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Implant abutment screw fracture and techniques of retrieval: a literature review based on a novel abutment screw fracture classification

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KEYWORDS Abutment screw fracture; Implant screw fracture; Abutment screw head stripping; Classification.

ABSTRACT

Aim For the last four to five decades, osseointegrated implant-supported prostheses have become the most commonly used treatment modality for the replacement of missing teeth. Even with high success rates, biological and mechanical complications are inevitable. Incidence of abutment screw fracture ranges from 0.5% to 8%. Removing the fractured abutment screw without damaging the internal surface of the implant body, and replacing it with a new abutment screw, is challenging. So, the purpose of this literature review was to evaluate the various types of abutment screw fractures and documented techniques of retrieval.

Materials and methods A search of the electronic database PUBMED/MEDLINE was conducted in Feb 2020. articles published in the English language from 2000 to 2019 were considered. The search terms included were as follows (((Abutment screw fracture) OR Stripped abutment screw head) OR implant screw) AND fracture. All fields in each search term were considered. A hand search of references of included articles (Cross-referencing) was also conducted.

Results The database search of PubMed/MEDLINE identified a total of 3,234 records. Titles and abstracts were screened, 3,219 articles were excluded, as they did not meet the selection criteria. The full texts of the remaining 15 articles were evaluated and included in the systematic review. No articles were identified in the hand search of included studies.

Conclusion It can be observed from this review that: 1) The most documented fracture retrieval was for the ASF3 and ASF2 respectively; 2) From the retrieval techniques discussed in the included articles, ASF3 fracture resulted to be very difficult to be retrieved; 3) Many times, customized techniques could be a better choice, than the use of fractured screw removal kits available on the market.

INTRODUCTION

Osseointegrated implant-supported prostheses have become the most commonly used treatment modality for replacement of the missing teeth for last four to five decades (1,2). Even with 97% to 99% of success rate, biological and mechanical complications are inevitable (3,4). Biologically related complications include peri-implantitis, soft tissue inflammations, radiographic signs of loss of osseointegration. Whereas the mechanical complications include loss of retention, fracture of porcelain, or framework or screw (5). One of the most common problems is screw loosening, which is seen more frequently in single implant-supported prostheses with external connection in distal position (molars) (6,7,8,9). Incidence of abutment screw fracture ranges from 0.5% to 8% but it is a challenging technical complication of implant-retained restorations. It may occur due to bruxism, unfavorable design and shape of the superstructure, overloading, malfunction, premature occlusal contacts, metal fatigue after screw loosening, and component misfit (10,11,12). Removing the fractured abutment screw without damaging the internal surface of the implant body, and replacing it with a new abutment screw, is challenging (13). The location of the screw fracture determines the successful removal of the fractured screw (14). If the screw fractured above the implant head, the screw can be removed easily with hemostats. However, if a screw fractures below the implant head, special screw retrieval kits from various manufactures, such as Retrieval Instruments (Nobel Biocare, Zurich, Switzerland), Neo Screw remover Kit (Neobiotech, Seoul, Korea), and Implant Repair Kit (ITI, Waldenburg, Switzerland), should be considered for use (15,16,17).

Another complication which jeopardizes implant

function is stripping of the abutment screw head. This can be the result of applying excessive force to the screw head or improper engagement of the driver and screw head. Most of the time, the so-called compatible driver may not engage the screw head properly. In the literature several techniques have been proposed for the retrieval of the fractured abutment screw (13,15,18,19).
The purpose of this literature review was to evaluate the various types of abutment screw fractures and documented techniques of retrieval.

MATERIALS AND METHODS

Focused question

The focused question was: what are the various methods/techniques of retrieval of fractured abutment screw based on the novel classification of abutment screw fracture.

Search strategy

A search of the electronic database MEDLINE (via PubMed) was conducted in Feb 25th 2020. articles published in the English language from 2000 to 2019 were considered. The search terms included were as follows: (((((Dental Implant abutment)) OR (abutment screw)) OR (implant screw)) AND ((Fracture) OR (stripping))) AND (((removal) OR (retrieval)) OR (management)). All fields in each search term were considered. A hand search of references of included articles (cross-referencing) was also conducted.

Selection criteria

Inclusion criteria: Clinical case series and case reports on abutment screw fracture and their management were included in this systematic review due to unavailability of the randomised clinical trials and other observational and cohorts studies.
Exclusion criteria: Finite element analysis studies, reports on prosthetic accessory screws (e.g., occlusal screw, cross pinning), abutment screw loosening, fracture of abutments, and reports that did not provide adequate data were excluded as described below.

Screening process

Two authors (NKS, RC) performed the search and screening process following the PRISMA (Fig. 1). Titles and abstracts were first screened and then full-text articles were analyzed with careful and thorough reading based on the inclusion and exclusion criteria for subsequent data extraction. Any disagreements between the authors with the selection or rejection of studies were resolved carefully with thorough discussion, and studies were selected for inclusion in the review.

Data extraction

A single examiner performed data extraction. The data collected from the clinical reports were as follows;

a) Type of fracture;
b) Author and year;
c) Study design;
d) Implant system;
e) Observation time;
f) Implant abutment connection;
g) Type of restoration and region of restoration;
h) Method of retrieval.
The data mentioned above were collected and organized in tables. No statistical data analysis was attempted, as clinical case reports do not provide an adequate source of evidence. The data were collected and described to categorize clinical observational trends and to report on the success of the various retrieval techniques applied in the clinical setting of the dental community.

Abutment screw design and type of restoration

In the implant to abutment connection, the abutment screw allows the preload to tightly connect the implant and the abutment and maintain the stability of this connection under external force. The characteristics of the abutment screw material, such as yield strength, modulus of elasticity, and fatigue life, are essential factors that affect the implant-abutment connection's stability (20). According to the research of Shinohara et al. (21), the screws made of grade 4 pure titanium led to significantly more loosening than the screws made of titanium alloy Ti-6Al-4V.

Classification of abutment screw fracture

To better understand the abutment screw fractures, the authors proposed to classify the abutment screw fracture (ASF) into ASF-1, ASF-2, and ASF-3 (Fig. 2). This is based on the design of the abutment screw.
The abutment screw can be divided into a) screw head, b) screw shank and c) screw thread (Fig. 3).

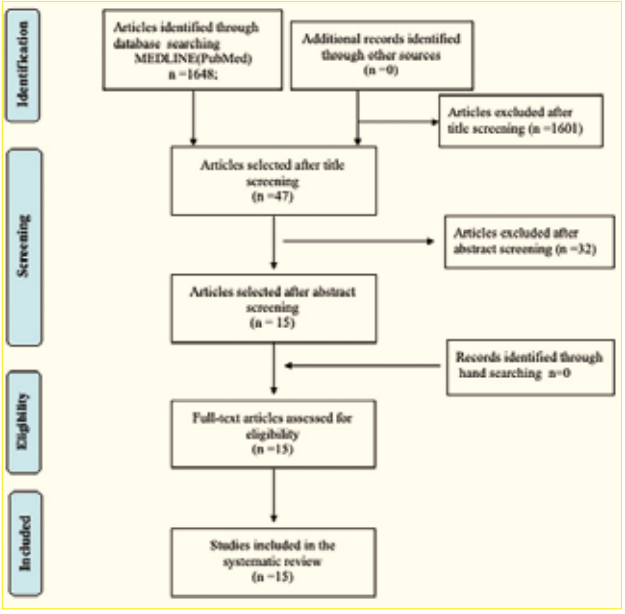
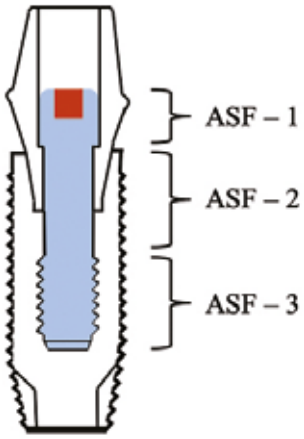


FIG. 1 PRISMA flow chart of literature search.

ASF-1: Stripping of the abutment screw head. This can result in applying excessive force to the screw head or the improper engagement of the driver and screw head (Fig. 4).
ASF-2: The screw shank is the cylindrical length of the screw that extends from the underside of the head to the first thread. Fractures occurring in this region are categorized as ASF-2 (Fig. 5).
ASF-3: Screw thread is the portion of the screw that

FIG. 2 Classification of abutment screw fracture based on the location.



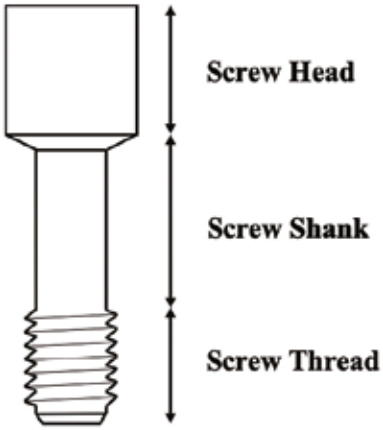
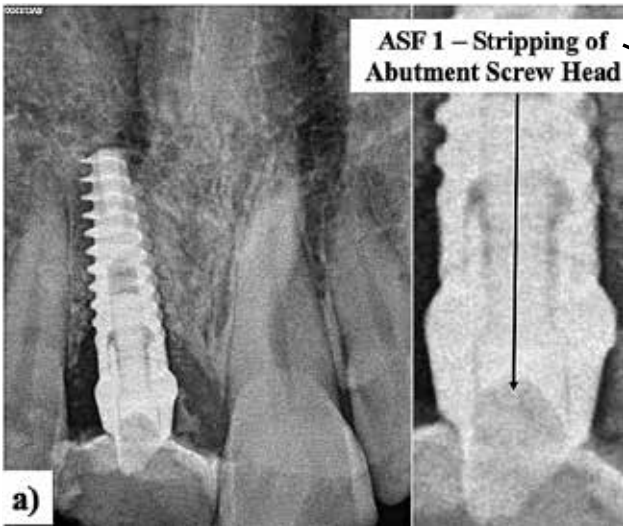


FIG. 3 Parts of the abutment screw.



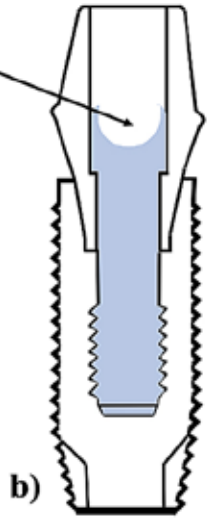
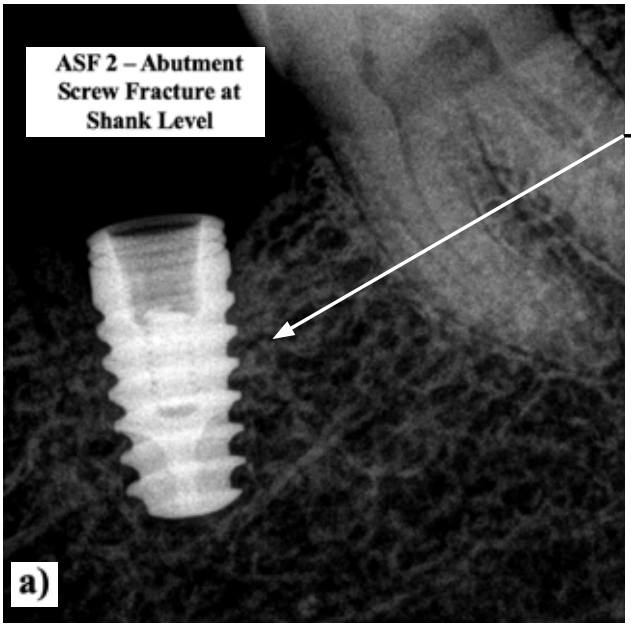


FIG. 4 Example of abutment screw fracture at head level.



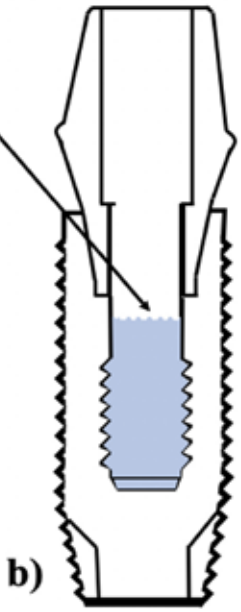


FIG. 5 Example of abutment screw fracture at shank level.

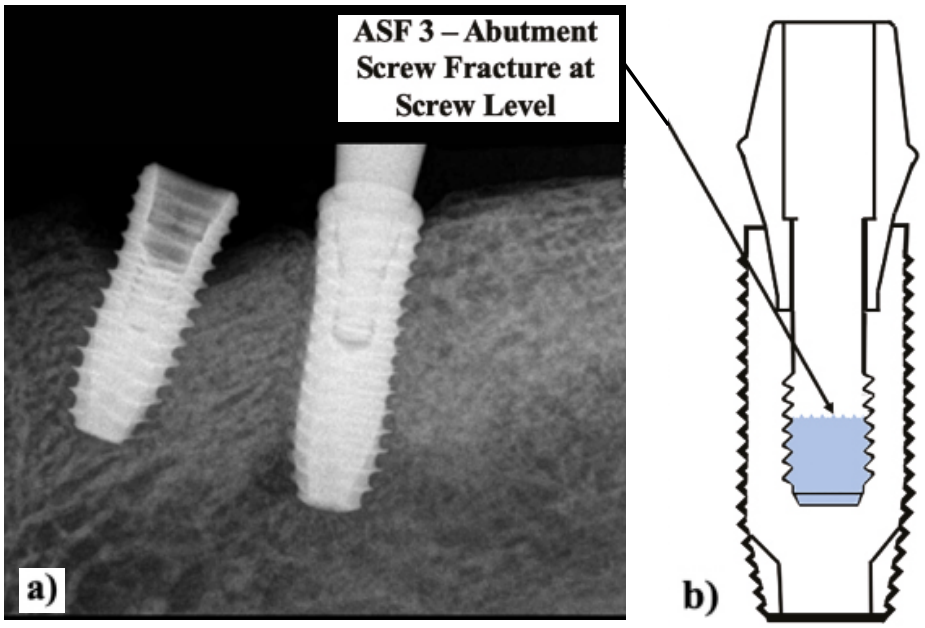


FIG. 6 Example of abutment screw fracture at screw level.

engages the implant. Fractures in this region are categorized as ASF-3 (Fig. 6).

RESULTS

Literature search

The database search of PubMed/MEDLINE identified a total of 1,648 records; 1,601 articles were excluded after title screening; from the remaining 47 articles, 32 articles were excluded after abstract screening, based on the selection criteria. The full texts of the remaining 15 articles were evaluated for inclusion in this systematic review. No articles were identified in the hand search of the references of the included studies (Fig. 1). A total of 15 articles were included in the present systematic review.

Study characteristics

A total of 15 articles were included, fourteen of which reported on abutment screw fracture and one reported on both loosening and fracture. The reported data of clinical case series and case reports showing the various techniques for retrieval are summarized in table 1, based on the region of screw fracture (15,16,17,23,24).

The 15 included studies were categorised based on the proposed classification, in which 1 study was of ASF-1 (17), 3 articles were of ASF-2 (16,25,26), 10 articles of ASF-3 (18,27,28,29,30,31,32,33,34,35), and 1 article described both ASF-2 and ASF-3 (36).

DISCUSSION

Replacement of missing teeth with implant-supported restorations is one of the most commonly used treatment options. However, complications such as abutment screw loosening and fracture are encountered at times (37,38). These abutment screw fractures are mostly related to the design of the implant-abutment connection, poorly fitting framework, reduced clamping force and screw joint movement, bone remodelling and release of pre-tension in the screw joint, heavy occlusal forces, and metal fatigue after screw loosening (12,24).

Loading of the abutment screw along with the abutment depends on the type of restoration. Single implants with a crown are more prone to screw loosening than implant-supported fixed bridges when the retention modes of the superstructure are the same. The latter has an incidence of screw loosening of 5.6% in the 5-year follow-up, whereas the former reached 12.7% (22). It is speculated that the stresses from the external forces are evenly distributed in cases of fixed implant-supported bridges as it acts as a whole to work better in anti-rotation. However, in cases of single implant supported crowns, the stress concentrates on the implant-abutment junction, especially on the abutment screw, thereby leading to a higher incidence of screw loosening (23). Most of the time fractures occur at the junction of the screw head and screw shank or the junction of the screw shank and screw thread (24). As for the techniques for retrieval, as documented in Table 1, based on the ASF classification (16,17,18,25-36), the following can be observed.

ASF-1 (Abutment screw fracture 1)

Abutment screw fracture involving stripping of the abutment screw head, which could be due to excessive force to the screw head or to the improper engagement of the hex drive, mainly happens when a substitute driver to that of the original is used (17). The entire tightness of the abutment screw engaging the abutment to the implant is mainly due to the proper seating of the extensions of the screw head. So, the authors believe that in the situation

Type of fracture	Authors and Year	Study design	Implant system	Observation time (Y)	Implant abutment connection	Type of restoration/region	Method to retrieval
ASF-1	17 -Maalhagh-Fard et al., 2010	Clinical report	N/A	N/A	Internal morse taper connection	Screw retained. An interim crown on an implant in the area of the maxillary right central incisor	A trough was made between the abutment screw head in the internal section of the implant using a no. 2 round rotary cutting instrument the head of the abutment screw was then loosened with the use of fine forceps
ASF-2	25 - Walia MS et al., 2012	Clinical report	Zimmer screw vent	6 years	Internal hex, step ladder.	Cement retained restoration in the mandibular left first molar	A notch on the occlusal surface of the fractured part of the abutment was made between the center of the screw and its periphery by using a tungsten carbide bur. The notch was engaged with an ultrasonic scaler tip, at low speed, counter-clockwise and thus loosened and removed
ASF-2	16 - Taira et al., 2012	Clinical case report	Brånemark system	13 years	Splinted crowns Were veneered with a resin composite/ external hex abutment	Maxillary right central incisor	Stainless steel tubes of 2 sizes were prepared to fabricate a guide tube. The narrow tube (1.5 mm external diameter, 4 mm length) was attached inside the thick tube (1.8 mm external diameter, 4 mm length) with a cyanoacrylate bonding agent to form a single tube, 6 mm long. A hole was drilled in the center of the failed abutment screw with a highspeed air-turbine
ASF-2	26 - Flanagan et al., 2016	Clinical case series of three cases	N/A	1.5 years	Internal hex	1. Cement retained crown in maxillary right first premolar. 2. Locator attachment in 22 region	The lateral flukes of a latch #557 bur were removed, with the end cutting blades intact. With the counter-clockwise slow rotation to engage the fractured part of the abutment screw. The burr was slowly rotated against the fractured piece to reverse rotate the screw fragment out of the fixture.
ASF-3	27 - Nergiz et al., 2004.	Clinical case report	ITI dental implant system	N/A	Magnet retained overdenture prosthesis. / internal hex	Mandibular canine region	The implant repair system Imz twin plus repair set k 3.3 (Dentsply Friadent) consisting of 4 burs. First, the center bit, rotating counter-clockwise with a maximum speed of 1300 rpm, was used to roughen the fragment at its center—next, two twist drills. The conical instrument for retrieving the fragment was inserted into the hole drilled into the fragment; the fragment was then removed under gradual rotation
ASF3	18 - Satterthwaite et al., 2007	Clinical case report	Brånemark mark III	N/A	Cement retained external hex	Maxillary left central incisor	Endodontic instruments were used to remove the fragment
ASF-3	28 -Satwalekar et al., 2013	Clinical report	Uniti system	N/A	Internal hex	Cement retained implant crown in the mandibular left second premolar region	A groove was made on the upper end of the broken screw using a bur without damaging the internal anatomy of the implant. The cut end of the modified spoon excavator was used to engage the prepared groove on the fractured abutment screw, which was left in the implant for the removal
ASF-3	29 - Turkyilmaz et al., 2013	Clinical case report	Straumann	N/A	Locator abutment/ internal hex, morse taper	Locator abutment/ mandibular canine	With the help of an initial twist drill of 1.3 mm diameter, the screw fragment was perforated centrally, and later the fragment was taken out under gradual manual rotation

TABLE 1 A **Retrieval techniques based on abutment screw fracture.** ./.

Type of fracture	Authors and Year	Study design	Implant system	Observation time (Y)	Implant abutment connection	Type of restoration/region	Method to retrieval
ASF-3	30 - Kurt et al., 2013	Clinical case report	N/A	N/A	Ball attachment / internal hex	Ball attachment/ mandibular right canine	Modified flame-shaped bur (Komet, Gerbr. Brasseler Gmbh, Lemgo, Germany) was used to prepare a groove on the fractured screw. A detected tungsten carbide bur was made into a handmade screwdriver, with a thin tip of 1.5 mm width
ASF-3	31 - Bhandari et al., 2013	Clinical case report	Xive, Friadent.	N/A	Healing abutment	Right maxillary second premolar	By stabilizing the piezoelectric scaler tip on the top surface of the fractured fragment, the oscillations were started with minimal power and copious irrigation. With gentle reverse torque intermittently, the vibrating scaler tip contacted the top surface of the screw so that the fractured screw should spin out of the screw hole
ASF-3	32 - Imam et al., 2013	Clinical case report	N/A	N/A	Screw retained external hex	N/A	Special fork-shaped tip of the long-shank stainless steel instrument (fragment fork; Astra tech) is used to thread the broken screw fragment deeper into the implant, by gently rotating the re-tapping tool clockwise by no more than 180 degrees and then rotating it counter clockwise
ASF-3	33 - Gooty et al., 2014	Clinical report	N/A	3 years	Internal hex	Implant-supported crown in the region of the lower left first molar	Using a round bur in high-speed, a 1 mm deep pit was made across the most occlusal portion of the broken screw fragment. Then using an ultrasonic scaler with no. 3 tip placed in the pit prepared to move in anticlockwise direction slowly, the broken abutment screw was retrieved
ASF-3	34 - Yoon et al., 2014	Clinical case report	N/A	7 years	Internal hex	Screw retained metal-ceramic crown/lower left 2nd molar	The access hole in the center of the broken screw. To be able to maintain the bur position at the center of the coping, the impression coping was modified using self-curing acrylic resin (to make the hole, a #329 tungsten carbide bur was used). The central access hole with a depth of 0.5 mm was made with a #329 bur on top of the broken screw, and the reverse tap drill was used in a contra-angle handpiece with a counter-clockwise
ASF-3	35 Carneiro Tap et al., 2015	Clinical case report	Brånemark system	4 years	External hex	Left 1st mandibular molar	Drilling through the fractured abutment screw was done using 1.6 mm helicoidal drill (Neodent, Curitba, Brazil). A fractured screw was completely drilled, the internal implant threads were re-tapped
ASF-2 ASF-3	36 - Al-Rawee et al., 2019	Clinical case series	N/A	1.7 years 2.12years 3 years	Only in 2 cases screw were retrieved	N/A	A screw was retrieved by means of an ultrasonic scaler

TABLE 1 B **Retrieval techniques based on abutment screw fracture.**

of stripping of the abutment screw head, trimming off the head can loosen the abutment, and then the screw can be retrieved.

Maalhag Ford et al. mentioned that access to the stripped abutment screw had to be achieved to loosen and remove the abutment successfully (17). This was achieved by creating a trough between the abutment screw head and the internal aspect of the implant. This can be achieved using a high-speed handpiece with a no. 2 round rotary cutting instrument (Brasseler USA, Savannah, Ga) under copious irrigation without causing damage to the implant head. Then, the fine forceps (Castroviejo Needle Holder; Miltex, Inc, York, Pa) were used to loosen the head of the abutment screw. This facilitated the removal of the fractured abutment screw (17). There are certain precautionary measures that a clinician should perform to prevent stripping and fracturing of abutment screws. A comprehensive diagnostic examination should be performed to identify parafunctional habits such as bruxism, which may contribute to implant and abutment fracture. The clinician should completely understand the torque wrench and its components for inserting the abutment with appropriate torque. To prevent stripping of abutment screw heads, a manufacturer- specified driver and torque wrench has to be used while tightening/ loosening the abutment screw. Further, it is recommended that the clinician always ensure that the abutment screw head is free of debris, to allow the driver to engage the abutment screw fully. Finally, one must ensure that the restoration is free of premature occlusal contacts (17).

ASF-2 (Abutment screw fracture 2)

The screw shank is the cylindrical length of the screw that extends from the underside of the head to the first thread (Fig. 3). Fracture occurring in this region is categorized as ASF-2. This is the most unsupported and no contact area of the abutment screw. Breaking of the screw is not that common. Owing, mostly, to a masticatory load in the posterior region of the arch, implant components are known to fracture more frequently in this region (10,39). Similarly, retrieval of the fractured screw is documented in posterior teeth. In the technique mentioned by Walia et al., first, the crown, along with the abutment, was removed by making an access hole through the crown. With the help of a tapered carbide bur, a notch on the occlusal surface of the fractured part of the shank was made. Then, with the help of an ultrasonic scaler tip, the notch was engaged, and mechanically the tip of the scaler was moved counter-clockwise, and thus the remaining part of the screw was removed (25). In the other technique by Flanagan, a bur is used, with the lateral blades reduced and just the apical blades rotating slowly counter-clockwise, engaging the broken part, to remove the screw (26).

ASF-3 (Abutment screw fracture 3)

The screw thread is the portion of the screw that engages the implant (Fig 2). Fractures in this region are categorized as ASF-3. This is one of the most common types of fracture, wherein the junction of the shank and the first thread is involved, as according to numerical studies and *in vitro* experimental studies, it is documented that maximum bending stress is recorded in first thread region of the abutment screw (30).

Among the techniques followed for the retrieval of the fractured screw, in ASF-3 situation, there is the one by Yoon et al. In this technique an access hole was made in the center of the broken screw using a #329 tungsten carbide bur. Impression coping was modified using selfcuring acrylic resin to have the position of the bur in the center (34). On the top portion of the fractured screw an access hole with a depth of 0.5 mm was made using a #329 and then a reverse tap drill attached to a contra-angle handpiece was used in a counter-clockwise direction to remove the broken screw. To achieve this, the reverse tap drill was engaged to the broken screw by applying a light vertical force along the long axis of the implant (34). In another technique, Turkyilmaz et al. tried an implant repair kit (ITI Dental Implant System; Institute Straumann AG, Waldenburg, Switzerland), including an initial drill, two instrument guides, and three manual tapping instruments. After the first drill guide was inserted on the implant, the corresponding initial twist drill with a diameter of 1.3 mm was used to perforate the screw fragment centrally, rotating clockwise at a maximum speed of 800 rpm. To achieve a proper axial preparation, a drill guide was used by stabilizing it directly on the top of the implant, which helped in not damaging the internal aspect of the implant body during drilling. The manual tapping retrieved the broken piece of the fractured abutment screw (29). Kurt et al., and Satwalekar et al., customized a bur and spoon excavator respectively in a small screwdriver shape and by making agroove or slot in the broken part of the abutment screw, engaged the customized screwdriver and with anticlockwise rotation removed the broken screw (28,30). Many times, when the broken part of the abutment screw cannot be removed without damaging the internal implant thread, different methods of restoration have been mentioned in the literature, such as the non-removal broken screw, and the internal threading of the implant is removed with a bur, and an alternative treatment option is post-core (41).

The limitations of the present systematic review include the following.

1) As this systematic review was based on the techniques of retrieval of fractured abutment screw, which did not present any clinical trials, hence reviewing of the articles was carried out by a single examiner and agreed by the second after discussion of the same.
2) Quality assessment of the articles included in this systematic review could not be done as all the articles reviewed were on the technique of fractured screw retrieval and did not include any clinical trials. Hence the criteria of risk of bias may not fit to evaluate the articles.

Proper identify the fracture sight and planning meticulously can succeed in the retrieval of the fractured piece.

CONCLUSION

It can be observed from this systematic review that:

1. The most documented fracture retrieval was for the ASF-3 and ASF-2, respectively.
2. From the retrieval techniques discussed from the included articles, it makes ASF-3 fracture very difficult to retrieve.
3. Many times, customized techniques could be a better choice than the use of fractured screw removal kits available in the market.

Competing interests

Not applicable

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Author's contribution

RC: Concept, and design of the study, The acquisition, analysis, interpretation of the data and revising the article critically, Final approval of the work.
NKS: Concept, and design of the study, Interpretation of data for the work, revising the article critically, Drafting the paper, final approval.
JGN: The acquisition, analysis, Interpretation of data for the work, final approval.

REFERENCES

1. Adell R, Lekholm U, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of edentulous jaw. Int J Oral Surg 1981; 10:387-416.
2. Misch CE. Contemporary implant dentistry, 3rd eds. Mosby, 2007, p3.\
3. Ekelund JA, Lindquist LW, Carlsson GE, et al. Implant treatment in the edentulous mandible: a prospective study on Brånemark system implants over more than 20 years. Int J Prosthodont 2003; 16:602-608.
4. Lindquist LW, Carlsson GE, Jemt T. A prospective 15year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. Clin Oral Implants Res 1996; 7:329-36.
5. Brägger U, Aeschlimann S, Bürgin W, et al. Biological and technical complications and failures with fixed partial dentures (FPD) on implants and teeth after four to five years of function. Clin Oral Implants Res 2001; 12:26-34.
6. Binon PP. The effect of implant/abutment hexagonal misfit on screw joint stability. Int J Prosthodont 1996; 9:149-160.
7. Jemt T. Failures and complications in 391 consecutively inserted fixed prostheses supported by Brånemark implants in edentulous jaws: A study of treatment from the time of Prosthesis placement to the first annual checkup. Int J Oral Maxillofac Implants 1991; 6:270-276.
8. Jemt T. Multicenter study of overdentures supported by Brånemark. Int J Oral Maxillofac Implants 1992; 7:513-22.
9. Jemt T, Linden B, Lekholm U. Failures and complications in 127 consecutively inserted fixed prostheses supported by Brånemark implants: from prostheses treatment to first annual checkup. Int J Oral Maxillofac Implants 1992; 7:40-43.
10. Eckert SE, Meraw SJ, Cal E et al. Analysis of incidence and associated factors with fractured implants: a retrospective study. Int J Oral maxillofac Implant 2000; 15:662-667.
11. Bakeen LG, Winkler S, Neff PA. The effect of implant diameter, restoration design, and occlusal table variations on screw loosening of posterior single-tooth implant restorations. J Oral implantol 2001; 27:63-72.
12. Schwarz MS. Mechanical complications of dental implants. Clin Oral Implants Res 2000; 11 suppl 1:156-58.
13. Igarashi K, Afrashtehfar KI, Schimmel M, Gazzaz A, Brägger U. Performance of a repair service set for the retrieval of fractured abutment screws: a pilot in vitro study. Int J Oral Maxillofac Implants 2019; 34:567–573.
14. Agustín-Panadero R, Labaig-Rueda C, Castillo-Rodriguez B, Ferreiroa A, Fernanda Solá-Ruíz M. In vitro evaluation of three methods for the retrieval of fractured screw fragments from dental implants Int J Oral Maxillofac Implants 2017;32: e119 – e12 4.
15. Williamson RT, Robinson FG. Retrieval technique for fractured implant screws. J Prosthet Dent 2001; 86:549-550.
16. Taira Y, Sawase T. A modified technique for removing a failed abutment screw from an implant with a custom guide tube. J Oral Implantol 2012; 38:165-169.
17. Maalhagh-Fard A, Jacobs LC. Retrieval of a stripped abutment screws. J Prosthet Dent 2011; 105:137-138.
18. Satterthwaite J, Rickman L. Retrieval of a fractured abutment screw thread from an implant: a case report. Br Dent J 2008; 204:177-80.
19. Mizumoto RM, Jamjoom FZ, Yilmaz B. A risk-based decision making tree for managing fractured abutment and prosthetic screws: A systematic review. J Prosthet Dent 2018;119:552–559.
20. Yousef H, Luke A, Ricci J, Weiner S. Analysis of changes in implant screws subject to occlusal loading: a preliminary analysis. Implant Dent 2005; 14:378-382
21. Shinohara R, Udea K, Watanabe F. Influence of the difference between implant body and screw materials on abutment screw loosening. Dent Mater J 2019; 38:150-156.
22. Pjeturrson BE, Brägger U, Lang NP, Zwahlen M. Comparison of survival and complications rates of tooth -supported fixed dental prostheses (FDPs) and implant-supported FDPs and single crowns (SCs). Clin Oral Implants Res 2007; 18:97-113.
23. Sailer I, Mühlemann S, Zwahlen M et al. Cemented and screw -retained implant reconstructions: a systematic review of the survival and complication rates. Clin Oral Implants Res 2012; 23:163-201.
24. Quek CE, Tan KB, Nicholls JI. Load fatigue performance of a single- tooth implant abutment system: effect of diameter. Int J Oral maxillofac Implants. 2006; 21:929-936.
25. Walia MS, Arora S, Luthra R, Walia PK. Removal of fractured dental implant screw using a new technique: a case report. J Oral Implantol 2012; 38:747-50.
26. Flanagen D. Management of a fractured implant abutment screw. J Oral Implantol. 2016; 42:508-511.
27. Nergiz I, Schmage P, Shahin R. Removal of a fractured implant abutment screw: a clinical report. J Prosthet Dent 2004; 91:513-7.
28. Satwalekar P, Chander KS, Reddy BA, Sandeep N, Sandeep N, Satwalekar T. A simple and cost effective method used for removal of a fractured implant abutment screw: A case report. J Int Oral health 2013; 5:120-3.
29. Turkyilmaz I, Vierra MJ, Asar NV. Removal of a fractured locator abutment screw fragment. J Contemp Dent Pract 2013; 14:968-72.
30. Kurt M, Guler AU, Duran I. A technique for removal of a fractured implant abutment screw. J Oral Implantal 2013; 39:723-5.
31. Bhandari S, Aggarwal N, Bakshi S. Ultrasonic oscillations for conservative retrieval of a rare fracture of implant healing abutment. J Oral Implantol 2013; 39:475-8.
32. Imam AY, Moshaverinia A, Chee WW, McGlumphy EA. A technique for retrieving fractured implant screws. J Prosthet Dent 2014; 111:81-3.
33. Gooty JR, Palakuru SK, Guntakalla VR, Nera M. Noninvasive method for retrieval of broken dental implant abutment screw. Contemp Clin Dent 2014; 5:264-7.
34. Yoon JH, Lee H, Kim MY. Safe removal of a broken abutment screw with customized drill guide and rotary instrument: A clinical Report. J Prosthodont 2016; 25:170-3.
35. Carneiro T de A, Prudente MS, E pessoa RS, Mendonca G, das Neves FD. A conservative approach to retrieve a fractured abutment screw- case report. J Prosthodont Res 2016; 60:138-42.
36. Al-Rawee RY, Mohammad FA, Tawfeeq BA. Salvage of fractured abutment screw by transfer cap screw replacement (original study). Clin Case Rep 2019; 7:1204-1210.
37. Soeno K, Jimbo R, Sawase T, Taira Y. A cast metal core for a deformed implant body: case report.Implant Dent 2006; 15:347-352.
38. Goodacre CJ, Kan JY.Rungcharassaeng K. Clinical complications of osseointegrated implants . J Prosthet Dent. 1999; 81:537-552.
39. Green NT, Machtei EE, Horwitz J, Peled M. Fracture of dental implants: literature review and report of a case. Implant Dent 2002; 11:137-143.
40. Wu T, Fan H, Ma R, Chen H, Li Z, Yu H. Effect of lubricant on the reliability of dental implant abutment screw joint: An in vitro laboratory and three -dimension finite element analysis. Mater Sci Eng C Mater biol Appl 2017; 75:297-304.
41. Gupta V, Prithviraj DR, Muley N. A new restorative technique for the perishing implant due to abutment screw fracture. J Oral Implantol 2014; 40: 755-7.