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ORIGINAL ARTICLE

Fracture of Osseointegrated Dental Implants: A Comprehensive Review

Osseointegre dental implantların fraktürleri: Kapsamlı bir derleme

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Abstract

Aim: Dental implants constitute functional and aesthetic solutions for edentulous patients. Despite their high success rates, complications may occur. Implant fracture is a severe complication since it usually results in loss of the implant. This comprehensive review study aims to present the causes and treatment options for implant fractures.
Methods: A literature review was carried out utilizing electronic databases and international scientific journals. Of the articles included, most were reviews of the literature, some reviews of the literature combined with case reports, cohort studies, and case reports. A meta-analysis was also included in the sample.
Results: Many factors have been implicated to cause dental implant fractures, including faulty design or production, ill-fitting restorations, loading protocols, bruxism or heavy occlusal forces, design of the restoration, implant location and diameter, metal fatigue, and bone loss around the implant. In the literature, three different treatment options are mentioned: complete extraction of the fractured implant, removal of the coronal portion of the fractured implant, and either placement of a new prosthetic post or leaving the remaining apical part dormant in the bone.
Conclusions: As implant treatment becomes popular, dentists are more likely to encounter and treat implant fractures. This is a frustrating complication for the patient and the dentist because it usually leads to the loss of the implant and the restoration. Therefore, it is suggested that clinicians study the possible causes of implant fractures and plan the treatment properly to prevent fractures and apply the best individualized treatment option should it occur.

Keywords: Dental implants, Peri-implant fracture, Implant removal, Peri-implantitis.

ÖZ

Amaç: Dental implantlar dişsiz hastalara fonksiyonel ve estetik çözümler sağlamaktadır. Yüksek başarı oranlarına rağmen tedavi süresince çeşitli komplikasyonlar meydana gelebilmektedir. İmplant fraktürleri genellikle implantın kaybıyla sonuçlanan ciddi bir komplikasyondur. Bu kapsamlı derleme çalışması, implant kırıklarının nedenlerini ve tedavi seçeneklerini sunmayı amaçlamaktadır.
Gereç ve Yöntemler: Farklı bilimsel veritabanları ve çeşitli uluslararası bilimsel dergiler kullanılarak literatür taraması yapılmıştır. Elde edilen yayınların arasından sistematik derlemeler, meta-analizler ve randomize kontrollü çalışmalar seçilerek örnekleme dahil edilmiştir.
Bulgular: Hatalı tasarım veya üretim, uyumsuz restorasyonlar, yükleme protokolleri, bruksizm veya ağır oklüzal kuvvetler, restorasyonun tasarımı, implant konumu ve çapı, metal yorgunluğu ve implant çevresindeki kemik kaybı da dahil olmak üzere dental implant fraktürlerine neden olan birçok faktör bildirilmiştir. Literatürde üç farklı tedavi seçeneğinden bahsedilmektedir. Bunlar; kırılan implantın tamamen çıkarılmasını, kırılan implantın koronal kısmının çıkarılmasını veya apikal kısma yönelik birtakım girişimleri içermektedir.
Sonuçlar: İmplant tedavisi yaygınlaştıkça diş hekimlerinin implant kırıklarıyla karşılaşma ve tedavi etmek zorunda kalma olasılıkları da artmaktadır. Bu hem hasta hem de diş hekimi için can sıkıcı bir komplikasyondur çünkü genellikle implantın ve restorasyonun kaybı ile sonuçlanmaktadır. Bu nedenle klinisyenlerin implant kırıklarının olası nedenlerini araştırmaları, tedaviyi kırıkları önleyecek şekilde planlamaları ve kırık meydana gelmesi durumunda ilgili hasta için en uygun tedavi seçeneğine karar verebilmeleri önemlidir.

Anahtar Kelimeler: Diş implantları, İmplant fraktürleri, İmplant çıkarılması, Peri-implantitis

Introduction

Dental implants are considered a huge leap in modern dentistry, enabling dentists to present both functional and aesthetic solutions to patients with partially or edentulous jaws. This treatment method, which has been reported to have a 90 to 95% initial success rate, is a reasonable and predictable alternative for edentulous patients (1-4).

The survival rate of dental implants is very high. Specifically, in a previous study, the survival rate in patients with a history of chronic periodontitis was reported to be 90.5% while it was 96.5% for those with no history of periodontitis (5).

Criteria of success according to Karoussis et al. (5) include the following:

1. No mobility (6).

2. No persistent subjective complaints such as pain, foreign body sensation, and/or dysesthesia (6).

3. No pocket probing depth ≥ 5 mm and bleeding on probing (7).

4. No continuous radiolucency around the implant (6).

5. Annual vertical bone loss ≤ 0.2 mm, after the first year of function (8, 9).

Even though implant treatment has a high success rate, the more implants and implant-supported prostheses become popular, the possibility of complications associated with these treatment options increases (10). Complications associated with implant treatment may

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be evaluated under three headings, considering their origins: biological mechanisms, mechanical problems, and lack of patient adaptation. Also, a time-related classification was previously described: complications during surgery, early complications, and late complications (1). Many complications may lead to implant failure, which could be evaluated under two categories:

• Early failure: usually occurs before initiation of the prosthetic phase of the treatment and is mostly caused by surgical problems (2).

• Late failure: usually originates from pathological events associated with an already osseointegrated implant (2).

Late complications include loosening or fracture of the abutment screw and more significantly fracture of the implant itself. Implant fractures may be considered as one of the most severe mechanical complications and a tiring problem both for patients and clinicians, because they are usually managed by removal of the implants and thus loss of the prostheses (2, 3, 10).

The frequency of implant fractures is quite rare, with reported incidences of 0.2 to 1.5% (10-17). Balshi (11) reported that of the 4045 implants inserted, only 0.2% presented with fractures during the first five years of function. In another study by Adell et al. (18), of the 4636 implants placed, the average implant fracture rate was no more than 5%, with a rate of 6% in the maxilla and 3% in the mandible after 15 years (18). Eckert et al. (15) found the fracture rate of 4937 implants to be 0.6%, and there was no statistical significance between jaws (15). According to a meta-analysis that was carried out by Pommer et al. (19), fracture incidence of implants has been reported to range between 0.1% and 7.5%, and the frequency depended on patient, implant, and prosthesis-related factors (19). It has been reported that implants, especially in the posterior regions, are at greater risk of fracture; because the bite forces in these areas are nearly three times higher than the forces implants in the anterior region are exposed to and it usually occurs during the first two to three years of functioning (10,12,20).

The purpose of this comprehensive review was to investigate the causes of dental implant fractures and present the treatment alternatives for this complication, to aid clinicians in the prevention of such complications by thoroughly evaluating the important biomechanical aspects of this treatment method and choosing the best available treatment when facing an implant fracture.

Materials and Methods

A literature review was carried out through electronic databases (MEDLINE [PubMed], Google Scholar, and Scopus) and international scientific journals ("International Journal of Oral & Maxillofacial Implants", "Clinical Oral Implants Research", "Journal of Oral Implantology", and "Implant Dentistry"). There was no restriction on dates; all search results were scanned and filtered using the words "dental fracture", "dental implant fracture", "dental fracture causes", "dental implant complications", "dental fracture treatment", and "dental implant fracture treatment" as keywords. The search was completed in 2022, which is the reason there are no references dated after 2021.

Results

From compiled 41 articles, the majority were reviews of the literature, some of which were reviews of the literature combined with case reports. There were also cohort studies, case reports, and a meta-analysis included in the sample.

Causes of dental implant fractures

A wide range of factors has been suggested as probable causes of dental implant fractures (1, 10):

1. Design or production flaws. Faulty production and/or design of dental implants were previously interpreted as the least likely reasons for dental implant fractures, since microscopic analysis of fractured implants revealed no defects or porosity in the titanium structure of the implant. Thus, manufacturing errors could not be considered as one of the main reasons for implant fractures (11,21).

2. Inadequate fit of the superstructure. A non-passive fit may create undesirable forces, producing a constant tension on the implant (1,2).

3. Load factors. These factors are strongly associated with the magnitude and direction of occlusal forces (1). Occlusal forces generated during chewing are nearly three times stronger in the posterior regions concerning the anterior region (2). Although occlusal forces are mainly vertical in the posterior regions, when the inclination of opposite dental cusps contact each other during chewing, the mandible performs a horizontal movement, creating undesirable lateral forces that are transferred to both the implant and the bone (22).

4. Bruxism or heavy occlusal forces. Parafunctional activity, such as bruxism or clenching, may contribute to a potential overload on the implants. With these parafunctions, the load amount, duration, and frequency are increased, and the direction of the load changes undesirably (1,23). Moreover, both grinding and clenching movements may result in implant overload and metal fatigue. Any kind of parafunctional activity has been reported to be one of the major causative factors associated with implant fractures (2). It has been reported in previous studies that nearly 80 to 90% of implant fractures are encountered in patients with parafunctional habits (10). Thus, in treatment planning regarding patients with parafunctional habits, the use of an increased number of implants and occlusal splints should be considered (12,23-25).

5. Design of the restoration. The type of the superstructure may have an influence on the load and stress that are transmitted to the implant. For example, an implant-supported removable prosthesis transfers greater forces to the implant compared to an implant-supported bridge, which consequently has a smaller tendency to fracture (1). Cantilever design bridges have been reported to be associated with implant fractures because they increase the amount of undesirable stresses on an implant (11,15,26,27). Therefore, it has been recommended to avoid posterior cantilevers wherever possible (2). Furthermore, implant fractures have been reported to occur more frequently in single-implant restorations (11,15,27) and combined tooth-implant supported restorations (3).

6. Implant location. The implant location has been considered a possible cause for implant fractures. Posterior mandible is the most common area where implant fractures have been reported to occur (1-3,21). This finding is justified by the fact that lateral jaw movements and cusp contact during chewing generate excessive lateral forces on the implant (1,3).

7. Implant diameter. Implants with small diameters are more prone to fractures than implants with larger diameters (1,2). An implant with a 3.75 mm diameter has a titanium wall thickness of 0.4 mm (2). It has been reported that an implant with a 5 mm diameter is three times, and an implant with a 6 mm diameter is six times more resistant to fractures compared to an implant with a 3.75 mm diameter (1,2,28).

8. Metal fatigue. In a microscopic analysis, Piattelli et al. (21) found fatigue grooves in all fractured implants (21). Furthermore, according to Morgan et al. (29), most implant fractures encountered during loading protocols were found to be caused by metal fatigue and not overload 29. Vast levels of stress are required to induce fractures in dental implants, believed to be caused by three conditions: cross-sectional changes in the implant, peri-implant bone resorption and stress accumulation on the screw threads (1,2).

9. Bone resorption around the implant. Bone resorption around implants may be encountered as a result of biomechanical imbalance (30). The stress transmitted through the implant to the surrounding tissue, exceeding the bone's functional adaptation capacity, may disturb the biomechanical balance. This may cause peri-implant mucositis (superficial inflammation) or peri-implantitis (deep tissue inflammation), which consequently may lead to marginal bone loss (2). Even though crestal bone loss was not significantly associated with implant fractures in some studies (10), others revealed that such resorption was associated with implant fractures. Vertical bone loss is believed to produce a higher bending stress on the implant, especially when it reaches the level that corresponds to the endpoint of the abutment screw. At this level, the bending resistance of the implant is mostly exhausted. A ''V'' shaped radiolucent image may be noticed around the neck of the implant, which is usually characteristic for these cases (13).

For diagnostic purposes, risk factors associated with dental implant fractures have been categorized into three main groups (2,31):

1. Patient-related factors: pocket depth ≥5 mm, bone resorption, and parafunctional habits.

2. Implant-related factors: diameter of the implant <4 mm, implant design, and crown/implant ratio >1.

3. Prosthesis-related factors: loosening or torsion of the prosthetic screws, use of cantilevers and ceramic fractures.

The risk of dental implant fractures is considered to be high when three or more of the above factors are present (2,12,32,33).

Clinical manifestations

Patients usually present with spontaneous bleeding and mobility when implant fractures occur. Clinical examination frequently reveals bleeding on probing, mobility, increased pocket depth, and gingival indexes. Plaque accumulation may also be observed

occasionally due to pain during brushing (2).

Diagnosis

In addition to the clinical signs of mucosal inflammation that are mentioned above, bone loss around the implant is usually determined (2). Therefore, a radiographic examination with a radiograph or computed tomography (CT) may contribute significantly to the diagnosis. It may be detected as a radiolucent line on the radiopaque structure of the implant (34). It should be noted that in most cases, the extent of the marginal bone resorption goes beyond the end of the fracture line (35). In this study, the causes and treatment alternatives are presented, excluding possible prosthetic fractures that occur more frequently and alter the treatment planning.

Prognosis

Implant fracture is a severe complication that leads to implant failure, and removal of the implant is inevitable most of the time (2).

Implant fracture treatment

As far as implant fracture treatment is concerned, three different options are mentioned in the literature. The first solution, usually constituting the treatment of choice, is the removal of the fractured implant completely using a trephine (Figure 1). The implant has to be atraumatically removed with minimum bone loss. Different designs of trephines may be used in each case, according to the implant's dimensions. After the extraction of the fractured implant, a new implant may be placed at the same surgical bed or another place. If the implant is to be inserted in the same surgical bed, then one with a larger diameter and/or a longer implant should be chosen. If there is significant bone loss or bone defects after the removal of the implant, then an augmentation procedure may be considered before insertion of another implant (2,34). The dental surgeon has to be careful to use the proper diameter of the explantation trephine, as it may influence the primary stability of the newly inserted implant. Considering that premature occlusal forces may affect osseointegration, the prosthetic phase ought to begin when the osseointegration period is completed (12). An alternative technique for the removal of fractured implants, called the "apicoectomy technique," was proposed in a recent study. It is a convenient technique used to remove fractured implants and insert new implants at the same appointment. This technique requires opening a hole in the bone to enhance visualization of the broken apical fragments of the implant and to remove them through this hole. After that, a new implant may be inserted, and the hole may be closed with the bone that was previously removed from the same surgical site (2,36).

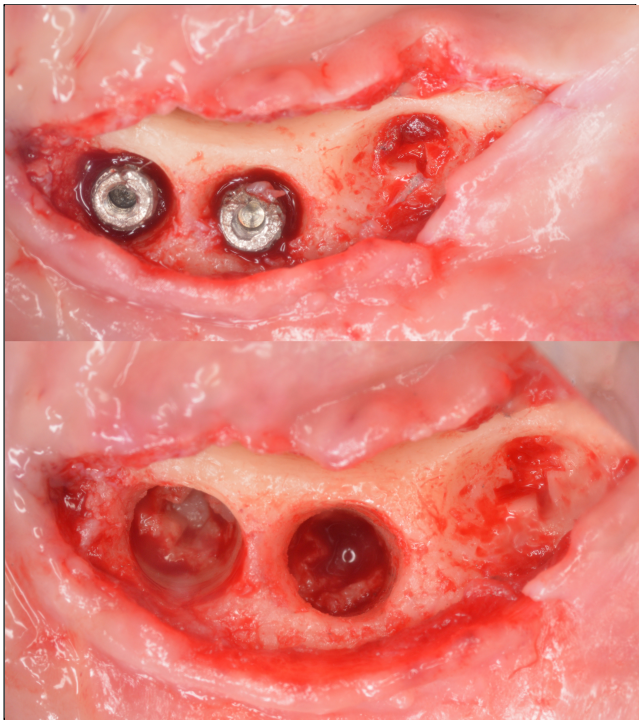

Figure 1. Removal of 2 fractured implants with trephines of appropriate size

The second treatment option is to remove the coronal portion of the fractured implant to place a new prosthetic post (12). This is more applicable when the bone-implant contact ratio is high and the fracture does not progress too far apically. For this purpose, the absence of radiolucency should be confirmed radiographically, and mobility of the fragment should be determined electronically. This option may be preferred when the remaining internal threads are adequate to provide ample prosthetic post retention (11). Moreover, it is worth mentioning that some brands of implants offer a kit that includes a rotary instrument to smooth the edges of the fractured implant and an instrument to accomplish new internal threading to the implant (12).

The third treatment option is to remove the coronal portion of the fractured implant, leaving the remnant osseointegrated apical fragment in the bone as a dormant implant (Figure 2). In which case, the absence of the fractured implant should not negatively affect the support of the prosthesis; however, the prosthesis

should be modified to ensure adequate fitting. If this cannot be accomplished, additional implants are considered necessary and could be placed elsewhere, always considering the existing anatomical limitations (7,11,12).

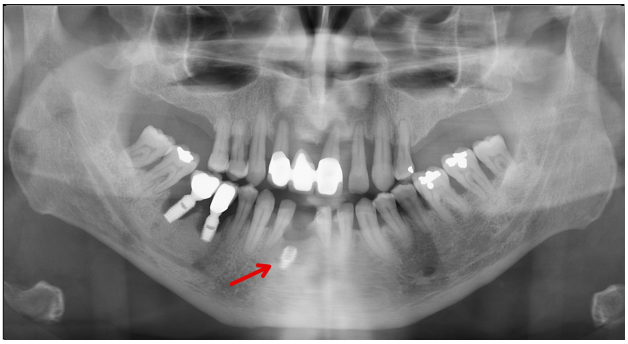

Figure 2. Apical fragment of the fractured implant remaining dormant in the bone (red arrow)

In cases when osseointegration of the implant is not fully successful, removal of the entire implant is a suitable treatment (Figure 3). In these cases, the implant already has mobility, and it should be extracted.

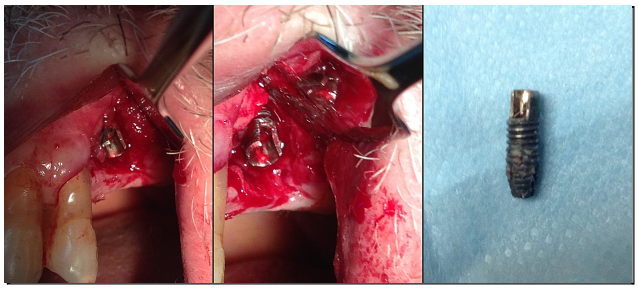

Figure 3. Mobile, non-osseointegrated, fractured implant removal

Discussion

Osseointegrated dental implants have significantly high success and survival rates, which have been reported to be close to 90 to 95%. Although one of the infrequent causes of dental implant failure is fracture, the incidence of implant fractures ranges from 0.1 to 14.3% with fluctuations among different studies (19,20,24). In a review article by Schwarz et al. (37), a 12.5% and 14.3% implant fracture rate has been reported for maxillary and mandibular implants, respectively.

Many factors have been implicated in causing implant fractures, but mechanical overload, parafunctional activity, and peri-implant vertical bone loss were reported to be the most important. Mechanical overload and patients' physiological alterations, such as bruxism, may lead to metal fatigue and denture fracture due to surpassing of the resistance limit of metal. Other factors that may be related to overloading were the prosthetic origin, the presence of distal extensions or cantilevers in implant-supported prostheses, and lack of prosthetic passive fit over the implants (1,10,23).

Marginal bone resorption may be a consequence of both chronic peri-implant tissue inflammation and abnormal occlusal stress. The risk of implant fracture is higher when the vertical bone loss reaches the third apical thread of the implant, which usually corresponds to the apical limit of the abutment screw, connecting the abutment and the implant (23,26,35). At this level, the torque resistance of the implant is lower, which may enhance metal fatigue (35). Some mechanical problems may be indicators of implant overload and precede implant fractures (26). Most of the time; screw loosening, screw fracture or ceramic fracture may be interpreted as an indicator of biomechanical overload or metal fatigue; which will most likely result in implant fractures (35). In these cases, the superstructure should be reassessed. The prosthesis' adaptation should be considered before any other measure. If there is a correct adjustment between the implant and the prosthesis system, then overload should be considered. Hence, the cantilever length and design, occlusion, and position of implants have to be re-examined. In this case, the cantilever length and prosthetic crown size should be reduced, and occlusal contact should be centralized. In addition, the placement of more implants and the manufacturing of a new prosthesis have to be considered, as it may be inevitable in some situations. Therefore, implant fractures can be prevented if clinical monitoring takes place regularly and thoroughly. This assessment may reveal if occlusion loads and forces on the dental implants are distributed equally (2).

When implant fractures occur, the treatment option of choice is to remove the fractured implant remaining in either jaw. If a new implant is to be placed, it should be wider than the previous and the occlusal forces need to be evaluated and adjusted to prevent overload. In cases where this treatment option cannot be executed, there are two alternatives, which may be applied according to the circumstances. One treatment alternative is to modify the fractured implant and remanufacture the prosthetic portion. This solution may be useful when the fracture is not located too apically, and fixation of the connection between the implant and the prosthesis system can still be achieved. Another treatment alternative is to alter

the existing prosthesis and leave the fractured part of the osseointegrated implant dormant in the jaws. If no additional implant placement is needed, the prosthesis may be adjusted to fit the current status. However, if a new implant is needed to be able to support the prosthesis, it should be inserted in a neighboring area, and the restoration should be altered (12). Taking into consideration the needs of each patient, one of the above options may be chosen. Nevertheless, it is of great value to ensure the absence of peri-implant inflammation and implant mobility to be able to proceed with the treatment safely (5).

The importance of pre-planning or revising the treatment after the occurrence of implant fractures has been emphasized previously. To investigate the possible causes of implant failure, or more specifically, implant fractures, micro-CT imaging of removed implants may be a useful approach. There are studies utilizing micro-CT analyses to investigate the implant-abutment connection surfaces and micro-gap measurements and the effect of implantoplasty on implant size and surface alterations (38,39). Moreover, Choi et al. (40) have suggested that the evaluation of fractured areas of implants may be used as a guide to understanding the fracture mechanism (40). In 2015, Narra et al. (41) evaluated eight retrieved implants with micro-CT analysis and reported worn-out, dented, defective surface properties, micro-scratches on various surfaces, and micro-cracks on the implant surfaces. They also emphasized the importance of micro-CTs in understanding the underlying causes of implant fractures and how this may influence future implant designs (41).

Conclusion

In conclusion, it is suggested that dentists be aware of the causes that lead to dental implant fractures, take the appropriate precautions required to prevent fractures from happening, and plan the best individualized solution for each patient. Considering that fracture of an implant is a severe complication in the majority of cases, and it is usually nearly impossible to maintain function as it is, prevention may be the most effective treatment. Also, care should be taken on the prosthetic and non-prosthetic causes of fracture, as the treatment planning changes according to the causes.

Conflict of interest

The authors declare no conflicts of interest.

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