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Clinical Paper
Dental Implants

Analysis of fractured dental implant body from five different implant systems: a long-term retrospective study

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H. Yu, L. Qiu: 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.

Abstract. 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 3477 patients who received 8588 implants from five implant systems was performed. Overall, 2810 patients who received 7502 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 two patients with three Brånemark implants, 13 patients with 15 Nobel Replace implants, eight patients with eight Camlog implants, eight 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 ($P = 0.005$) and between regular and narrow diameter implants ($P = 0.009$). 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.

Key words: Dental implant; Peri-implant fractures; Dental implant-abutment connection; Prosthodontics; Bone–implant interface.

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Dental implants are one of the most common treatment options for the rehabilitation of edentulous patients.[1,2] Although long-term maintenance of osseointegration has been confirmed in several studies, fracture of the implant body is a potential mechanical complication that poses a challenge.[3–5] The reported incidence of implant body fracture is in the range of 0.16–3.5%,[3,6] with most fractures occurring after 5 years of clinical function. According to a systematic review on implant complications, the cumulative incidence of fracture of the implant body is 0.4% after 5 years and 1.8% after 10 years.[3]

In brief, implant fractures develop as a result of progressive metal fatigue, which occurs for various reasons. As far as implant systems are concerned, fractures may occur due to implant and prosthetic

Table 1. Distribution of implant fracture based on the type of prosthetic restoration.

Implant brand	Unsplinted crown				Splinted crown			
	Maxilla		Mandible		Maxilla		Mandible	
	Total implants, *n*	Fractured implants, *n*	Total implants, *n*	Fractured implants, *n*	Total implants, *n*	Fractured implants, *n*	Total implants, *n*	Fractured implants, *n*
Brånemark	5	0	10	3	0	0	0	0
Nobel	201	5	176	8	320	2	287	0
Camlog	604	6	579	2	68	0	79	0
Ankylos	462	4	519	2	301	1	386	2
Thommen	478	0	503	0	637	0	704	0
Total	1750	15	1787	15	1326	3	1456	2
Implant brand	Full-arch implant-supported fixed dentures				Implant-supported overdentures			
	Maxilla		Mandible		Maxilla		Mandible	
	Total implants, *n*	Fractured implants, *n*	Total implants, *n*	Fractured implants, *n*	Total implants, *n*	Fractured implants, *n*	Total implants, *n*	Fractured implants, *n*
Brånemark	0	0	0	0	0	0	0	0
Nobel	113	0	60	0	68	0	64	0
Camlog	24	0	18	0	14	0	16	0
Ankylos	80	0	74	2	64	0	80	0
Thommen	176	0	220	0	56	0	56	0
Total	393	0	372	2	202	0	216	0

design defects.[7] From the perspective of implant surgery, the indication for treatment selection, the number and diameter of the implants, and the three-dimensional position of the implant may all affect the occurrence of implant fracture.[7] Prosthetic factors such as the prosthesis/abutment material, one-/two-piece implant structure, and splinted/unsplinted restoration result in different load distributions and stress concentrations. Such factors could be a possible reason for implant body fracture.[8] In addition, several patient-related factors, including implant site and parafunctional habits, may also lead to implant fracture. According to a previous study, an implant body fracture is more likely to occur in the maxilla than in the mandible owing to the weaker bone structure with more bone loss at high loads.[7] On the other hand, another study reported no significant difference in fracture susceptibility based on the anatomical location of the implant.[9] Eckert et al.[10] reported that implant body fractures were seen in both arches at similar rates, with an incidence of 0.6% each in the maxilla and mandible. Moreover, single implants placed in the posterior area, particularly in the molar area, have been reported to be at a higher risk of developing this complication.[11]

The different brands of implant have unique designs with features of rotational resistance, indexing, and lateral stabilization. The purpose of this study was to retrospectively evaluate the incidence of implant body fracture after long-term follow-up and to identify possible risk factors for implant fracture. This study was performed in accordance with the STROBE guidelines (https://www.strobe-statement.org/).

Patients and methods

Patient selection

In this retrospective evaluation, the outcomes of all implants that were placed in consecutive patients by the study authors between January 1, 1998 and December 31, 2016, at Peking University School and Hospital of Stomatology, were screened. Inclusion criteria were age > 18 years, completion of the final restoration, and implants that had maintained osseointegration and had not been removed for any reason other than fracture. The following exclusion criteria were applied: patients who did not return to the hospital and could not be followed up by telephone for at least 2 years. Although different implant systems were used during different time periods in the study hospital, all implants were placed following standard surgical protocols by experienced surgeons.

The study protocol was evaluated and approved by the Institutional Ethics Committee of Peking University School and Hospital of Stomatology (PKUSSIRB-2016113115).

Clinical assessments and follow-up

The follow-up protocol included patient assessments at 1, 3, 6, and 12 months after surgery and annually thereafter. Standardized panoramic radiographs were taken immediately after surgery and every year thereafter. The clinical records were evaluated and the data recorded by trained assistants. The following information was obtained for each implant body fracture case: implant system (connections and anti-rotational components), location of the fractured implant, date of implant fracture, dimensions of the fractured implant, prosthetic strategy, and date of complications (if any) before implant fracture. Observations of excessive wear made by the clinician and/or a history of fracture of the natural teeth or veneering material were considered as bruxism or heavy occlusal forces. Telephone interviews to confirm any possible implant body fracture were conducted for patients who failed to return for clinical follow-up examinations. The follow-up period was defined as the number of years from implant placement to the most recent appointment or telephone follow-up date, or the date of implant failure.

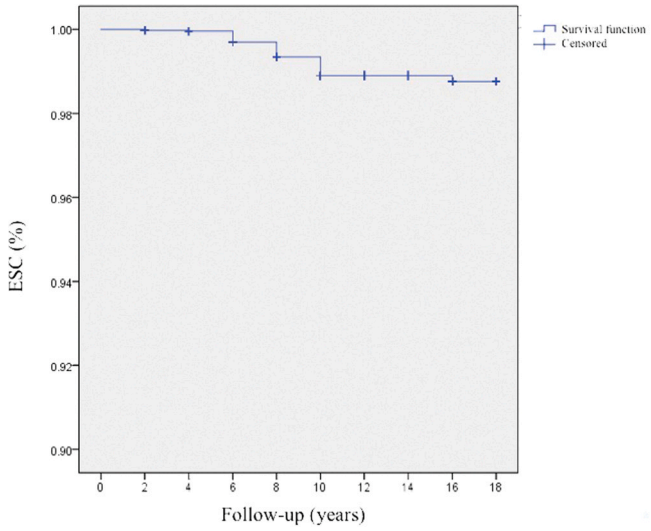

Fig. 1. Kaplan–Meier estimated cumulative survival (ECS) curve for implant body fracture.

Statistical analysis

All data were analysed using SPSS software version 14.0 (SPSS Inc., Chicago, IL, USA). The χ^2 test or Fisher's exact test, as appropriate, was used to determine the effect of factors influencing implant fracture. *P*-values < 0.05 were considered statistically significant.

Results

The initial study sample comprised 3477 patients with 8588 implants. During the recruitment phase, 667 patients with 1086 implants were unable to attend the recall visit and could not be followed up by telephone within 2 years; these patients were excluded. Hence the final sample comprised 2810 patients who received 7502 implants. The patients were followed up for up to 18 years (mean 6.9 years, range 2–18 years). The study sample included eight patients with 15 Brånemark implants with 9–18 years of follow-up, 591 patients with 1402 Camlog implants with 2.5–15 years of follow-up, 450 patients with 1289 Nobel Replace implants with 5–15 years of follow-up, 601 patients with 1966 Ankylos implants with 2.5–16 years of follow-up, and 1160 patients with 2830 Thommen implants with 2–6 years of follow-up. The distribution of the implants according to the restorative structure type is shown in Table 1.

There were 37 recorded cases of implant body fracture during the follow-up period. The overall fracture rate was 0.49%. The estimated cumulative implant body fracture rate was 1.24% (Fig. 1). Fractures were observed in two patients with three Brånemark implants (20% of implants), 13 patients with 15 Nobel Replace implants (1.16% of implants), eight patients with eight Camlog implants (0.57% of implants), and eight patients with 11 Ankylos implants (0.56% of implants); none of the 2830 implants in the 1160 patients with Thommen implants had an implant body fracture.

The average time from implantation to implant fracture was 7.16 years (range 2–15 years). Table 2 summarizes the distribution and characteristics of the fractured implants, including the type/location of the fracture, for the four different implant brands used: 19 implant body fractures were reported in the mandible (Brånemark: 3/10, Nobel Replace: 8/587, Camlog: 2/692, Ankylos: 6/1059) and 18 in the maxilla (Brånemark: 0/5, Nobel Replace: 7/702, Camlog: 6/710, Ankylos: 5/907), with a similar incidence rate of implant body fracture in the two arches. Of the 37 fractures, 29 occurred in the molar region, seven in the premolar region, and one in the anterior region. Tables 1 and 2 also summarize the types of prosthetic restoration associated with the fractured implants. On comparison of the distribution of implant fractures according to the type of prosthetic restoration, most fractures were found to occur in single implant-supported restorations (30/37). A statistically significant difference between splinted and unsplinted restorations was revealed, with a higher frequency of implant fracture in unsplinted restorations (χ^2 = 8.372, *P* = 0.005). In addition, the implant diameter (narrow vs regular; *P* = 0.009) was found to be a risk factor for implant body fracture. Although implant fracture occurred more frequently in cases with a conical connection when compared to a butt joint, this difference did not reach statistical significance (*P* = 0.059). The main outcomes are summarized in Table 3.

The implant body fractures were subsequently categorized into three types. Of the 37 implant fractures, 14 had occurred along the thinnest wall of the implant neck and had propagated apically to the root of the implant threads (Fig. 2), another 14 fractures had occurred in the apical region of the self-tapping threads (Fig. 3), while nine fractures had occurred at the self-tapping thread (Fig. 4).

In 12 patients, previous bone destruction apically extending to the level of the implant fracture was documented before any clinical signs of fracture. The clinical records revealed that screw loosening was observed before fracture in 10 patients. Moreover, parafunctional habits had been reported in 28 of the patients with implant body fractures.

Six of the fractured implants had been removed and replaced simultaneously with a larger-diameter implant. Four patients with four fractured implants rejected this second implant placement. The other cases were allowed a healing period of 3–6 months, which was followed by a second-stage surgery.

Discussion

This study, based on retrospective data, analysed implant body fractures in patients treated with five different implant systems after long-term follow-up and was conducted to determine the potential causes of dental implant body fracture.

The fracture of a dental implant body is an uncommon occurrence, with most studies reporting an implant fracture incidence in the range of 0.16–3.5%[6,11]; the incidence reported in the present study is within this range. Previous studies have reported an incidence of implant fracture with Brånemark implants ranging from 0.17% to 1.5%,[12,13] while this rate was 20% in the present study. This difference may be explained by the limited number of Brånemark implants that were used by

Table 2. Distribution and characteristics of fractured implants.

Implant brand	Sex	Time after implantation (years)	Implant site	Width/ length (mm)	Implant prosthesis method	Abutment material	Occlusal material	Location of fracture [a]
Camlog	Male	8	36	4.3 × 13	Single	Titanium	Zirconia	N
	Male	10	25	3.8 × 11	Single	Titanium	Zirconia	N
	Male	10	26	5.0 × 11	Single	Titanium	Zirconia	N
	Male	2.5	27	4.3 × 11	Single	Titanium	Zirconia	E
	Male	10	17	4.3 × 13	Single	Titanium	Zirconia	N
	Female	2	26	4.3 × 11	Single	Titanium	Zirconia	N
	Female	4.5	26	4.3 × 11	Single	Titanium	Zirconia	N
	Male	8	37	4.3 × 11	Single	Titanium	Porcelain	N
Brånemark	Female	15	46	3.75 × 13	Single	Titanium	Porcelain	E
	Male	9	46	3.75 × 13	Single	Titanium	Porcelain	E
		10	36	3.75 × 13	Single	Titanium	Porcelain	E
Nobel Replace	Female	5	36	4.3 × 13	Single	Gold	Metal	N
	Female	6.5	46	4.3 × 13	Single	Gold	Metal	E
	Male	5	46	4.3 × 14	Single	Gold	Metal	E
	Female	5.5	26	4.3 × 15	Single	Gold	Metal	N
	Male	9	45	4.3 × 13	Single	Gold	Metal	E
	Male	7.5	36	4.3 × 16	Single	Gold	Metal	E
	Male	8.5	46	4.3 × 13	Single	Gold	Metal	E
	Female	10.5	16	4.3 × 11	Single	Gold	Metal	N
	Female	8	16	4.3 × 11	Single	Gold	Porcelain	E
	Female	8.5	37	4.3 × 13	Single	Gold	Metal	N
	Male	5.5	25	4.3 × 13	Single	Gold	Metal	N
	Male	7	25	4.3 × 13	Splinted	Gold	Metal	N
		6	26	4.3 × 13	Splinted	Gold	Metal	E
	Male	8	15	4.3 × 13	Single	Gold	Porcelain	N
		5	37	4.3 × 11	Single	Gold	Metal	E
Ankylos	Male	7	36	3.5 × 11	Single	Titanium	Zirconia	S
		7	26	4.5 × 11	Single	Titanium	Zirconia	S
	Female	2	26	3.5 × 11	Single	Titanium	Zirconia	S
	Female	6	14	3.5 × 11	Splinted	Titanium	Zirconia	S
	Male	6	36	3.5 × 11	Splinted	Titanium	Zirconia	S
		7	37	3.5 × 11	Splinted	Titanium	Zirconia	S
	Male	5.5	16	4.5 × 11	Single	Titanium	Zirconia	E
	Male	8	36	3.5 × 11	Single	Titanium	Zirconia	S
	Female	6	32	3.5 × 11	Full-arch	Titanium	Porcelain	S
		6	34	3.5 × 9.5	Full-arch	Titanium	Porcelain	S
	Male	10	16	4.5 × 11	Single	Titanium	Porcelain	E

[a]N: the thinnest wall portion of the implant neck; E: the end of the self-tapping threads region; S: the self-tapping thread.

the present authors. Moreover, in this study, there was no significant difference in the incidence of implant fracture between the other implant systems. A previous data analysis concluded that most fractures occurred after 5 years of clinical function,[4] which is concordant with the findings of the present study. The average time between implantation and implant body fracture was 7.16 years. There were no cases of fracture with Thommen implants, but the observation time for this implant system was relatively short (2–6 years).

Based on previous reports, implant body fractures are more likely to occur in the maxilla than in the mandible.[14] However, in the present study, the rate of implant body fracture in the maxilla did not differ significantly from the corresponding rate in the mandible, which is in agreement with the results reported by Eckert and Wollan.[15] Moreover, 29 of the 37 implant body fractures occurred in the molar region, while seven occurred in the premolar region and one in the anterior region. These findings are in agreement with those of previous studies, which reported 80–100% of implant body fractures located in the molar and premolar regions.[11,16] The molar region is located near the temporomandibular joint and has a larger occlusal table, thereby creating a mechanically unfavourable situation.[10]

The results of this study demonstrated that fractured implants occurred more frequently in unsplinted than splinted restorations. Splinted restorations are thought to have a better load distribution and lower stress concentrations compared with unsplinted restorations.[17] Since a metal or zirconia occlusal surface (seen in 28 of the 37 fractured implants) is believed to transfer the load to the implant directly, single implant-supported restorations with a metal or

Table 3. Analysis of fracture according to the implant diameter and connection.

		Fractured	Non-fractured	*P*-value
Diameter	Regular	25	6336	0.009[a]
	Narrow	12	1129	
Connection	Conical	15	1951	0.059
	Butt joint	22	5514	

[a]Statistically significant difference.

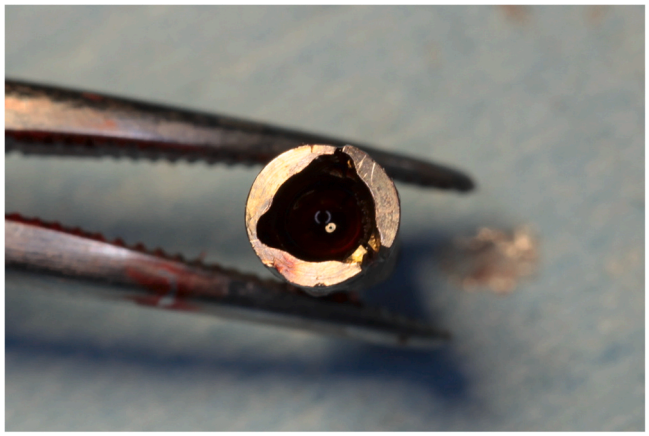

Fig. 2. Cracks in the thinnest section of the internal configuration, which have propagated apically.

zirconia surface are subjected to an increased force that exerts a larger bending movement on the implant body, thereby increasing the risk of fracture.[18,19] A major cause of implant body fracture is overloading due to various parafunctional habits such as bruxism and inadequate occlusion. In the case of overload, ceramic occlusal restorations are recommended, with regular re-examination.

Regarding the fracture location, implant body fractures can be categorized into three types: implant neck, self-tapping thread, and those at the end of the self-tapping thread region. The stability of the abutment–implant connection depends on the implant system,[20] with micromovements between the implant and abutment potentially resulting in excessive loading on the screws and implant body, thereby causing possible implant fracture.[21] Implants with a reduced diameter may be more prone to fracture due to a high stress concentration or excess load. In the present study, 32.4% (12/37) of fractured implants had a reduced diameter, and narrow diameter implants showed a tendency to fracture more easily than standard diameter implants under certain circumstances, which is in accordance with the findings of a previous study.[22]

Overall, 37.8% of fractures occurred in the thinnest wall portion of the implant neck and propagated apically to the implant threads, resulting in an implant body fracture. The average diameter of this type of fractured implant was 4.3 mm, and the thinnest wall was almost 0.3 mm. Lee et al.[14] demonstrated that implants with a coronal wall thickness of less than 0.3 mm displayed a significantly low elastic limit and load-bearing capacity. According to a previous finite element analysis, implants with a tri-channel configuration are prone to fail as a result of fracture of the thinnest part of the cut-out area, which is in accordance with the clinical outcomes of the present study.

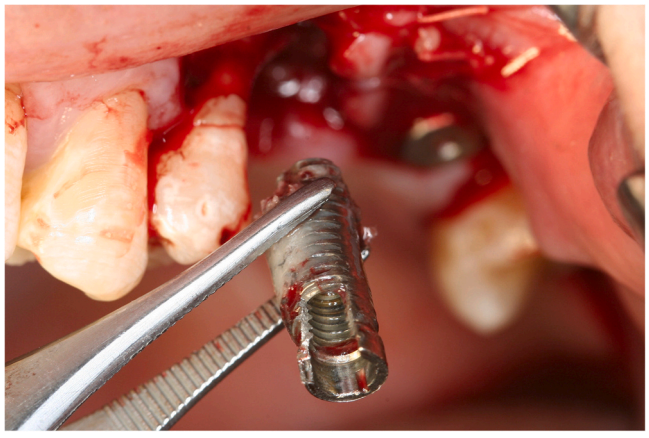

Fig. 3. Implant fracture at the fourth thread.

Meanwhile, 24.3% of the fractures occurred at the self-tapping thread; all of this fracture type occurred with the Ankylos system. With Ankylos implants, the tapered internal connection is introduced as a Morse taper system, achieving a clamping force that minimizes micromovements.[23] Progressive vertical interlocking was noted under loading conditions,[24] resulting in a loss of screw tension at the connection. It seems that implants with a conical connection are prone to fracture at the implant shoulder part. Thus, considering the possibility of abutment fracture,[25] single Ankylos implant-supported restorations are not recommended for use in the rehabilitation of posterior missing teeth.

In accordance with a previous in vitro study,[20] 37.8% of implants failed at the end of the screw. The end of the screw presents a change in geometry along the implant, in which the thread notches into the implant cross-section, becoming a weak point.[26] The risk of fracture is particularly evident in the case of bone resorption and narrow implants.[22] According to Rangert et al.,[27] implants with a smaller dimension do not exhibit typical fatigue behaviour as seen in standard implants. Based on our experience, implants with a diameter > 4.5 mm are therefore recommended in the molar region.

Increased marginal bone loss seems to be associated with implant body fractures. However, whether bone loss is the cause or an effect of implant body fracture could not be determined in the present study. According to a 15-year study by Adell et al.,[28] fixtures that had rapid bone loss of approximately 3 mm/year presented with mechanical complications such as implant fracture. In order to reduce the risk of fracture due to bone resorption, patient monitoring at regular intervals is essential, ensuring that the load is evenly distributed. When marginal bone loss is observed during follow-up, it should raise the suspicion of a fracture that has occurred or is about to occur.

A limitation of the present study is that a number of the patients were followed up by telephone. Although a questionnaire was designed to identify whether implant fracture had occurred or not, in-person examination is known to be more accurate and reliable.

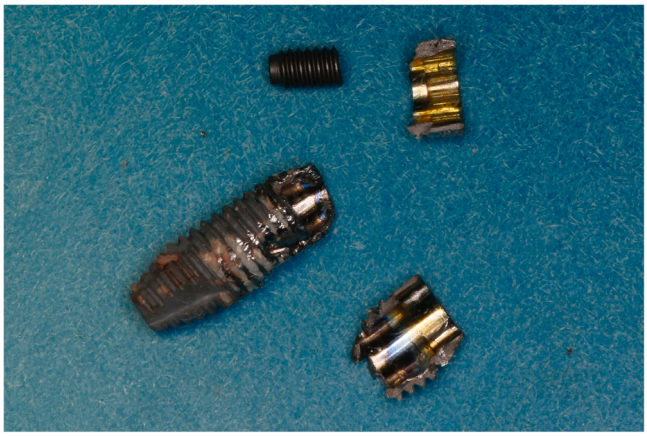

Fig. 4. Fractures at the self-tapping thread.

In conclusion, 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.

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Ethical approval

The study protocol was evaluated and approved by the Institutional Ethics Committee of Peking University School and Hospital of Stomatology (PKUSSIRB-2016113115).

Patient consent

Not required.

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Competing interests

None.

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