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 frustrating 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 44,521 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 fractures 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 of 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 European Journal of Prosthodontics and Restorative Dentistry, Oral Surgery, Oral Medicine, Oral Pathology, and Oral Radiology, Schweiz Monatsschrift fur Zahnmmedizin, 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 (CI95%) 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% [CI95% 0.0–2.8%] (717 out of 44316 implants in 43 investigations). A highly significant difference ($\chi^2 = 82.1, df = 1, \text{and } P < 0.001$) was observed between fracture incidence rates reported in prospective studies (2.1% [CI95% 0.0–2.7%], 524 out of 24980 implants in 22 investigations) and retrospective studies (1.0% [CI95%, 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 (71%). 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 occurred in the upper jaw (64.9%), while 230 fractures were located in the lower jaw (35.1%). The vast majority (84.5%) occurred 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 |
| Crain 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%) |
| lezzi 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 Sonnerby 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%) |
| Örstorp 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%) |
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 not preceded by technical complications.

### 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% [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

### Table 1: Continued

| Study                        | Study design | Number of implants | Implant fractures |
|------------------------------|--------------|--------------------|-------------------|
| Sennerby et al. 1991 [59]    | case series  | 7                  | 1                 |
| Snaauwaert 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                 |
| Velasquez-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 | 44394          | 787               |

Implant fractures occurred after 1 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.

### 3.5. Time Point of Fracture
Implant fractures occurred 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.

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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 occurred 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 occurrence 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.

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