Analysis of Incidence and Associated Factors with Fractured Implants: A Retrospective Study

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Osseointegrated threaded titanium screw-type implants rarely lose integration after the first year of clinical function. Implant failure can occur for other reasons, with implant fracture being one of the major reasons for late failure. The purpose of the present study was to determine the incidence of implant fracture in completely edentulous and partially edentulous arches and to determine what factors may predispose an implant to a higher fracture risk. A retrospective evaluation of 4,937 implants was performed to determine the incidence of and factors common to fractured implants from a sample of implants placed and restored in one institutional setting. Based on the results of this study, the following observations were made: implants fracture at similar rates in the maxilla as in the mandible (0.6%), implant fractures occur more frequently in partially edentulous restorations (1.5%) than in restorations of completely edentulous arches (0.2%), all observed fractures occurred with commercially pure 3.75-mm-diameter threaded implants, and prosthetic or abutment screw loosening preceded implant fracture for the majority of the implants. More studies would be helpful to further explore the relationship and progression of factors associated with implant fracture. (INT J ORAL MAXILLOFAC IMPLANTS 2000;15:662–667)

Key words: *endosseous dental implantation, implant maintenance, osseointegration, retrospective studies*

Endosseous implants are used to support and retain dental prostheses in numerous clinical situations.[1–5] The efficacy of this treatment modality has been confirmed in many research protocols.[6–8] The immediate goal following surgical placement of the implant is osseointegration, a process that should occur during the initial undisturbed healing phase.

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Long-term maintenance of osseointegration seems to be a reasonable expectation, but this does not ensure the ongoing survival of the dental restoration supported by the implant, nor does it guarantee trouble-free prosthetic service. One major complication that can jeopardize prosthesis success is implant fracture. Rangert and colleagues[9] conducted a retrospective review of implant fracture experience in a number of clinical practices. This study suggested that posterior prostheses supported by 1 or 2 implants are subjected to an increased bending force that could overload the implant, thereby increasing the susceptibility to implant fracture. However, the study did not provide extensive data on the original patient group from which the implant fractures occurred. The study concentrated on factors that were common to many of the fractured implants but did not provide data regarding the incidence of fracture in clinical applications.

In a study by Adell and coworkers,[10] a 3.5% implant fracture rate was seen, with most of the fractures occurring after 5 years of clinical function. The authors of this study described a reduction in the implant fracture rate associated with improved fit of the prosthetic framework.

The risk for implant fracture in the partially edentulous arch was discussed by Eckert and Wollan.[11] In this study, no significant difference was seen in implant susceptibility to fracture based on anatomic location, despite the fact that most of the implant fractures were in the posterior mandible and there were no fractures in the anterior maxilla or mandible. The small percentage of implant fractures seems to be responsible for this lack of statistical significance. This paper also described significant improvement in implant fracture rates with the advent of newer implant restorative components.

The purpose of the present study was to determine the incidence of implant fracture in completely edentulous and partially edentulous arches and to determine what factors might predispose an implant to a higher fracture risk. A retrospective evaluation was done to determine those factors common to fractured implants from a large sample of implants placed and restored in one institutional setting.

MATERIALS AND METHODS

The computer records of all patients treated at the Mayo Clinic Department of Dental Specialties were examined to gather the following data: the number of implants in maxillae and mandibles, the number of implants in edentulous and partially edentulous arches, the number of different diameter implants used, and the number of fractured implants.

Clinical records were evaluated to determine the following: location of the fractured implants, date of implant fracture, dimensions of fractured implants, date of complications prior to implant fracture, birthdate, gender, date of prosthesis placement, and date of implant placement. Radiographs, clinical photographs, and master casts were evaluated to confirm the fractured implant locations, presence or absence of cantilevers in the prosthesis, occlusal material, and the number of teeth being replaced in the prosthesis. With the data gathered in this process, the following calculations were made: duration of prosthetic service before implant fracture, number of complications before fracture, time interval between complications, percentage of fractured implants in partially edentulous or edentulous arches, percentage of fractured implants in the maxillary or mandibular arches, and the presence or absence of cantilevers or excessive occlusal table dimensions.

RESULTS

The first implant placements at the Mayo Clinic were performed in October of 1983 and continue to the present time. When implants that had been restored by January of 1998 were considered, a total of 4,937 was included in this review, with 1,719 maxillary implants (Table 1) and 3,218 mandibular implants (Table 2). The majority of the implants (n = 3,704) were used to support restorations in completely edentulous arches, with the remaining implants (n = 1,233) supporting restorations in partially edentulous arches. Implant fractures were seen in both arches at similar rates, with 10 maxillary implant fractures (0.6% incidence) and 18 mandibular implant fractures (0.6% incidence). Implant fractures were seen in 18 different patients, with an even gender distribution of 9 females and 9 males. Fractures were observed more frequently in the partially edentulous arches, with 18 episodes of implant fracture (1.5% incidence), versus 10 fractured implants (0.2% incidence) in completely edentulous arches.

Factors related to the number of teeth replaced, the time until implant fracture, implant location, and restorative materials are shown for completely edentulous patients (Table 3), partially edentulous patients (Table 4), and single-tooth-replacement patients (Table 5). All fractures were observed after functional loading, rather than at the time of implant placement or second-stage surgical uncovering. All fractured implants were 3.75-mm-diameter implants, as seen in Tables 3 to 5. In the completely edentulous patients, acrylic resin denture teeth were used for all patients, while the partially edentulous and single-tooth-replacement patients had occlusal materials that were either metal or porcelain.

Clinical records demonstrated that screw loosening was observed prior to fracture in all patients, with the exception of 1 edentulous patient who had received a bone graft and an overdenture prosthesis supported by independent (ie, non-splinted) implants with O-ring abutments. Screw loosening was observed with the prosthetic retaining screw and the abutment retaining screw. The radiographic appearance typically showed cupping of bone, with bone destruction extending apical to the point of implant fracture (Figs 1a and 1b). Scanning electron microscopy of the fractured surface of an implant is shown in Figs 2a to 2c with signs of damage that are compatible with fatigue failure of the implant, such as fracture on multiple planes and the presence of fatigue striations.[12,13]

Table 1 Distribution of Maxillary Implants by Type and Length

	Brånemark implant*			Brånemark MK II*		Brånemark	Brånemark self-tapping
Implant length	3 mm	4 mm	5 mm	3.75 mm	5 mm	3.75-mm implant*	(3.75-mm) implant*
6 mm	—	—	3	—	—	—	—
7 mm	—	2	—	—	—	47	—
8 mm	—	—	6	—	—	—	—
8.5 mm	—	—	—	—	1	2	—
10 mm	2	34	8	2	2	65	142
11.5 mm	—	—	—	—	1	—	—
12 mm	—	—	8	—	—	—	—
13 mm	3	26	—	13	2	81	230
15 mm	—	38	—	34	—	73	353
18 mm	—	39	—	20	—	44	389
20 mm	—	—	—	—	—	49	—
Total	5	139	25	69	6	361	1114

*Nobel Biocare, Göteborg, Sweden.

Table 2 Distribution of Mandibular Implants by Type and Length

	Brånemark implant*			Brånemark MK II*				Brånemark	Brånemark self-tapping	
Implant length	3 mm	4 mm	5 mm	3.3 mm	3.75 mm	5 mm	5.5 mm	3.75-mm implant*	(3.75-mm) implant*	ITI 4.1-mm solid screw†
6 mm	—	—	2	—	—	—	—	—	—	—
7 mm	—	21	—	—	—	—	—	101	—	—
8 mm	—	—	9	—	—	—	—	—	—	—
8.5 mm	—	—	—	—	—	—	—	6	—	—
10 mm	—	68	28	—	2	3	1	413	97	—
11.5 mm	—	—	—	—	—	2	—	—	—	—
12 mm	—	—	49	—	—	—	—	—	—	—
13 mm	3	60	—	—	11	7	1	465	97	—
15 mm	—	44	—	3	11	—	—	655	136	—
16 mm	—	—	—	—	—	—	—	—	—	5
18 mm	—	55	—	—	—	—	—	502	106	—
20 mm	—	—	—	—	—	—	—	255	—	—
Total	3	248	88	3	24	12	2	2397	436	5

*Nobel Biocare, Göteborg, Sweden. †Straumann Institut, Waldenburg, Switzerland.

Table 3 Characteristics of Fractured Implants in Complete Edentulism Restorations

Date of implant placement (m/d/y)	No. of implants in prosthesis	Occlusal material	Days of implant service	Implant site	Implant diameter (mm)	Implant length (mm)
3/13/85	5	Acrylic resin	915	Md-P	3.75	18
3/16/88	5	Acrylic resin	1219	Mx-P	3.75	15
3/16/88	5	Acrylic resin	1219	Mx-P	3.75	15
3/16/88	5	Acrylic resin	1427	Mx-CI	3.75	15
3/16/88	5	Acrylic resin	1427	Mx-M	3.75	13
3/16/88	5	Acrylic resin	1427	Mx-M	3.75	13
5/31/88	5	Acrylic resin	1842	Md-P	3.75	15
5/31/88	5	Acrylic resin	1842	Md-P	3.75	15
2/1/90	3	Acrylic resin	2419	Mx-LI	3.75	13
8/21/91	7	Acrylic resin	775	Md-C	3.75	18

Md = Mandibular; Mx = maxillary; CI = central incisor; LI = lateral incisor; C = canine; P = premolar; M = molar.

Table 4 Characteristics of Fractured Implants in Multiple-Implant, Partial Edentulism Restorations

Date of implant placement (m/d/y)	No. of implants in prosthesis	No. of teeth replaced	Cantilever present?	Occlusal material	Days of implant service	Implant site	Implant diameter (mm)	Implant length (mm)
9/17/86	3	5	Yes	Metal	1868	Md-P	3.75	15
9/17/86	3	5	Yes	Metal	2252	Mx-M	3.75	10
9/17/86	3	5	Yes	Metal	2252	Mx-M	3.75	7
1/15/87	2	3	No	Metal	1167	Md-P	3.75	10
1/15/87	2	3	Yes	Metal	3290	Md-P	3.75	10
1/15/87	2	3	Yes	Metal	3290	Md-M	3.75	10
11/18/87	2	2	No	Metal	1700	Md-M	3.75	10
1/16/89	2	4	Yes	Metal	1121	Md-P	3.75	15
3/17/89	2	2	Yes	Metal	1141	Md-M	3.75	13
3/17/89	2	2	Yes	Metal	1141	Md-M	3.75	13
3/30/89	2	2	No	Porcelain	851	Mx-P	3.75	18
3/30/89	2	2	No	Porcelain	851	Mx-P	3.75	10
9/5/91	2	2	Yes	Metal	575	Md-M	3.75	15

Md = Mandibular; Mx = maxillary; CI = central incisor; LI = lateral incisor; C = canine; P = premolar; M = molar.

Table 5 Characteristics of Fractured Implants in Single-Implant, Partial Edentulism Restorations

Date of implant placement (m/d/y)	No. of implants in prosthesis	Molar replacement?	Occlusal material	Days of implant service	Implant site	Implant diameter (mm)	Implant length (mm)
6/14/88	1	Yes	Metal	777	Md-M	3.75	15
2/7/89	1	Yes	Metal	819	Md-M	3.75	13
3/7/89	1	Yes	Metal	888	Md-M	3.75	13
10/25/89	1	Yes	Metal	2457	Md-M	3.75	15
8/2/90	1	Yes	Porcelain	2437	Md-M	3.75	13

Md = Mandibular; Mx = maxillary; CI = central incisor; LI = lateral incisor; C = canine; P = premolar; M = molar.

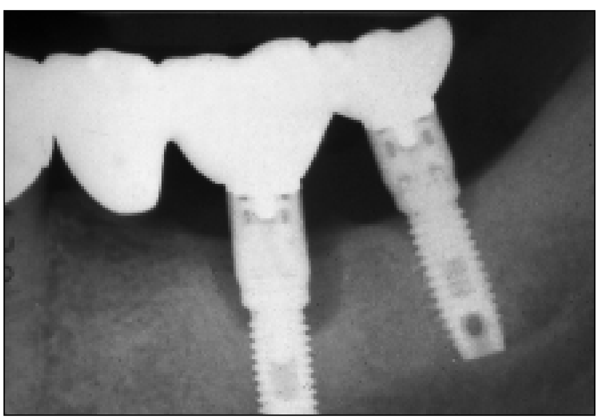

Fig 1a *(Above)* Radiographic "cupping" of the bone preceding implant fracture.

Fig 1b *(Right)* Removal of the fractured coronal section 7.5 months later. Note the position of bone loss apical to the fracture point.

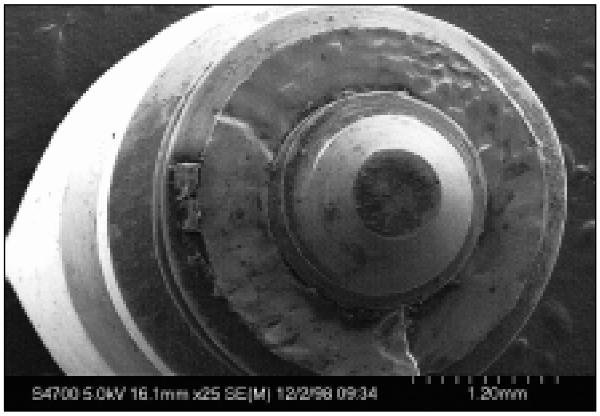

Fig 2a Representative scanning electron microscopy of the fractured implant surface (original magnification ×25).

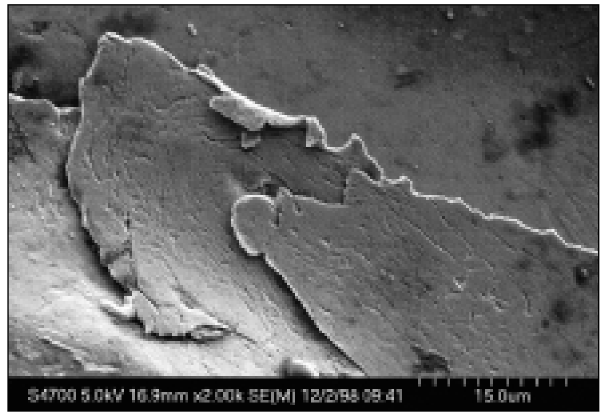

Fig 2b Close-up view of the tear area demonstrates multiple planes of fracture (original magnification ×2,000).

Fig 2c Fatigue striations can be seen under high magnification (×5,000).

DISCUSSION

According to Brånemark, endosseous implants reach a "steady state" after 1 to 2 years of functional loading.[14] This period is described as a time of low implant loss and relative stability of supporting bone. Eckert and Wollan described late implant failure in the partially edentulous arch as a consequence of implant fracture more often than loss of integration.[11] It is reasonable to expect that a reduction in the rate of implant fracture will have a positive effect on long-term implant survival.

This retrospective study describes a number of factors that are common to fractured implants. In this review, all of the fractured implants were 3.75 mm in diameter, and all of the implants were made from commercially pure grade 1 titanium. The fractured implants had all been used to support and retain dental prostheses, and virtually all of the implant-supported prostheses had previously experienced mechanical complications in the form of screw loosening. The only exception to this was seen when independent (non-splinted) implants were used to retain a maxillary overdenture in an onlay bone graft patient. The implants in that patient fractured at the graft/host bone interface.

Screw loosening has been reported as a common occurrence with implant-supported prostheses. This is generally thought to be a minor complication or inconvenience, since it is easily rectified. However, this impression must change if screw loosening carries with it a significant risk of implant fracture. Screw loosening and fracture may be caused by framework misfit, excessive occlusal force, poor prosthetic component design, unfavorable leverage, or parafunctional activities.[15] In addition, improper prosthesis connection could result in insufficient or excessive torque to the retaining screws. Once encountered, screw loosening should be assessed and corrected before irreversible damage occurs within the implant.

A specific bone loss pattern has been described as a primary cause of implant fracture.[9] An alternative view is that implant fracture involves progressive fatigue failure until the implant lacks adequate strength to maintain integrity, culminating in a catastrophic failure. During the progression of the fracture process, it is possible that an infective process may be involved in the observed pattern of bone loss. In the former situation, bone loss is an etiologic factor for the fracture, while the latter instance would have the fracture causing bone loss. At this point it is unclear which event precedes the other. If bone loss is a predisposing factor, then early intervention to reduce occlusal forces to the implant seem to be justified. Conversely, if the initial tearing of the implant body results in bone loss because of a secondary infection, then occlusal adjustment would be of no value, since the weakened implant is destined to fracture. This relationship between fracture and bone loss should be investigated to determine whether intervention is warranted or beneficial.

Single implant–supported restorations fractured only in molar areas, but it is unlikely that, given the small number of fractures in question, this is a significant observation. Previous reports from this institution have failed to show statistical differences in implant fracture rates on the basis of anatomic location.[16] Despite the lack of statistical significance, this clinical observation makes it appear prudent to consider the single implant–supported molar to be at a higher risk of fracture. The proximity of the molar to the temporomandibular joint creates a mechanically unfavorable situation because of the high magnitude of force transmission. In a similar sense, the molar has a larger occlusal table than premolar or anterior teeth. The larger occlusal surface, supported by a single implant, will create forces that are not in line with the long axis of the implant. These tipping forces may lead to chronically high, complex force patterns that contribute to implant fracture. Resolution of this problem may occur with larger-diameter implants or through the use of multiple implants. Larger-diameter implants provide more bulk of metal to resist the off-axis load, while multiple implants diminish the magnitude of the off-axis load by supporting the prosthesis at its extremes. An additional alternative is to use a different implant material to provide a higher threshold for fatigue failure, since fatigue appears to have some relationship with the tensile strength of the implant material.[17] These suggestions are dependent upon similar rates of osseointegration with different implant designs or materials. Further testing of this hypothetical solution is suggested.

CONCLUSIONS

A retrospective review of fractured implants was performed to determine the incidence of fractures and any common factors that may indicate methods to eliminate fractures. The following observations were made.

- Implants fractured at the same rate in the maxilla as in the mandible (0.6%).
- Implant fractures occurred more frequently in partially edentulous restorations (1.5%) than in restorations of the completely edentulous arch (0.2%).
- All observed fractures occurred with commercially pure titanium 3.75-mm-diameter threaded implants.
- Prosthetic or abutment screw loosening preceded implant fracture for the majority of the implants.

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