2	7%
no complications	14	52%
Fractured Region		0%
coronal third	21	78%
middle third	6	22%
apical third	0	0%

deviation length of the fractured implants was 11.2 ±1.7 mm, and the mean ±standard deviation diameter of the fractured implants was 4.0 ±0.5 mm, with 56% (15 out of 27) of the fractured implants being Ø3.75 mm or less. A total of 21 implants fractured in the coronal third (78%), while 6 implants fractured in the middle third (22%), and no implant fractured at the apical third.

Regarding the management of these 27 fractured implants, 19 implants were removed, 6 were buried, and 2 were adjusted, smoothed, and restored with a new prosthesis. Out of the 19 implants removed, 5 implants fractured further during the surgical removal, leaving an apical fragment permanently in the bone (Table 2, Figs. 2–4).

A total of 10 implants supported single crowns, 8 implants supported complete arch fixed dental prostheses, 6 implants supported fixed multiunit prostheses restoring partial edentulism, and 3 implants supported complete removable dental prostheses. Among the fixed prostheses, 23 implants supported screw-retained restorations, and 2 implants supported cemented restorations. A total of 12 implants supported a fixed prosthesis with a cantilever.

Fractured implants were opposed by natural dentition in 14 out of the 27 clinical situations. Mechanical complications (such as screw loosening, screw fracture, or prosthesis fracture) were observed in 13 implants and supported prostheses prior to FOI, with an average of 2.4 prior complications per fractured implant. Screw loosening was observed as the most common complication in 7 implants, followed by prosthesis fracture in 4 implants, and screw fracture in 2 implants.

DISCUSSION

This retrospective clinical study aimed to determine the incidence of FOI in an academic setting and identify its potential risk factors. The findings supported the research hypothesis that FOI would be influenced by implant diameter, location, prosthesis design, and patient-specific factors. The results indicate that narrow-diameter implants, posterior placement, long cantilevers, and specific implant designs were associated with an increased risk of fracture.

A retrospective design was the most appropriate in this clinical study for the assessment of a relatively rare outcome like FOI and its risk indicators. This design provided straightforward data collection and less concern for loss to follow-up without reducing the ability for risk assessment.[25]

The calculated incidence of implant fracture following loading was 0.35%, consistent with the previously reported incidence. For example, a review by Goodacre et al[6] reported an overall 1% implant fracture rate among 12 157 implants. Similarly, Balshi[19] analyzed the etiology and management of fractured implants and reported a small incidence of 0.2% implant fractures among 4045 implants during 5 years of follow-up. Eckert et al[23] reviewed records at the Mayo Clinic on a total of 4937 implants and reported that 1.5% of implants in partially edentulous arches fractured and 0.2% of implants in edentulous arches fractured. Gargallo-Albiol et al[24] reported a 1.4% fracture incidence among 1500 implants.

Different factors have been reported as a possible risk for FOI, in general, either resulting in elevated forces

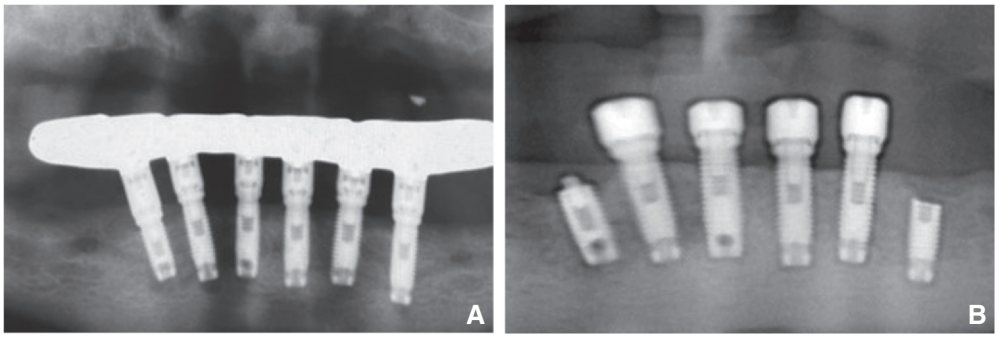

Figure 2. Panoramic radiographs of participant who experienced FOI. A, Fixed implant-supported prosthesis fabricated over 6 implants. B, Two most distal implants supporting fixed complete arch prosthesis fractured. Fractured implants buried, and removable implant-supported prosthesis fabricated instead. FOI, Fracture of osseointegrated implant.

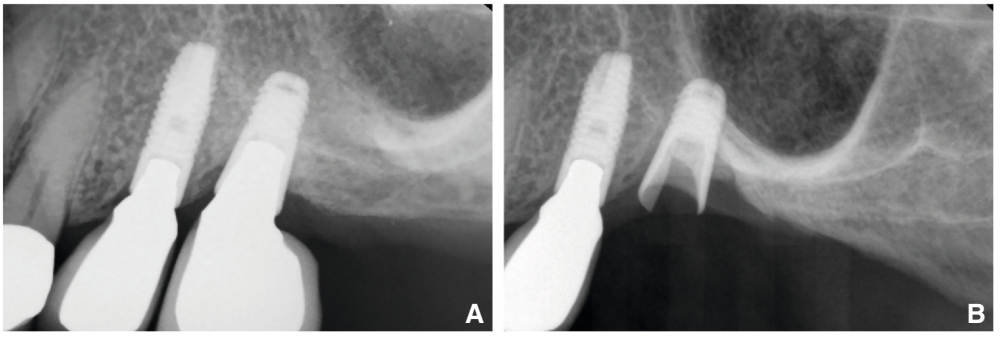

Figure 3. Periapical radiographs of patient who experienced FOI. A, Two implant-supported crowns inserted on implants replacing maxillary left second premolar and first molar. B, Implant supporting maxillary left molar fractured associated with off-axial loads and parafunction. FOI, Fracture of osseointegrated implant.

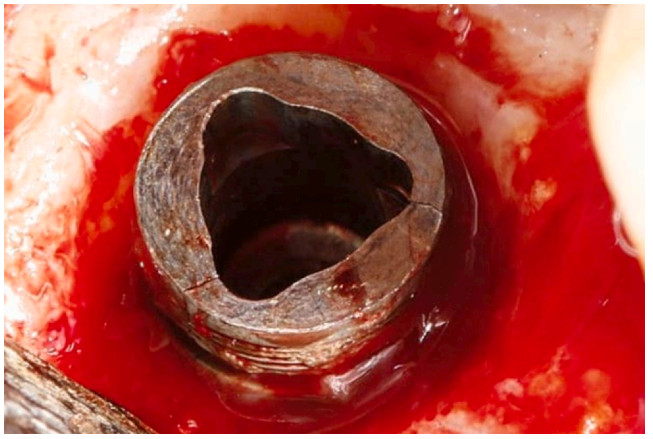

Figure 4. Intraoral image of FOI showing Nobel Replace implant (Tri-Channel design) with regular connection (Ø4.3 mm) used to replace single crown in posterior mandible (right first molar location) of patient with a history of parafunction (Courtesy Dr J. Kermali, Richmond Hill, Canada). FOI, Fracture of osseointegrated implant.

being transmitted to the implant(s) or reducing the ability of the implant(s) to withstand these forces.[10] To better understand these factors, they were divided them into patient level, implant level, and prostheses level factors.

In the overall implant population in this study, 55% of the implants (4247 of 7712) were placed in women. However, the fractured implants were more frequently in men (2:1). A similar observation that implants fracture were more common in men than in women (15:4) was reported by Gargallo-Albiol et al,[24] possibly related to the higher overall forces generated and transferred to the implant in men than in women.[24]

The majority of the FOI in the study (24 out of 27) were in patients with parafunction. Chrcanovic et al[7] identified the presence of parafunction as a major cause of overloading associated with a higher risk of implant fracture.[26] Others also identified bruxism and heavy occlusal forces as factors associated with an increase in implant loading and an increased risk of fracture.[19,24]

In this study, 73% of the implants (5615 out of 7712) were placed in the posterior region. It is not surprising that 81% of the fractured implants (22 out of 27) were placed in the posterior region. Similarly, most fractures reported in the literature also occurred in the posterior quadrants equally distributed between the maxilla and mandible. For example, Gargallo-Albiol et al[24] noted a higher incidence of implant fractures (80.9%) in the molar and premolar sites, which may be associated with bending overload created by a combination of

parafunctional forces and posterior cantilevers.[19] The higher incidence may also have been associated with the increased occlusal loads in the posterior area, which are 3 times greater than occlusal loads in the anterior area.[8,19,27] Single implants in the posterior region are particularly vulnerable to occlusal overload, as the load-sharing within multi-unit restorations typically shields a single implant from undue occlusal forces.[8,11]

Contemporary implants have an improved design that favors dissipation of interfacial stress through enlarged implant surface area with the concept of double-threaded or triple-threaded implants.[13] Modern implants also have an improved material composition by using commercially pure titanium (cpTi) with higher oxygen content (0.4%) (that is, grade 4 cpTi) as well as titanium alloys (mainly Ti-6Al-4V) to have improved mechanical properties that make them more fracture-resistant.[14,28] Nonetheless, a narrow diameter implant of contemporary design and material composition may still have less ability to withstand forces compared with the regular and wide diameter implants. In the present study, using a Ø3.75 mm or narrower implant was a risk indicator for implant fracture, although this was found primarily in the Brånemark external hexagon implants. This result was also noted in retrospective studies by Eckert et al[23] and Balshi[19] who reported that all fractured implants were 3.75 mm in diameter.[19,23] Shemtov-Yona et al[12] reported that fractures occurred where thin metal cross-sections in narrow implants coexisted with sharp notches. A recent retrospective analysis by Tabrizi et al[29] reported that standard or narrow diameter implants are sometimes used in the molar area to avoid bone augmentation, which in turn increases the risk of implant fracture.

In the present study, fractured implants were seen more in implant-supported fixed multi-unit prostheses in partially edentulous patients. The type of restoration (fixed or removable implant-supported prosthesis) may influence the load and stress that are transmitted to the implant.[23,24] Fractured implants have been reported to be most often supported by fixed prostheses, while few fractured implants supported removable prostheses.[20,24] Rangert et al[8] reported that all fractured implants supporting multi-unit fixed prostheses had straight-line alignment and concluded that this geometry created undesirable bending moments on the implants.

Screw-retained restorations were found in 85% of the fractured implants (23 out of 27) which is likely because of the predominant use of screw retention at the Faculty of Dentistry, University of Toronto as a means of prosthesis retention. Tabrizi et al[29] reported that the incidence of implant fracture was the highest among single screw-retained prostheses. Screw-retained restorations have been reported to have more technical complications than cement-retained ones,[30] possibly because of stress being transferred directly to the implant in screw-retained type, which may be amplified by the presence of a misfit of the multi-unit prostheses.[14] Screw loosening in fixed implant-supported prostheses has been reported to often precedes implant fracture and could be considered a warning sign.[19,23] Screw loosening and fracture may be caused by framework misfit, excessive occlusal force, poor prosthetic component design, unfavorable leverage, or parafunction.[31]

The treatment of fractured implants represents a clinical challenge. Management depends on the location of the fracture (between teeth or in a terminal position), the level of the fracture (superficial or deep), the space remaining between the implant and the adjacent teeth, the condition of adjacent teeth or implants, and the patient's esthetic and functional needs.[21] Three management protocols for fractured implants were identified in the present study: 19 implants were removed, 6 were buried, and 2 were modified and then restored. This was similar to management protocols reported previously.[19] It should be noted that the management of the fractured implant must be undertaken with the prosthodontic end-goal in mind. If the implant is to be removed, this should be accomplished atraumatically.[22]

Limitations of this retrospective clinical study included those inherent to the retrospective cohort design employed to analyze existing records.[25] As with any retrospective clinical study, insufficient chart documentation, the reliability of clinical reports, and the possibility of selection bias among clinicians can contribute to missing data.[32] The study population was limited to the patients who received dental implant-supported prostheses at the Faculty of Dentistry, University of Toronto. The academic setting and the strict treatment protocols provided standardization for the procedure and facilitated the identification of risk indicators. However, this may reduce the generalizability of the findings, and a different incidence might be expected in other settings, such as private practice or of providers with different levels of expertise. Despite these limitations, this retrospective clinical study has several strengths, employing a comprehensive, multi-prong approach to systematically search dental records and ensure the identification of all FOI. Additionally, its retrospective design allowed for data collection spanning nearly 41 years, a significantly longer period compared to most prospective dental studies, which typically have shorter follow-up durations.

These findings have implications for research, clinical practice, and education. By identifying possible risk indicators associated with FOI, this retrospective clinical

study may lead to better planning and execution of the implant treatment. Based on the results of this study, clinicians should carefully consider the use a narrow diameter implants when planning for posterior implants, pay extra attention to controlling and reducing occlusal forces, especially in participants with parafunction, follow a robust follow-up protocol to identify any early signs of mechanical complications, and ensure a passive fit of the prosthesis to reduce stress being transferred to the implant.

Additional clinical studies are needed to further explore the relationship between the risk indicators and implant fracture. Future in vitro studies should focus on improving the design and materials used to increase the strength of the implant body.

CONCLUSIONS

Based on the findings of this retrospective clinical study, the following conclusions were drawn:

1. The incidence rate of implant fracture in an academic setting was low.
2. Risk indicators for implant fracture, such as narrow diameter, might affect the incidence of implant fracture.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This retrospective cohort study was performed in adherence to The Code of Ethics of the World Medical Association and is in line with the Recommendations for the Conduct, Reporting, Editing and Publication of Scholarly Work in Medical Journals. The study was approved by the University of Toronto (Protocol No. 40222).

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIAL

Data tables are included in the manuscript.

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