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Review Article

Meta-Analysis of Oral Implant Fracture Incidence and Related Determinants

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Dental implant fracture is a rare biomechanical complication, however, one of the most serious and frustating ones as it is generally associated with implant and prosthesis failure as well as the surgical hazards of explantation and reimplantation. To gain insights into implant fracture rates and the impact of patient-, surgery-, and prosthetic-related factors, systematic review and meta-analysis of the English literature were performed. Electronic and hand searches yielded 69 relevant publications reporting on 827 fractures out of 44521 implants investigated. The overall incidence of implant fractures was 1.6%. Mean patient age at the time of implant fracture was 54 ± 11 years, and 70% occurred in males. The vast majority (85%) occurred in posterior regions of the mouth (premolar or molar positions). No tendency of increased fracture rates could be noted for short implant lengths or narrow implant diameters. Implant fractures occurred after 4.1 ± 3.5 years of loading, on average, in most cases (88%) supporting fixed restorations; however, only 56% were preceded by screw loosening. Although further investigations are needed to fully explore the characteristics and causes of this rare complication, it can be concluded that no more than 2.8% of implants fracture is within a mean loading period of 8.3 years.

1. Introduction

Rehabilitation of the incomplete dentition by means of osseointegrated dental implants represents a highly predictable and widespread therapy [1]. Despite its high success rate, dental implant therapy—in the long term—is not free of complications [2] even though early failure rates of modern rough-surfaced implants of at least 10 mm in length are as low as 0.7% [3]. While early losses are predominantly due to lack of establishment of osseointegration, there are two main reasons for late implant failures [4]: loss of supporting tissue (secondary to infection or peri-implantitis) and mechanical problems (such as biomechanical overload or implant fracture).

Possible causes of implant fracture include inadequate fit of the superstructure, defects in the production or design of the material, long-term metal fatigue, magnitude or direction of occlusal forces, parafunctional habits, implant location, implant length, implant diameter, and bone resorption around the implant. The clinical crown-to-implant ratio naturally increases with marginal bone loss, resulting in even greater biomechanical load. In many cases, however, fractures due to bone resorption and bone resorption due to factures are hard to distinguish in retrospect.

In a recent review article [4] Sánchez-Pérez and coworkers categorized frequent clinical findings related to implant fracture into patient-, implant-, and prosthetic-related factors. Fracture incidence has been reported to range between 0.0% and 7.5% of implants overall. The aim of the present systematic review and meta-analysis thus was to gain insights into dental implant fracture rates as well as related determinants. The focused question was how patient-, surgery-, and prosthetic-related factors may influence the occurrence of implant fracture.

2. Material and Methods

2.1. The Literature Search. A MEDLINE search of the English literature was conducted using the key words "dental implant fracture" (458 hits), "dental implant failure" (2257 hits), "dental implant complication" (231 hits), and "dental implant overload" (90 hits) limited to the time period between January 1st, 1990, and January 1st, 2010, and supplemented by hand searching of following journals: British Journal of Oral and Maxillofacial Surgery, Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, Clinical Oral Investigations, Compendium of Continuing Education in Dentistry, Implant Dentistry, The International Journal of Oral and Maxillofacial Implants, International Journal Oral Maxillofacial Surgery, International Journal Periodontics and Restorative Dentistry, The International Journal of Prosthodontics, The Journal of American Dental Association, The Journal of the Canadian Dental Association, The Journal Clinical Periodontology, The Journal of Cranio-maxillofacial Surgery, The Journal of Dental Research, The Jorunal of Oral and Maxillofacial Surgery, The Journal of Oral Rehabilitation, The Journal of Prosthetic Dentistry, The Journal of Prosthodontics, The European Journal of Prosthodontics and Restorative Dentistry, Oral Surgery, Oral Medicine, Oral Pathology, and Oral Radiology, Schweiz Monatsschrift für Zahnmedizin, Journal of Oral Implantology, and Quintessence International. In addition, the references of relevant publications and review articles were screened.

2.2. Study Selection. Studies were considered if they met the following inclusion criteria: (1) prospective or retrospective clinical investigation, case report, or case series (2) reporting on fracture of dental implants, and (3) providing details on either fracture incidence, patient age and gender, implant location (maxilla versus mandible, anterior versus posterior regions), implant length, implant diameter, time of implant fracture, type of prosthetic restoration, history of screw loosening prior to implant fracture, or hypothesized fracture reason. Two reviewers (L. Bucur and B. Pommer) independently screened titles and abstracts of the search results. After exclusion of 2212 duplicates, a total of 3036 publications underwent title and abstract screening. Full texts of all papers that were considered eligible for inclusion by one or both reviewers were obtained for further assessment against the stated criteria. Disagreements were resolved by consensus. Out of 169 articles screened in full text, 69 publications were selected as preliminary candidates and underwent data abstraction in duplicate. When multiple reports on the same patients were identified, the most recent publication was cited.

2.3. Quantitative Data Synthesis. The final selection constituted 69 publications [5–73] reporting on 44521 implants and a total of 827 implant fractures (Table 1). For calculation of implant fracture incidence rates (number of fractures by total number of implants placed) results from case series and case reports were not considered. 95% confidence intervals ($CI_{95\%}$) were computed based on the binomial test. Comparison of incidence rates of prospective versus retrospective investigations was performed using Pearson's chi-squared test. Level of significance was set at $P < 0.05$. All analyses were performed using R 2.4.0 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1. Fracture Incidence. A total of 827 implant fractures were reported in the 69 included publications: 524 fractures in prospective studies (63.4%), 193 fractures in retrospective studies (23.3%), 100 fractures in case series (12.1%), and 10 fractures in case reports (1.2%). The overall incidence of implant fractures (after exclusion of case series and case reports) was 1.6% [$CI_{95\%}$ 0.0–2.8%] (717 out of 44316 implants in 43 investigations). A highly significant difference ($\chi^2 = 82.1$, df = 1, and $P < 0.001$) was observed between fracture incidence rates reported in prospective studies (2.1% [$CI_{95\%}$ 0.0–2.7%], 524 out of 24980 implants in 22 investigations) and retrospective studies (1.0% [$CI_{95\%}$ 0.0–3.2%], 193 out of 19336 implants in 21 investigations). Fracture incidence (range: 0.1%–26.1%) was not correlated to the sample size of studies ($r = -0.129$, $P = 0.416$).

3.2. Patient-Related Factors. Information about patient gender could be collected for 59 of the 827 fractured implants (7.1%). Forty-one of these implants fractured in male patients (69.5%), while only 18 implants fractured in females (30.5%). Patient age could be ascertained for 34 of the 827 fractured implants (4.1%). Mean patient age at the time of implant fracture was 53.7 ± 11.3 years showing a normal distribution: one fracture was recorded in patients between 20 and 29 years of age (2.9%), 2 fractures in patients between 30 and 39 years of age (5.9%), 7 fractures in patients between 40 and 49 years of age (20.6%), 14 fractures in patients between 50 and 59 years of age (41.2%), 7 fractures in patients between 60 and 69 years of age (20.6%), and 3 fractures in patients between 70 and 80 years of age (8.8%). Presence of parafunctional habits could be extracted from the included studies for 48 of the 827 fractured implants (5.8%) of which 43 implants (89.6%) fractured in bruxers.

3.3. Implant Position. The position of investigated implants could be recorded for 656 of the 827 fractured implants (79.3%). 426 implant fractures occured in the upper jaw (64.9%), while 230 fractures were located in the lower jaw (35.1%). The vast majority (84.5%) occured in posterior regions of the mouth (premolar or molar positions) compared to anterior jaw regions (incisor or canine positions). For 110 implants the exact jaw location could be ascertained: 13 implants fractured in the anterior maxilla (11.8%), 34 implants in the posterior maxilla (30.9%), 4 in the anterior mandible (36.4%), and 59 in the posterior mandible (53.6%). Further analyses revealed no differences in fracture rates between premolar implants (43.8%) and molar implants (40.7%).

3.4. Implant Dimension. Implant length could be determined for 83 of the 827 fractured implants (10.0%): one fractured

Table 1: Details of the 69 included publications on dental implant fracture: study design (prospective study, retrospective study, case series, and case report), number of implants investigated, and number (incidence) of implant fractures observed.

Study	Study design	Number of implants	Implant fractures
Adell et al. 1981 [5]	prospective	2768	69 (2.5%)
Adell et al. 1990 [6]	prospective	4636	334 (7.2%)
Anneroth et al. 1990 [7]	case report	1	1
Bahat 2000 [8]	prospective	660	4 (0.6%)
Balshi 1996 [9]	retrospective	4045	8 (0.2%)
Bianchi et al. 1997 [10]	case report	1	1
Brägger et al. 2001 [11]	prospective	105	2 (1.9%)
Brånemark et al. 1977 [12]	retrospective	1618	13 (0.8%)
Brocard et al. 2000 [13]	prospective	1022	8 (0.8%)
Brunel et al. 2000 [14]	case report	1	1
Buser et al. 1997 [15]	prospective	2359	3 (0.1%)
Conrad et al. 2008 [16]	case series	2	1
Corpe et al. 1999 [17]	case series	11	5
Covani et al. 2006 [18]	case series	9	9
Cranin et al. 1990 [19]	case series	22	14
Eckert and Wollan 1998 [20]	retrospective	1170	15 (1.3%)
Eckert et al. 2000 [21]	retrospective	4937	28 (0.6%)
Gargallo-Albiol et al. 2008 [22]	prospective	1500	21 (0.1%)
Gibney 2004 [23]	case report	1	1
Gunne et al. 1994 [24]	prospective	558	3 (0.5%)
Henry et al. 1995 [25]	retrospective	83	1 (1.2%)
Iezzi et al. 2008 [26]	case series	2	1
Ivanoff et al. 1999 [27]	retrospective	299	1 (0.3%)
Ivanoff et al. 2000 [28]	retrospective	207	15 (7.2%)
Laine et al. 2005 [29]	retrospective	30	1 (3.3%)
Lekholm et al. 1994 [30]	prospective	558	5 (0.9%)
Lekholm et al. 1999 [31]	prospective	461	8 (1.7%)
Lekholm et al. 2006 [32]	retrospective	112	4 (3.6%)
Levine et al. 1999 [33]	retrospective	174	3 (1.7%)
Malmqvist and Sennerby 1990 [34]	prospective	47	2 (4.3%)
Mau et al. 2003 [35]	case series	6	6
Mericske-Stern et al. 1994 [36]	prospective	66	1 (1.5%)
Mericske-Stern et al. 2001 [37]	retrospective	132	7 (5.3%)
Morgan et al. 1993 [38]	case series	5	5
Muroff 2003 [39]	case report	1	1
Naert et al. 1992 [40]	prospective	589	3 (0.5%)
Naert et al. 1992 [41]	prospective	509	5 (1.0%)
Naert et al. 2001 [42]	retrospective	339	5 (1.5%)
Noack et al. 1999 [43]	retrospective	1964	14 (0.7%)
Örtorp and Jemt 2006 [44]	retrospective	1028	6 (0.6%)
Piattelli et al. 1998 [45]	case series	4	4
Piattelli et al. 1998 [46]	case report	1	1
Piattelli et al. 1998 [47]	case series	7	4
Piattelli et al. 1998 [48]	retrospective	230	60 (26.1%)
Polizzi et al. 1999 [49]	prospective	30	1 (3.3%)
Proussaefs et al. 2001 [50]	case series	3	1
Pylant et al. 1992 [51]	retrospective	102	1 (1.0%)
Quirynen et al. 1992 [52]	retrospective	509	5 (1.0%)
Rangert et al. 1995 [53]	case series	41	41
Romanos and Nentwig 2000 [54]	retrospective	58	1 (1.7%)
Romeo et al. 2004 [55]	prospective	759	3 (0.4%)
Rosenberg and Torosian 1998 [56]	prospective	958	18 (1.9%)
Saadoun and Le Gall 1996 [57]	prospective	1499	7 (0.5%)
Scholander 1999 [58]	retrospective	259	1 (0.4%)

Table 1: Continued.

Study	Study design	Number of implants	Implant fractures
Sennerby et al. 1991 [59]	case series	7	1
Snauwaert et al. 2000 [60]	prospective	4971	21 (0.4%)
Steflik et al. 1994 [61]	case series	50	2
Tagger Green et al. 2002 [62]	case report	1	1
Takeshita et al. 1996 [63]	case series	9	1
Tawil et al. 2006 [64]	retrospective	262	1 (0.4%)
Tolman and Laney 1992 [65]	retrospective	1778	3 (0.2%)
Traini et al. 2006 [66]	case report	1	1
Uehara et al. 2004 [67]	case series	4	2
Vantaggiato et al. 2008 [68]	case series	13	3
Velásquez-Plata et al. 2002 [69]	case report	1	1
Virdee and Bishop 2007 [70]	case report	1	1
Weber et al. 2000 [71]	prospective	112	3 (2.7%)
Weibrich et al. 2001 [72]	prospective	515	1 (0.2%)
Zinsli et al. 2004 [73]	prospective	298	2 (0.7%)
Total	22 prospective 21 retrospective 16 case series 10 case reports	44394	787

implant was 7 mm in length (1.2%), one implant was 8 mm in length (1.2%), 32 implants were 10 mm in length (38.6%), one implant was 11 mm in length (1.2%), 10 implants were 12 mm in length (12.0%), 21 implants were 13 mm in length (25.3%), 13 implants were 15 mm in length (15.7%), and 4 implants were 18 mm in length (4.8%). Implant diameter could be ascertained for 167 of the 827 fractured implants (20.2%): three fractured implants were 3.0 mm in diameter (1.8%), 11 implants were 3.3 mm in diameter (6.6%), 9 implants were 3.5 mm in diameter (5.4%), one implant was 3.7 mm in diameter (0.6%), 119 implants were 3.75 mm in diameter (71.3%), 8 implants were 3.8 mm in diameter (4.8%), 6 implants were 4.0 mm in diameter (3.6%), and 10 implants were 4.1 mm in diameter (6.0%).

3.5. Time Point of Fracture. Implant fractures occured after 4.1 ± 3.5 years, on average, and detailed information regarding the time point of fracture was available for 165 of the 827 included implants (20.2%); eleven implants fractured within the first year of loading (6.7%), 20 implants after one year (12.1%), 26 implants after 2 years (15.8%), 38 implants after 3 years (23.0%), 16 implants after 4 years (9.7%), 23 implants after 5 years (13.9%), 10 implants after 6 years (6.1%), one implant after 7 years (0.6%), 2 implants after 8 years (1.2%), 4 implants after 9 years (2.4%), one implant after 10 years (0.6%), 3 implants after 11 years (1.8%), 7 implants after 14 years (4.2%), one implant after 16 years (0.6%), and 2 implants after 17 years (1.2%). This compares to a mean followup of included studies of 8.3 ± 4.3 years.

3.6. Prosthetic-Related Factors. Details regarding the type of prosthetic restoration could be gathered for 300 of the 827 fractured implants (36.3%): 125 fractured implants supported overdentures (41.7%), 140 implants supported fixed partial dentures (46.7%) of which 36 were cantilever implant bridges (12.0%), 12 fractured implants supported telescopic removable dentures (4.0%), and 23 implants supported single crowns (7.7%). Information on screw loosening prior to implant fracture could be extracted for 59 of the 827 fractured implants (7.1%). Single or multiple events of screw loosening were seen in 33 implants (55.9%) compared to 26 implant fractures (44.1%) that were not preceded by technical complications. Study authors speculated on fracture reasons in 137 cases of the 827 fractured implants (16.6%). The most common reasons cited were biomechanical overload (67 fractures, 48.9%), parafunctional habits (65 fractures, 47.4%), metal fatigue (33 fractures, 24.1%), marginal bone resorption due to peri-implantitis (7 fractures, 5.1%), and trauma (3 fractures, 2.2%).

4. Discussion

The present meta-analysis yielded an overall implant fracture incidence of 1.6% (717 out of 44316 implants in 43 investigations). These results compare to ranges of 0.1%–0.7% [74] and 0.0%–7.4% [4] reported in the literature reviews on the topic. These differences may be explained by variations in observation time as well as divergent patient inclusion criteria. Moreover it has to be considered that investigations that do not report on implant fractures as well as studies that do not detect any fractures during the observation period (implant fracture incidence of 0%) are generally not considered in the literature reviews. Significant differences, however, were also noted in the present analysis between results of prospective studies and retrospective investigations that reported a significantly lower implant fracture rate of 1.0% (compared to 2.1% in prospective studies), on average, while case reports and case series were excluded from the analysis (high fracture rates like 100% in a case report would have distorted overall estimates significantly). Prospective clinical studies, in general, carry a lower risk of bias; thus, we can estimate—with a certainty of 95%—that no more than 2.8% of implants fracture is within a mean follow-up period of 8.3 years.

Mean patient age at the time of implant fracture was 53.7 ± 11.3 years showing a normal data distribution. This may be

due to the fact that younger patients are generally underrepresented in clinical implant studies (as tooth loss and therefore also tooth replacement by the use of dental implants increases with age). Furthermore, it might be speculated that lower masticatory forces in the elderly population do not provoke equal numbers of implant fractures. The high rate of implant fractures in bruxers (90% of fractures occured in patients with parafunctional habits) should also be interpreted with caution. Reporting bias must be suspected as bruxing habits were assessed in 5.8% of the total sample only and possibly served as a convenient explanation after the occurence of the fracture.

Comparison between implant fractures in various regions of the mouth (upper jaw versus lower jaw, incisors and canines versus premolars and molars) is certainly hindered by the possible presence of confounding variables. Due to limited data reported in the included studies we do not know if gender distribution was equal or if there were any differences in mean patient age. Multifactorial analysis should also include implant length, implant diameter, type of prosthetic restoration (particularly the presence of cantilevers) and materials used; however, detailed information can hardly ever be ascertained from the publications. The high percentage of implant fractures in the posterior mandible (54%) might be explained by the combination of good bone quality and high masticatory forces in this region. On the other hand, no differences between premolars and molars could be substantiated, thus not supporting the hypothesis of biomechanical overload as reason for implant fracture.

Implant length as well as implant diameter could not be associated with the occurrence of implant fractures in the present analysis. It should be considered, however, that only a very limited number of short implants less than 10 mm in length (2 implants, 2.4%) as well as implants with a reduced diameter of less than 3.75 mm (24 implants, 14.4%) fractured throughout the included studies. Further investigations are needed to fully explore the characteristics and causes of this rare complication. Of the patient-, implant-, and prosthetic-related influencing factors suggested by Sánchez-Pérez and coworkers [4], which are pocket depth of more than 5 mm, bone loss, overload/bruxism, implant diameter less than 4 mm, crown-to-implant ratio higher than 1, implant design, loosening of prosthetic screws, cantilevers, and previous ceramic fractures, no determinant could be significantly correlated to an increased rate of implant fracture.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

References

[1] B. Pommer, W. Zechner, G. Watzek, and R. Palmer, "To graft or not to graft? Evidence-based guide to decision making in oral bone graft surgery," in *Bone Grafting*, A. Zorzi, Ed., InTech, Vienna, Austria, 2012, http://www.intechopen.com/books/bone-grafting/evidence-based-guide-to-decision-making-in-oral-bone-augmentation-surgery.

[2] C. W. Gealh, V. Mazzo, F. Barbi, and E. T. Camarini, "Osseointegrated implant fracture: causes and treatment," *Journal of Oral Implantology*, vol. 37, no. 4, pp. 499–503, 2011.

[3] B. Pommer, S. Frantal, J. Willer, M. Posch, G. Watzek, and G. Tepper, "Impact of dental implant length on early failure rates: a meta-analysis of observational studies," *Journal of Clinical Periodontology*, vol. 38, no. 9, pp. 856–863, 2011.

[4] A. Sánchez-Pérez, M. J. Moya-Villaescusa, A. Jornet-García, and S. Gomez, "Etiology, risk factors and management of implant fractures," *Medicina Oral, Patologia Oral y Cirugia Bucal*, vol. 15, no. 3, pp. e504–e508, 2010.

[5] R. Adell, U. Lekholm, B. Rockler, and P. I. Brånemark, "A 15-year study of osseointegrated implants in the treatment of the edentulous jaw," *The International Journal of Oral Surgery*, vol. 10, no. 6, pp. 387–416, 1981.

[6] R. Adell, B. Eriksson, U. Lekholm, P. I. Brånemark, and T. Jemt, "Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws," *The International Journal of Oral & Maxillofacial Implants*, vol. 5, no. 4, pp. 347–359, 1990.

[7] G. Anneroth, A. R. Ericsson, and L. Zetterqvist, "Tissue integration of Al_2O_3-ceramic dental implants (Frialit)—a case report," *Swedish Dental Journal*, vol. 14, no. 2, pp. 63–70, 1990.

[8] O. Bahat, "Brånemark system implants in the posterior maxilla: clinical study of 660 implants followed for 5 to 12 years," *The International Journal of Oral and Maxillofacial Implants*, vol. 15, no. 5, pp. 646–653, 2000.

[9] T. J. Balshi, "An analysis and management of fracured implants: a clinical report," *The International Journal of Oral and Maxillofacial Implants*, vol. 11, no. 5, pp. 660–666, 1996.

[10] A. E. Bianchi, G. Gallini, R. Fassina, F. Sanfilippo, and D. Zaffe, "Morphostructural relationships between bone and implant: comparative analyses by optical microscopy and microradiography," *International Journal of Periodontics and Restorative Dentistry*, vol. 17, no. 6, pp. 553–561, 1997.

[11] U. Brägger, S. Aeschlimann, W. Bürgin, C. H. F. Hämmerle, and N. P. Lang, "Biological and technical complications and failures with fixed partial dentures (FPD) on implants and teeth after four to five years of function," *Clinical Oral Implants Research*, vol. 12, no. 1, pp. 26–34, 2001.

[12] P. I. Brånemark, B. O. Hansson, R. Adell et al., "Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period," *Scandinavian Journal of Plastic and Reconstructive Surgery. Supplementum*, vol. 16, pp. 1–132, 1977.

[13] D. Brocard, P. Barthet, E. Baysse et al., "A multicenter report on 1, 022 consecutively placed ITI implants: a 7-year longitudinal study," *The International Journal of Oral and Maxillofacial Implants*, vol. 15, no. 5, pp. 691–700, 2000.

[14] G. Brunel, S. Armand, N. Miller, and J. Rue, "Histologic analysis of a fractured implant: a case report," *International Journal of Periodontics and Restorative Dentistry*, vol. 20, no. 5, pp. 521–526, 2000.

[15] D. Buser, R. Mericske-Stern, J. P. Bernard et al., "Long-term evaluation of non-submerged ITI implants, part 1: 8-year life table analysis of a prospective multi-center study with 2359 implants," *Clinical Oral Implants Research*, vol. 8, no. 3, pp. 161–172, 1997.

[16] H. J. Conrad, J. K. Schulte, and M. C. Vallee, "Fractures related to occlusal overload with single posterior implants: a clinical report," *Journal of Prosthetic Dentistry*, vol. 99, no. 4, pp. 251–256, 2008.

[17] R. S. Corpe, D. E. Steflik, T. R. Young et al., "Retrieval analyses of implanted biomaterials: light microscopic and scanning electron microscopic analyses of implants retrieved from humans," *The Journal of Oral Implantology*, vol. 25, no. 3, pp. 162–178, 1999.

[18] U. Covani, A. Barone, R. Cornelini, and R. Crespi, "Clinical outcome of implants placed immediately after implant removal," *Journal of Periodontology*, vol. 77, no. 4, pp. 722–727, 2006.

[19] A. N. Cranin, J. B. Dibling, A. Simons, M. Klein, and A. Sirakian, "Report of the incidence of implant insert fracture and repair of Core-Vent dental implants," *The Journal of Oral Implantology*, vol. 16, no. 3, pp. 184–188, 1990.

[20] S. E. Eckert and P. C. Wollan, "Retrospective review of 1170 endosseous implants placed in partially edentulous jaws," *Journal of Prosthetic Dentistry*, vol. 79, no. 4, pp. 415–421, 1998.

[21] S. E. Eckert, S. J. Meraw, E. Cal, and R. K. Ow, "Analysis of incidence and associated factors with fractured implants: a retrospective study," *The International Journal of Oral and Maxillofacial Implants*, vol. 15, no. 5, pp. 662–667, 2000.

[22] J. Gargallo-Albiol, M. Satorres-Nieto, J. L. P. Capablo, M. A. S. Garcés, J. P. Urgell, and C. Gay-Escoda, "Endosseous dental implant fractures an analysis of 21 cases," *Medicina Oral, Patologia Oral y Cirugia Bucal*, vol. 13, no. 2, pp. E124–E128, 2008.

[23] K. Gibney, "Fracture of the body of an implant and its management—a case history," *British Dental Journal*, vol. 197, no. 10, pp. 615–617, 2004.

[24] J. Gunne, T. Jemt, and B. Lindén, "Implant treatment in partially edentulous patients: a report on prostheses after 3 years," *The International Journal of Prosthodontics*, vol. 7, no. 2, pp. 143–148, 1994.

[25] P. J. Henry, R. C. Bower, and C. D. Wall, "Rehabilitation of the edentulous mandible with osseointegrated dental implants: 10 year follow-up," *Australian Dental Journal*, vol. 40, no. 1, pp. 1–9, 1995.

[26] G. Iezzi, A. Scarano, C. Mangano, B. Cirotti, and A. Piattelli, "Histologic results from a human implant retrieved due to fracture 5 years after insertion in a sinus augmented with anorganic bovine bone," *Journal of Periodontology*, vol. 79, no. 1, pp. 192–198, 2008.

[27] C. Ivanoff, K. Gröndahl, L. Sennerby, C. Bergström, and U. Lekholm, "Influence of variations in implant diameters: a 3- to 5-year retrospective clinical report," *The International Journal of Oral and Maxillofacial Implants*, vol. 14, no. 2, pp. 173–180, 1999.

[28] C. Ivanoff, K. Gröndahl, C. Bergström, U. Lekholm, and P. Brånemark, "Influence of bicortical or monocortical anchorage on maxillary implant stability: a 15-year retrospective study of Brånemark system implants," *The International Journal of Oral and Maxillofacial Implants*, vol. 15, no. 1, pp. 103–110, 2000.

[29] P. Laine, A. Salo, R. Kontio, S. Ylijoki, C. Lindqvist, and R. Suuronen, "Failed dental implants—clinical, radiological and bacteriological findings in 17 patients," *Journal of Cranio-Maxillofacial Surgery*, vol. 33, no. 3, pp. 212–217, 2005.

[30] U. Lekholm, D. van Steenberghe, I. Herrmann et al., "Osseointegrated implants in the treatment of partially edentulous jaws: a prospective 5-year multicenter study," *The International Journal of Oral & Maxillofacial Implants*, vol. 9, no. 6, pp. 627–635, 1994.

[31] U. Lekholm, J. Gunne, P. Henry et al., "Survival of the Brånemark implant in partially edentulous jaws: a 10-year prospective multicenter study," *The International Journal of Oral and Maxillofacial Implants*, vol. 14, no. 5, pp. 639–645, 1999.

[32] U. Lekholm, K. Gröndahl, and T. Jemt, "Outcome of oral implant treatment in partially edentulous jaws followed 20 years in clinical function," *Clinical Implant Dentistry and Related Research*, vol. 8, no. 4, pp. 178–186, 2006.

[33] R. A. Levine, D. S. Clem III, T. G. Wilson Jr., F. Higginbottom, and G. Solnit, "Multicenter retrospective analysis of the ITI implant system used for single-tooth replacements: results of loading for 2 or more years," *The International Journal of Oral & Maxillofacial Implants*, vol. 14, no. 4, pp. 516–520, 1999.

[34] J. P. Malmqvist and L. Sennerby, "Clinical report on the success of 47 consecutively placed Core-Vent implants followed from 3 months to 4 years," *The International Journal of Oral & Maxillofacial Implants*, vol. 5, no. 1, pp. 53–60, 1990.

[35] J. Mau, A. Behneke, N. Behneke et al., "Randomized multicenter comparison of 2 IMZ and 4 TPS screw implants supporting bar-retained overdentures in 425 edentulous mandibles," *The International Journal of Oral and Maxillofacial Implants*, vol. 18, no. 6, pp. 835–847, 2003.

[36] R. Mericske-Stern, T. S. Schaffner, P. Marti, and A. H. Geering, "Peri-implant mucosal aspects of ITI implants supporting overdentures. A five-year longitudinal study," *Clinical Oral Implants Research*, vol. 5, no. 1, pp. 9–18, 1994.

[37] R. Mericske-Stern, D. Aerni, A. H. Geering, and D. Buser, "Long-term evaluation of non-submerged hollow cylinder implants. Clinical and radiographic results," *Clinical Oral Implants Research*, vol. 12, no. 3, pp. 252–259, 2001.

[38] M. J. Morgan, D. F. James, and R. M. Pilliar, "Fractures of the fixture component of an osseointegrated implant," *The International Journal of Oral & Maxillofacial Implants*, vol. 8, no. 4, pp. 409–414, 1993.

[39] F. I. Muroff, "Removal and replacement of a fractured dental implant: case report," *Implant Dentistry*, vol. 12, no. 3, pp. 206–210, 2003.

[40] I. Naert, M. Quirynen, D. V. Steenberghe, and P. Darius, "A study of 589 consecutive implants supporting complete fixed prostheses. Part II: prosthetic aspects," *The Journal of Prosthetic Dentistry*, vol. 68, no. 6, pp. 949–956, 1992.

[41] I. Naert, M. Quirynen, D. van Steenberghe, and P. Darius, "A six-year prosthodontic study of 509 consecutively inserted implants for the treatment of partial edentulism," *The Journal of Prosthetic Dentistry*, vol. 67, no. 2, pp. 236–245, 1992.

[42] I. E. Naert, J. A. J. Duyck, M. M. F. Hosny, and D. van Steenberghe, "Freestanding and tooth-implant connected prostheses in the treatment of partially edentulous patients. Part I: an up to 15-years clinical evaluation," *Clinical Oral Implants Research*, vol. 12, no. 3, pp. 237–244, 2001.

[43] N. Noack, J. Willer, and J. Hoffmann, "Long-term results after placement of dental implants: longitudinal study of 1, 964 implants over 16 years," *The International Journal of Oral and Maxillofacial Implants*, vol. 14, no. 5, pp. 748–755, 1999.

[44] A. Örtorp and T. Jemt, "Clinical experiences with laser-welded titanium frameworks supported by implants in the edentulous mandible: a 10-year follow-up study," *Clinical Implant Dentistry and Related Research*, vol. 8, no. 4, pp. 198–209, 2006.

[45] A. Piattelli, A. Scarano, and M. Paolantonio, "Clinical and histologic features of a nonaxial load on the osseointegration of a posterior mandibular implant: report of a case," *The International Journal of Oral and Maxillofacial Implants*, vol. 13, no. 2, pp. 273–275, 1998.

[46] A. Piattelli, M. Piattelli, A. Scarano, and L. Montesani, "Light and scanning electron microscopic report of four fractured implants," *The International Journal of Oral and Maxillofacial Implants*, vol. 13, no. 4, pp. 561–564, 1998.

[47] A. Piattelli, A. Scarano, and M. Piattelli, "Histologic observations on 230 retrieved dental implants: 8 years' experience (1989–1996)," *Journal of Periodontology*, vol. 69, no. 2, pp. 178–184, 1998.

[48] A. Piattelli, A. Scarano, M. Piattelli, E. Vaia, and S. Matarasso, "Hollow implants retrieved for fracture: a light and scanning electron microscope analysis of 4 cases," *Journal of Periodontology*, vol. 69, no. 2, pp. 185–189, 1998.

[49] G. Polizzi, S. Fabbro, M. Furri, I. Herrmann, and S. Squarzoni, "Clinical application of narrow Brånemark System implants for single-tooth restorations," *The International Journal of Oral and Maxillofacial Implants*, vol. 14, no. 4, pp. 496–503, 1999.

[50] P. Proussaefs, J. Lozada, and M. Ojano, "Histologic evaluation of threaded HA-coated root-form implants after 3.5 to 11 years of function: a report of three cases," *International Journal of Periodontics and Restorative Dentistry*, vol. 21, no. 1, pp. 21–29, 2001.

[51] T. Pylant, R. G. Triplett, M. C. Key, and M. A. Brunsvold, "A retrospective evaluation of endosseous titanium implants in the partially edentulous patient," *The International Journal of Oral & Maxillofacial Implants*, vol. 7, no. 2, pp. 195–202, 1992.

[52] M. Quirynen, I. Naert, D. van Steenberghe, C. Dekeyser, and A. Callens, "Periodontal aspects of osseointegrated fixtures supporting a partial bridge. An up to 6-years retrospective study," *Journal of Clinical Periodontology*, vol. 19, no. 2, pp. 118–126, 1992.

[53] B. Rangert, P. H. Krogh, B. Langer, and N. van Roekel, "Bending overload and implant fracture: a retrospective clinical analysis," *The International Journal of Oral & Maxillofacial Implants*, vol. 10, no. 3, pp. 326–334, 1995.

[54] G. E. Romanos and G. H. Nentwig, "Single molar replacement with a progressive thread design implant system: a retrospective clinical report," *The International Journal of Oral and Maxillofacial Implants*, vol. 15, no. 6, pp. 831–836, 2000.

[55] E. Romeo, D. Lops, E. Margutti, M. Ghisolfi, M. Chiapasco, and G. Vogel, "Long-term survival and success of oral implants in the treatment of full and partial arches: a 7-year prospective study with the ITI dental implant system," *The International Journal of Oral and Maxillofacial Implants*, vol. 19, no. 2, pp. 247–259, 2004.

[56] E. S. Rosenberg and J. Torosian, "An evaluation of differences and similarities observed in fixture failure of five distinct implant systems," *Practical Periodontics and Aesthetic Dentistry*, vol. 10, no. 6, pp. 687–698, 1998.

[57] A. P. Saadoun and M. G. Le Gall, "An 8-year compilation of clinical results obtained with Steri-Oss endosseous implants," *Compendium of Continuing Education in Dentistry*, vol. 17, no. 7, pp. 669–674, 1996.

[58] S. Scholander, "A retrospective evaluation of 259 single-tooth replacements by the use of Brånemark implants," *International Journal of Prosthodontics*, vol. 12, no. 6, pp. 483–491, 1999.

[59] L. Sennerby, L. E. Ericson, P. Thomsen, U. Lekholm, and P. Astrand, "Structure of the bone-titanium interface in retrieved clinical oral implants," *Clinical Oral Implants Research*, vol. 2, no. 3, pp. 103–111, 1991.

[60] K. Snauwaert, J. Duyck, D. van Steenberghe, M. Quirynen, and I. Naert, "Time dependent failure rate and marginal bone loss of implant supported prostheses: a 15-year follow-up study," *Clinical Oral Investigations*, vol. 4, no. 1, pp. 13–20, 2000.

[61] D. E. Steflik, G. R. Parr, B. B. Singh et al., "Light microscopic and scanning electron microscopic analyses of dental implants retrieved from humans," *The Journal of Oral Implantology*, vol. 20, no. 1, pp. 8–24, 1994.

[62] N. Tagger Green, E. E. Machtei, J. Horwitz, and M. Peled, "Fracture of dental implants: literature review and report of a case," *Implant Dentistry*, vol. 11, no. 2, pp. 137–143, 2002.

[63] F. Takeshita, T. Suetsugu, Y. Higuchi, and M. Oishi, "Histologic study of failed hollow implants," *The International Journal of Oral & Maxillofacial Implants*, vol. 11, no. 2, pp. 245–250, 1996.

[64] G. Tawil, N. Aboujaoude, and R. Younan, "Influence of prosthetic parameters on the survival and complication rates of short implants," *The International Journal of Oral and Maxillofacial Implants*, vol. 21, no. 2, pp. 275–282, 2006.

[65] D. E. Tolman and W. R. Laney, "Tissue-integrated prosthesis complications," *The International Journal of Oral & Maxillofacial Implants*, vol. 7, no. 4, pp. 477–484, 1992.

[66] T. Traini, S. De Paoli, S. Caputi, G. Iezzi, and A. Piattelli, "Collagen fiber orientation near a fractured dental implant after a 5-tear loading period: case report," *Implant Dentistry*, vol. 15, no. 1, pp. 70–76, 2006.

[67] T. Uehara, K. Takaoka, and K. Ito, "Histological evidence of osseointegration in human retrieved fractured hydroxyapatite-coated screw-type implants: a case report," *Clinical Oral Implants Research*, vol. 15, no. 5, pp. 540–545, 2004.

[68] G. Vantaggiato, G. Iezzi, E. Fiera, V. Perrotti, and A. Piattelli, "Histologic and histomorphometric report of three immediately loaded screw implants retrieved from man after a three-year loading period," *Implant Dentistry*, vol. 17, no. 2, pp. 192–199, 2008.

[69] D. Velásquez-Plata, J. Lutonsky, Y. Oshida, and R. Jones, "A close-up look at an implant fracture: a case report," *International Journal of Periodontics and Restorative Dentistry*, vol. 22, no. 5, pp. 483–491, 2002.

[70] P. Virdee and K. Bishop, "A review of the aetiology and management of fractured dental implants and a case report," *British Dental Journal*, vol. 203, no. 8, pp. 461–466, 2007.

[71] H. Weber, C. C. Crohin, and J. P. Fiorellini, "A 5-year prospective clinical and radiographic study of non-submerged dental implants," *Clinical Oral Implants Research*, vol. 11, no. 2, pp. 144–153, 2000.

[72] G. Weibrich, R. S. R. Buch, J. Wegener, and W. Wagner, "Five-year prospective follow-up report of the Astra tech standard dental implant in clinical treatment," *The International Journal of Oral and Maxillofacial Implants*, vol. 16, no. 4, pp. 557–562, 2001.

[73] B. Zinsli, T. Sägesser, E. Mericske, and R. Mericske-Stern, "Clinical evaluation of small-diameter ITI implants: a prospective study," *The International Journal of Oral and Maxillofacial Implants*, vol. 19, no. 1, pp. 92–99, 2004.

[74] T. Berglundh, L. Persson, and B. Klinge, "A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years," *Journal of Clinical Periodontology*, vol. 29, supplement 3, pp. 197–212, 232-233, 2002.