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SYSTEMATIC REVIEW

A risk-based decision making tree for managing fractured abutment and prosthetic screws: A systematic review

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ABSTRACT

Statement of problem. In implant dentistry, a variety of techniques are used to manage fractured abutment and prosthetic screws. All of them pose various degrees of difficulty to both the clinician and patient and risk involving damage to the implants and prostheses.

Purpose. The purpose of this systematic review was to classify and organize the various reported techniques for managing fractured abutment and or prosthetic screws into a risk-based, decision making tree that could be used to guide the clinician through this difficult and time-consuming clinical procedure.

Material and methods. A systematic search of the PubMed/MEDLINE database for articles published before June 2016 was performed by 2 independent reviewers. Studies published in English that described a clinical technique to retrieve or manage a fractured abutment or prosthetic screws were included. Techniques were classified according to risk of irreversible damage to the implant. Low-risk techniques were defined as those involving the use of basic hand instruments and instrument modification; moderate-risk techniques were defined as those involving the use of screw retrieval kits, rotary instruments, and screw modification; and high-risk techniques were defined as those involving modification of the implant. Published techniques were then organized into a decision-making tree.

Results. A total of 35 articles were included. The reported techniques ranged from straightforward instrumentation and instrument modification to screw or implant modifications. Seven techniques were considered low risk, 17 moderate risk, and 11 high risk.

Conclusions. The proposed risk-based decision tree is a useful tool in helping clinicians choose the most appropriate strategy or sequence of strategies that offers maximum benefit to the patient while minimizing associated risks. (J Prosthet Dent 2018;119:552-9)

The use of osseointegrated implant-supported prostheses to replace natural, missing teeth is an effective and reliable treatment option.[1] Despite having a high success rate, implant therapy is not without problems, and various complications can occur, some of which may be mechanical in nature.[2]

The longevity and success of an implant-retained or implant-supported prosthesis depends primarily on biological and mechanical factors.[3] Biologic factors that can lead to failure include unsuccessful osseointegration or presence of peri-implantitis, whereas mechanical factors include the loosening and fracture of abutment or prosthetic screws and the wear and fracture of the prosthesis or various components in the system.[4,5]

Two types of screws are used in implant dentistry: abutment screws and prosthetic screws. Abutment and prosthetic screws come in various shapes and sizes and are made from a variety of materials, including gold, commercially pure titanium, and surface-treated or coated titanium alloys. Although seemingly simple, the mechanics of abutment and prosthetic screws are complex, a phenomenon described as screw joint mechanics.[6] A screw joint develops from the union of 2 parts by means of a screw that has the same 3 basic components: the screw head, the shank, and the thread. The screw head is the most coronal portion, which contains the driver-fitting site used to rotate the screw into place and apply a compressive, clamping force between 2 parts (the

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Clinical Implications

More than 30 techniques for managing abutment or prosthetic screw fracture have been published. By understanding the inherent risks associated with each technique and following a logical sequence, the process of managing a fractured abutment or prosthetic screw can be simplified.

implant and the abutment/prosthesis). The shank is the middle unthreaded portion of the screw, and the thread is the most apical portion, which engages the internal mating surface of the implant to create a force, called preload, within the screw itself.

The initial clamping force, or preload, is the tensile force that develops when the screw is tightened into place. Preload depends on the torque applied, material, and design of the screw, and surface roughness.[7] Frictional forces that develop between the screw threads make the applied torque inversely proportional to the preload, so the more torque that is applied, the more preload is lost.[7,8] If the torque delivered to a screw is not optimal, screw loosening may occur, making the system susceptible to fracture under occlusal load. Fractured abutment and prosthetic screws are a challenging and time-consuming complication in implant dentistry.[9] When a screw fractures, the fragment inside the implant or abutment must be removed, or the implant must be modified. Otherwise, it may lose its original ability to retain a prosthesis and could become useless (Fig. 1).[10]

In implant dentistry, strategies for managing a damaged or fractured screw pose various degrees of risk which must be analyzed. The concept of risk assessment in dentistry is not new. Dental caries and periodontal disease, for example, have been well studied in relation to this topic, and various evidence-based approaches have been developed to assist the clinician in improving patient care and treatment outcomes.[11] Generally, treatment or intervention should always mitigate future risk and improve the prognosis.[12] In certain situations, however, the intervention itself may be the biggest risk factor. In reviewing published studies, some techniques have been found to be clearly more likely to cause irreversible damage to the implant components and should therefore be considered higher risk procedures (Fig. 2). Because a direct relationship exists between the risk of damage and degree of difficulty, the clinician must understand not only the technique itself but also the inherent risks and difficulty associated with each technique. A PubMed/MEDLINE search was conducted by 2 independent reviewers (R.M., F.J.) to gather available reports that focused on the clinical management of a screw fracture in implant dentistry. Search terms included a combination of any of the following English words: "fractured," "broken," "damaged," "unsalvageable," "screw retrieval," "screw complication," "implant", "dental implant," "abutment screw," and "prosthetic screw." A list of published techniques organized by risk classification and year published is displayed Table 1.

Making decisions is one of the most important and frequent activities of dentists and other health care professionals.[11] In dentistry, a weighted thought process leads to the decision as to whether a treatment is needed or not.[13] Far too often, decisions are made under uncertain circumstances, which can lead to a variety of significantly different approaches being advocated for the same clinical scenario.[11] Therefore, decision trees in dentistry can be useful in managing situations that range from routine to highly complex.[13-15] The formation of a decision tree involves identifying all available choices and potential outcomes of each choice, and structuring a model of the decision process.[11]

In the situation of a fractured implant screw, initial treatment in the form of conservative retrieval is always the first and most preferable option. The question is not whether treatment needs to be initiated but rather what type of treatment should be initiated and what sequence of treatments should be followed. The purpose of this article was to introduce a risk-based decision making tree in relation to the various reported techniques for managing fractured screws. Application of the proposed decision making tree may allow for a logical and structured approach in managing fractured abutment and prosthetic screws (Fig. 3).

CLINICAL TECHNIQUES TO MANAGE BROKEN SCREWS

Examination and Diagnosis

The first step in managing any fractured screw is to obtain a detailed history and perform a thorough clinical examination. Every attempt should be made to determine the cause of the screw fracture to minimize the risk of subsequent complications. The next important step is to confirm that the screw is fractured and determine the location of the fracture. Generally, fractures that occur above the implant level are easier to manage than fractures occurring more apically (Fig. 4). Screw fracture may be confirmed by direct visualization, radiographic examination, tactile sensation through the use of an instrument, comparison with an undamaged screw of the same system, or by using other undamaged components of the same system to see if an obstruction is prohibiting complete seating (Fig. 5).

If the restoration has been missing for an extended period, the peri-implant soft tissue may overgrow, making access to and visualization of the implant difficult (Fig. 6). In this situation, a low-frequency diode laser may

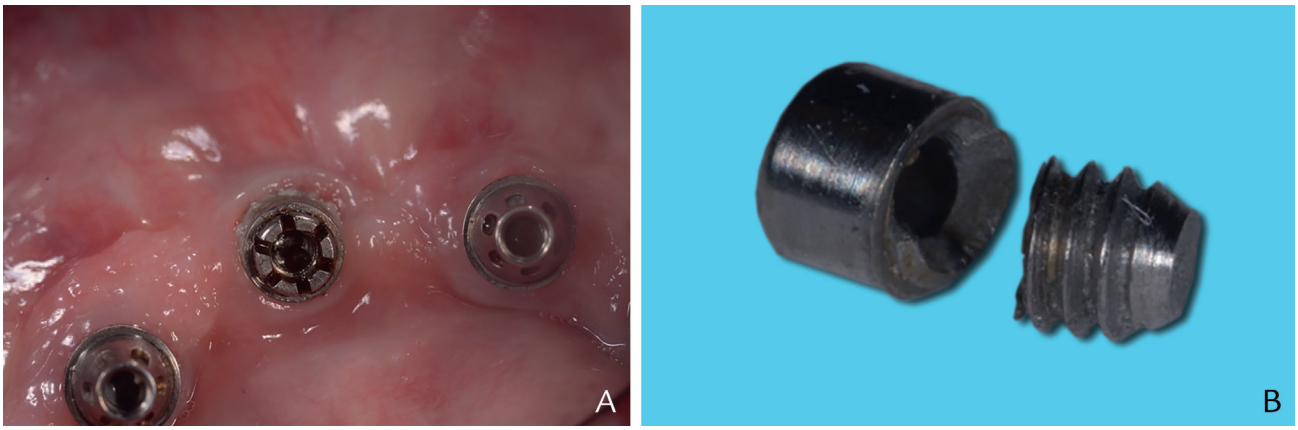

Figure 1. A, Fractured screw. B, Successful retrieval of screw fragment.

be used to trim the tissue and expose the implant platform. Use of an electrosurgery unit or scalpel should be avoided to avoid any heat transfer within the implant or scratching of the implant surface. Other techniques that may help to improve visualization include the use of dental loupes with a coaxial or light-emitting diode headlamp or a dental surgical microscope, especially in situations with deep screw fractures.[16]

Low Risk: Basic Instrumentation and Instrument Modification

Once the appropriate examination and diagnostic steps are complete, a tentative plan should be established using the proposed decision making tree.[3,10,17-20] A small rigid instrument such as a scaler, sickle explorer, or endodontic explorer was the initial instrument of choice for rotating the remaining apical portion counterclockwise and removing the fractured fragment (Fig. 7). Oblique fractures may be easier to manage with this technique because a purchase point usually exists in which the instrument may be engaged. Although this is considered a low-risk choice, care should always be used in engaging the broken segment with any instrument because the instrument may fracture or damage the internal threads of the implant. Flexible instruments such as endodontic files or modified instruments should be used with caution because of the decreased strength of the instrument.

If the fractured segment does not move with use of a hand instrument, an ultrasonic scaler can be used to loosen the screw.[19] This technique can be used in conjunction with standard instrumentation or in an alternating fashion, but care must always be taken not to damage the internal threads of the implant. In addition, this method should only be attempted a few times to ensure that the broken segment is not wedged further into the implant. Sometimes, even after the screw has been loosened, it is still difficult to grasp and remove. If a loose fragment is near the platform, a cotton tip applicator may be used as a driver, as the cotton threads can often grip the fragment, making removal easier.[20]

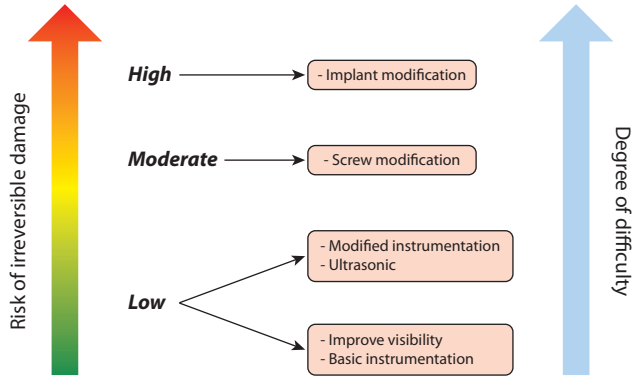

Figure 2. Direct relationship between risk of irreversible damage to implant and screw retrieval technique.

Moderate Risk: Screw Modification

If the remaining screw fragment cannot be rotated with basic hand instruments, it may be rotated using rotary instruments.[9,21-35] This can be done by introducing a bur, a drill, or a trephine mounted on a handpiece into the internal chamber of the implant until it contacts the screw fragment. Then, as it is rotated counterclockwise, it may unwind the screw fragment.[22,23]

If the screw fragment cannot be engaged with an instrument, a dimple or access point can be created using a ½ round bur mounted on a handpiece under copious irrigation; this dimple may be modified into a slot for better engagement (Fig. 8).[9,26,29,32] Furthermore, burs and instruments may also be modified to allow for better engagement of the fragment and to prevent damage to the implant.[23,26]

Aftermarket screw retrieval kits are available, including Fragment Fork (Astra Tech; Dentsply Sirona), ITI Dental Implant System (Institut Straumann AG), IMZ TwinPlus Implant System1 (Dentsply Sirona), Screw

Table 1. Screw retrieval techniques organized by risk

Study	Title	Year	Technique Classification	Technique
Low-Risk Techniques				
Fauvell et al[17]	The lumen technique. Retrieval of broken gold screws in dental implants.	2006	Instrument modification	By seating applicator tip with apical pressure in implant fixture, wedged it between implant and screw surface. Then counterturned and successfully retrieved retention screw.
Satterwaite and Rickman[3]	Retrieval of a fractured abutment screw thread from an implant: a case report	2008	Miscellaneous	Used endodontic file with curved tip to engage and remove broken remaining threads
Patel et al[16]	The use of a dental surgical microscope to aid retrieval of fractured implant abutment screw	2010	Visualization	Used coaxial light, high powered magnification (×12) and ultrasonic instrumentation
Reyhanian et al[18]	The use of Er:YAG in laser-assisted broken abutment screw treatment	2010	Visualization	Used Er:YAG laser as auxiliary tool to remove soft tissue and expose implant platform
Bhandari et al[19]	Ultrasonic Oscillations for conservative retrieval of a rare fracture of implant healing abutment	2013	Ultrasonic oscillation	Used piezoelectric scaler on low, combined with reverse torque
Satwalekar et al[10]	A simple and cost effective method used for removal of a fractured implant abutment screw	2013	Instrument modification	Modified spoon excavator and made slot in screw fragment to back out broken screw
Barbosa et al[20]	The cotton driver- an alternative technique for removing a fractured screw fragment	2014	Instrument modification	Used explorer to rotate fragment counterclockwise, then press cotton swab into implant head and rotate counterclockwise
Moderate-Risk Techniques				
Ow and Ho[21]	Retrieval of the resilient element in an osseointegrated implant system	1992	Screw modification	Described techniques based on location and actual component (hollow threaded apical section, solid apical section) using either screwdriver or IMZ retrieval kit
Biller[22]	Removing broken abutment screws from internally threaded implants	1993	Screw modification	Using smallest trephine from Masserann Endodontic kit. Introduce trephine into channel of implant or abutment until contact is made with broken threaded piece. Move handpiece head in counterclockwise rotation as you attempt to contact screw
Lau and Pang[23]	A modified instrument for removing a fractured abutment screw.	1994	Screw modification	Remove all lateral blades of short-shank tapered fissure bur with 8 end-cutting blades. Use bur with electric torque controller rotated counterclockwise.
Rosen[24]	Salvaging endosseous implants with fractured abutment screws	1995	Screw modification	Used 2 commercially available screw removal kits
Luterbacher et al[25]	Fractured prosthetic abutments in osseointegrated implants: a technical complication to cope with	2000	Screw modification	Report using ITI service set
Williamson and Robinson[26]	Retrieval technique for fractured implant screws	2001	Screw modification	Drop of mineral oil, then use 1/4 round bur to attempt to back out screw. if not, use high speed to make slot in fractured screw, then modify #1 round bur to resemble flathead screw driver and use latch type handpiece in off position to rotate screw out
Nergiz et al[27]	Removal of a fractured implant abutment screw	2004	Screw modification	Use explore first, then use IMZ repair kit
Yilmaz and McGlumphy[28,41]	A technique to retrieve fracture implant screws	2011	Screw modification	Use Astra fragment fork in slow speed handpiece to engage screw undercut
Taira and Sawase[29]	A modified technique for removing a failed abutment screw from an implant with a custom guide tube	2012	Screw modification	Used custom drill guide tube to protect internal threads while making slot in screw
Walia et al[30]	Removal of fractured dental implant screw using a new technique	2012	Screw modification	Used Tri-Hawk bur to notch screw, then used ultrasonic tip to engage notch
Kurt et al[31]	A technique for removal of fractured implant abutment screw	2013	Screw modification	Fabricated handmade screwdriver out of tungsten carbide bur, and placed slot on fractured screw
Gooty et al[32]	Noninvasive method for retrieval of broken dental implant abutment screw	2014	Screw modification	Screw modification (slot) and ultrasonic with counterclockwise pressure
Imam et al[33]	A technique for retrieving fractured implant screws	2014	Screw modification	Used Fragment Fork to push fractured portion deeper, then used retapping instrument from Astra to repair threads, then used ultrasonic to remove screw fragment
Carneiro et al[34]	A conservative approach to retrieve a fractured abutment screw: case report.	2015	Screw modification	Screw completely drilled, implant internal threads retapped.
Yilmaz et al[35]	Salvaging an implant with damaged internal threads	2015	Screw modification	Previously restored implant with damaged internal threads retapped and new restoration fabricated
Yoon et al[9]	Safe removal of a broken abutment screw with customized drill guide and rotary instrument	2015	Screw modification	Used modified impression coping as drill guide to make hole in screw fragment, then reverse tap drill engaged hole and backed out screw

(*continued on next page*)

Table 1. (*Continued*) Screw retrieval techniques organized by risk

Study	Title	Year	Technique Classification	Technique
High-Risk Techniques				
Pipko et al[36]	Retrofitting a cast dowel core on salvaged dental implants	2004	Implant modification	Cast dowel core retrofitted into salvaged dental implant
Pow and Wat[37]	A technique for salvaging an implant-supported crown with a fractured abutment screw.	2006	Implant modification	Removed fractured end of abutment screw and internal threads, fabricated modified impression coping, fabricated definitive post-and-core crown.
Santos et al[38]	Fracture of abutment screw supporting a cemented implant-retained prosthesis with external hexagon connection	2007	Implant removal	Two screw fragments could not be removed so implants were removed surgically.
Maalhagh-Fard et al[39]	Retrieval of a stripped abutment screw: a clinical report	2010	Implant modification	Created trough between abutment screw head and internal aspect of implant using high-speed handpiece. Head of abutment screw then loosened with fine forceps.
Imam et al[40]	Salvaging an angled implant abutment with damaged internal threads: a clinical report.	2013	Implant modification	Threads of abutment were retapped and wide diameter/wide head retaining screw used to secure existing prosthesis on abutment. Head of screw tapered in occlusogingival direction with diamond rotary cutting instrument
Yilmaz and McGlumphy[28,41]	A technique to salvage a single implant supported dental prosthesis having a nonretrievable implant screw fragment	2013	Implant modification	Used washers to allow screw to engage and develop adequate preload, minimum of 2 internal threads necessary
Canpolat et al[42]	Management of fractured implant abutment screw	2014	Implant modification	Made impression of "post" space within implant and custom cast dowel with ball attachment fabricated and cemented into place.
Gupta et al[43]	A new restorative technique for the perishing implant due to abutment screw fracture	2014	Implant modification	Screw fragment removed with rotary instrumentation and custom post and core fabricated
Harshakumar et al[44]	Salvaging an implant with abutment screw fracture by a custom titanium post and core-supported prosthesis, a novel technique	2014	Implant modification	Coronal fragment of fractured segment removed using 8-mm round ended tapered diamond and tungsten carbide bur to provide space for sufficient length of post. Acrylic resin pattern for post fabricated directly in post space. Titanium post and core cemented in screw hole.
Lee JH et al[45]	Technique to retrieve implant abutment fragments.	2015	Miscellaneous	Modified tips of pair of round-tip scissors to have notched outer edge.
Shah and Lee[46]	An alternative approach for the management of fractured implant abutment screws on a mandibular implant-retained overdenture: a clinical report	2016	Implant modification	Replacement of 2 fractured, irretrievable, Locator abutment screws of mandibular implant-retained overdenture with cast post and laser welded Locator attachments.

Er:YAG, erbium-doped yttrium aluminum garnet.

Removal Kit Replace (Nobel Biocare), and Certain-Screw Removal Kit (Biomet 3i). These kits may be helpful when low-risk techniques have been unsuccessful (Fig. 9).[25,28,32]

If all attempts at rotating the screw fragment fail, it may be drilled out completely, although this technique requires a high degree of attention and care to prevent damage. Specialized systems and drill guides are important in these situations, and a screw tap tool may become necessary.[34]

An important consideration when removing a fractured screw is not to damage the internal threads of the implant, so care must always be taken whenever a rotary instrument is introduced into the internal chamber of the implant.[30,33] The use of drill guides or sleeves can help stabilize the drill and subsequently reduce the risk of damage to the internal threads.[9,25,27,33] Furthermore, there is a high risk of heat generation whenever screws are drilled, and for that reason, drilling should be performed intermittently at a reduced speed with copious irrigation.[25,29]

Figure 3. Fragments above platform are easier to visualize and retrieve.

High Risk: Implant Modification

In situations where removal of the screw fragments is not possible using a low- or moderate-risk technique, intentional modification of the implant may be necessary to keep the implant serviceable.[36-46] If the internal aspect

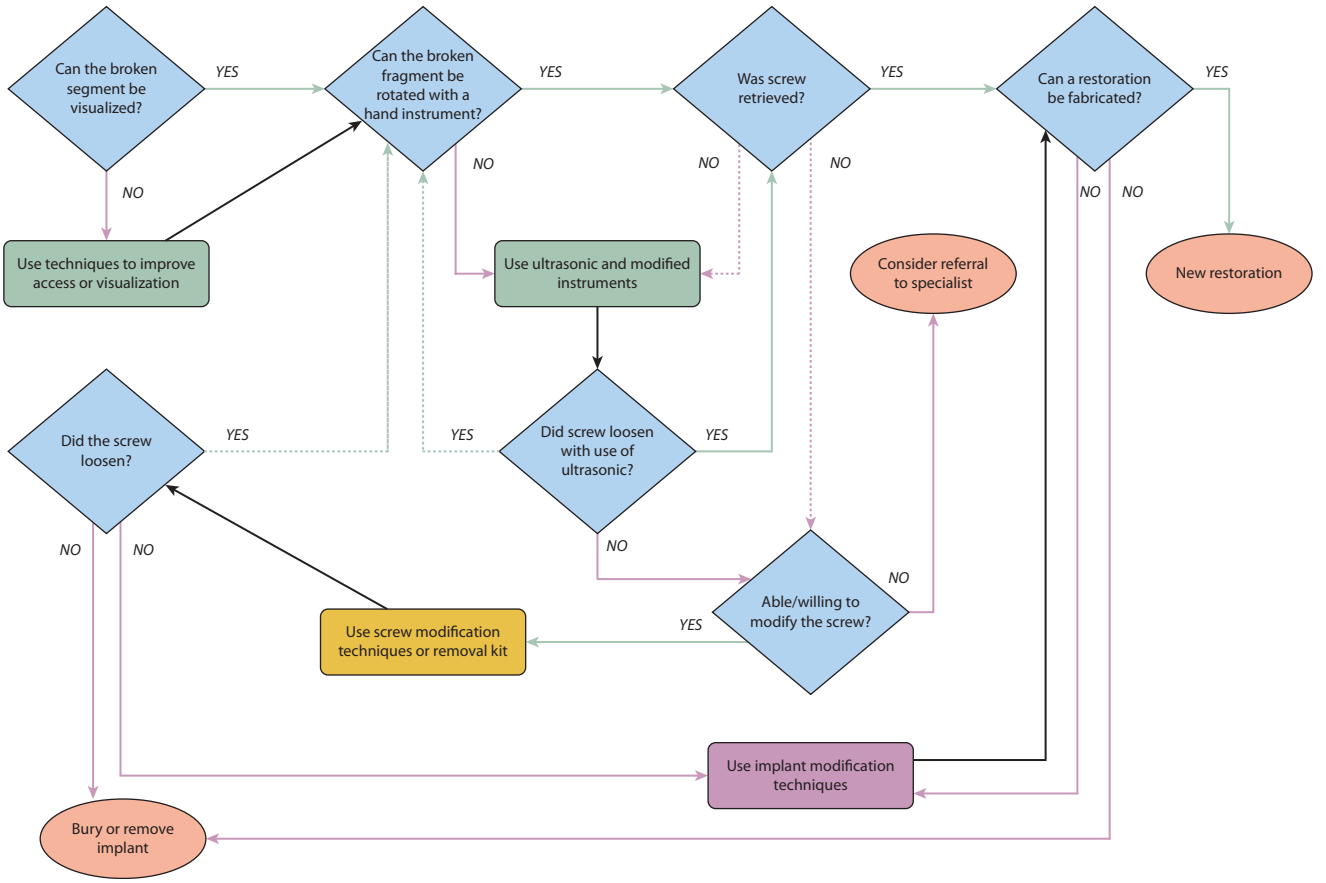

Figure 4. Risk-based decision tree for managing fractured screws.

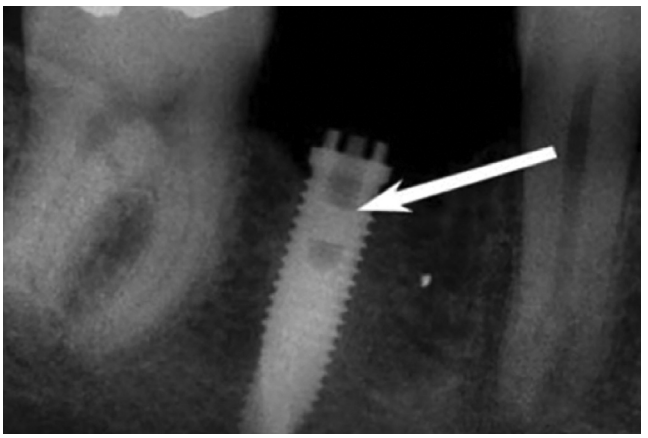

Figure 5. Radiograph used to confirm remaining screw fragment.

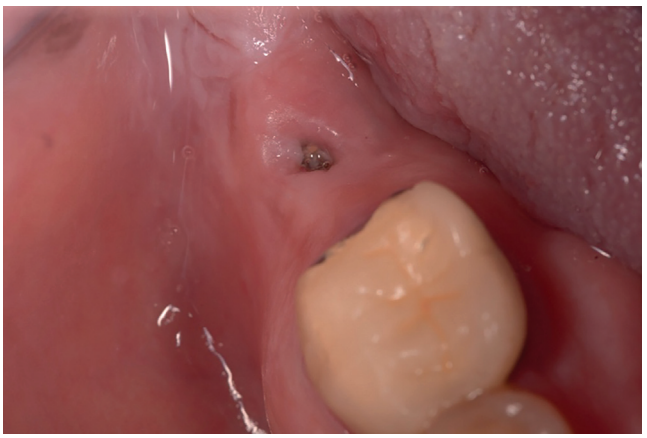

Figure 6. Overgrown peri-implant soft tissue, making access and visualization of implant difficult.

of the implant is significantly damaged or the screw fragment is irretrievable, the clinician may choose to remove the implant and place a new one. However, this decision can be influenced by financial factors, patient experience, and patient willingness to undergo additional surgery. An implant in such situations may also be completely buried in soft tissue, an option that may require the fabrication of a new prosthesis, and may compromise function and/or esthetics.[44,46,47]

If the patient is unwilling to sacrifice an irreversibly damaged implant, attempts can be made to maintain the use of this implant by retapping the internal threads once the irretrievable screw fragment is drilled out (Fig. 10). This can be accomplished with the use of specific retapping tools and may require alternative or modified parts to successfully restore the implant in question.[33,34,40]

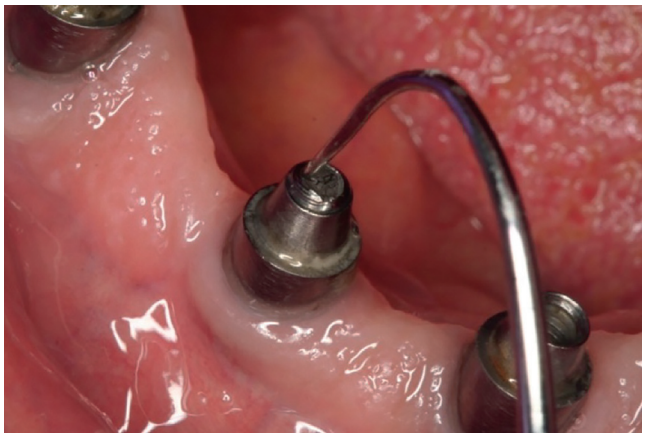

Figure 7. Retrieval of fractured screw fragment using explorer.

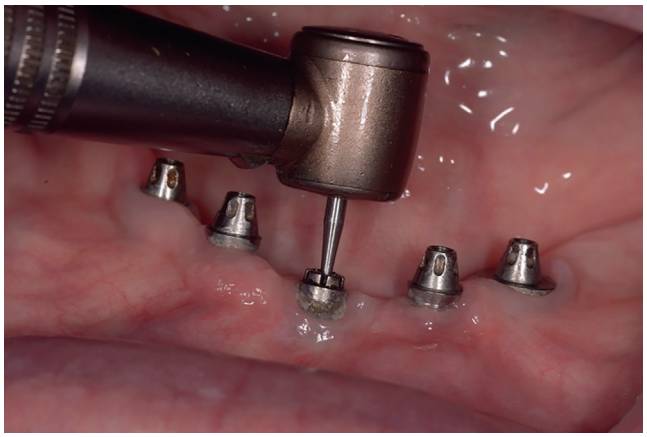

Figure 8. Modifying screw fragment with tungsten carbide bur.

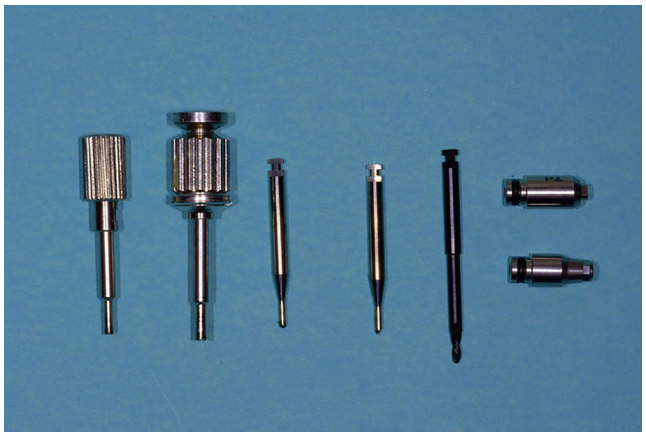

Figure 9. Various screw retrieval kits.

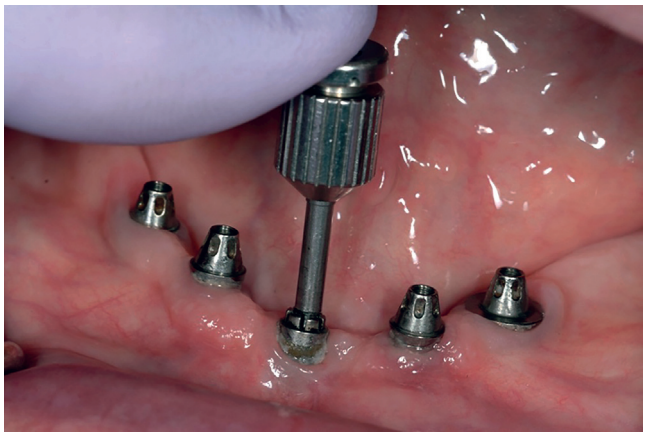

Figure 10. Retapping implant.

If all attempts fail and the patient is still unwilling to sacrifice the implant, a custom cast post and core may be fabricated for the implant.[36,37,42-44,46] These techniques generally start with the removal of remaining screw fragment, followed by removal of the internal threads of the implant by using a diamond rotary instrument or tungsten carbide bur in a high-speed handpiece under copious irrigation.[36,37,42-44,46] An autopolymerizing acrylic resin pattern can either be made directly on the prepared implant or indirectly on a stone cast. The pattern is then cast using nickel- or cobalt-chromium alloys, although other types of metal alloys have also been reported.[36,37,42-44,46] Once the seating of the custom cast post and core has been confirmed, it can be cemented. The appropriate restoration can then be fabricated following conventional prosthodontic protocols.

SUMMARY

Screw fractures can be a time consuming and frustrating complications in implant dentistry. Reviewing more than 30 published clinical techniques shows the situation has been managed mostly by trial and error. By understanding the inherent risks associated with each technique and following a logical sequence, the process of managing a fractured abutment or prosthetic screw can be simplified. As with any model, a decision making tree is a simplification of a complex clinical situation and is not a substitution for sound clinical diagnosis and judgement.[48] The proposed risk assessment and decision making tree, however, are useful tools in helping clinicians choose the most appropriate strategy or sequence of strategies that offers maximum benefit to the patient while minimizing the associated risks.

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