

Implant Surgery Complications: Etiology and Treatment

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Surgical complications during implant placement are not uncommon. According to a retrospective study by McDermott *et al*,¹ 677 patients (2379 implants) were investigated, and an overall frequency of complications was 13.9%. Operative complications made up a mere 1% of the overall, whereas inflammatory and prosthetic complications were 10.2% and 2.7%, respectively. Complications are expected and can lead to a number of poor treatment outcomes. The aim of this article was to address the etiology, and emphasize the potential problems as well as, basic treatments that occur during the surgical phases of implant treatment. Complications can be outlined in 4 categories (Fig. 1): treatment plan-related, anatomy-related, procedure-related, and other.

TREATMENT PLAN-RELATED COMPLICATIONS

Well organized, thorough treatment plans lead to successful implant treatment and patient satisfaction, which are the ultimate long-term goals. Patient selection is one of the most important determinants of success or of failure. Implant treatment planning should begin with reviewing pertinent medical history information and identifying any possible contraindications to anticipate problems before they occur. Predictability of implant success can be jeopardized by absolute

Implant surgery complications are frequent occurrences in dental practice and knowledge in the management of these cases is essential. The aim of this review was to highlight the challenges of treatment plan-related, anatomy-related, and procedure-related surgical

complications as well as to discuss the etiology, management and treatment options to achieve a satisfactory treatment outcome. (Implant Dent 2008;17:159–168)

Key Words: dental implants, implant complications, implant failures

and relative risk factors. For example, an 11 year retrospective study done by Moy *et al*,² showed relative risk ratios (RR): increasing age (60–79 y/o) had a strong association on risk with implant failure (RR = 2.24), as well as smoking (RR = 1.56), diabetes (RR = 2.75), head and neck radiation (RR = 2.73), and postmenopausal estrogen therapy (RR = 2.55).

Wrong Angulation

Implant angulation is yet another determinant for implant success. Proper angulation should be determined according to the future prosthesis with the consideration of bucco-lingual, apico-coronal, and mesio-distal positions. To place implants based on available bone often results in poor esthetic outcomes as well as long-term biomechanical instability. Although, there are many “rescue techniques” for restoring cases placed outside of the occlusion (*eg*, having to be with custom and angled abutments), the surgery should be planned for suitable angulation at the onset. Surgical guides can help control the implant placement angle if they are made and used correctly. Choi *et al*³ investigated the effects of dimensional factors of the surgical guides on implant placement and found that the length of the guide channel was the primary factor in reducing angle deviations in the mesio-distal and bucco-lingual direction. It

should be noted that computer-aided guides,^{4,5} made with no channel (*eg*, vacuum-formed matrix) and only a hole, do not merit angulation guidance.

Mandibular teeth in the natural dentition are lingually inclined in relation to both the mandibular base,⁶ specifically as 109 degrees,⁷ as well as the maxillary opposing arch dentition (*eg*, lingual cusp buccal inclination) and therefore implants should be placed at a similar inclination. Failure to do so may result in perforation of the lingual concavity, constriction of the lingual space or damage of the lingual artery. Restorations may be difficult to restore due to tongue impingement or incorrect opposing positions. In the posterior mandible, limited mouth opening prevents the drill and implant carrier from fitting correctly in the vertical direction. Teeth adjacent to implant sites and surgical guides with long drill channels, often require the use of drill extensions and maximum opening by the patient which may be strenuous. Short breaks to relieve muscle tension, using a bite block and having the patient shift their jaw to the opposite side can help ensure the correct angulation of the drill.

Yet another type of problem leading to incorrect implant angulation is the use of a finger rest while drilling (Fig. 2). Dentists have traditionally been taught to stabilize their hands by

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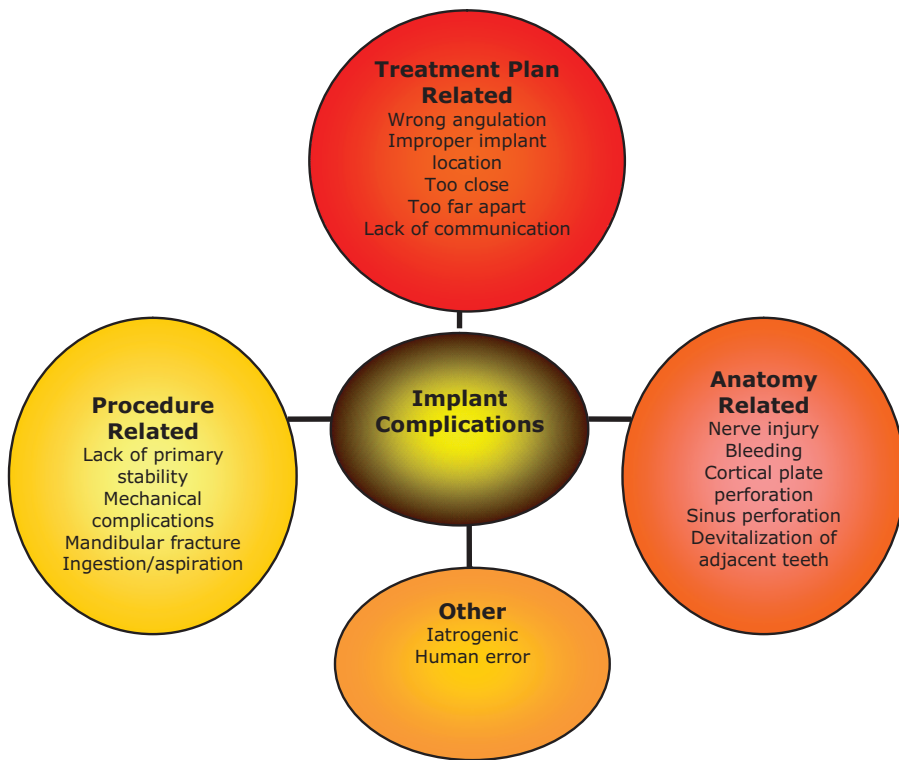


Fig. 1. Outline of common complications during implant surgery.

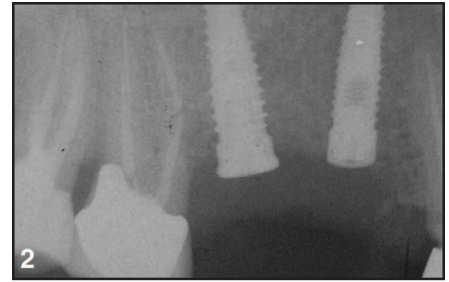


Fig. 2. Example of using a finger rest.
Fig. 3. Implant positioned too buccally.

placing a finger on adjacent teeth or the chin while using instruments/handpieces during periodontal and operative work to stabilize the hand as well as to reduce the muscle fatigue, but implant dentistry is different. Due to the length of implant drills (~10–20 mm), using a finger rest while drilling, results in an inclination of the drill towards the hand that is steadied. Hence, using finger rests is an ergonomic principle that should not be used for implant placement.

Surgical guides and proper treatment planning can alleviate angulation problems, but even so, angled abutments are hot selling items because clinicians are failing to abide by this important principle. The development of angled abutments has been a rescue technique for these wrongly placed implants and allows for a more successful esthetic outcome. In summary, use a surgical guide with a long channel that does not give leeway to veer and communicate with the restorative doctor.

Improper Implant Location

Adjacent teeth should be at least 1.5 mm from the implant body⁸ and more than 3 to 4 mm between adjacent

implants to prevent horizontal bone loss as well as to preserve esthetics.⁹ Preoperative measurements and planning are essential to achieve an ideal implant placement that facilitates future implant prosthesis. Placing an implant in the wrong location is a frustrating, embarrassing and avoidable complication (Fig. 3). Measurements (eg, interocclusal, interdental, ridge height, and ridge width) confirm whether implants are indicated in the first place. The spatial orientation should be in line with the occlusal plane and centered according to the opposing occlusion to prevent cross-bites or additional stresses on the prosthesis. Many times fixtures are ideally intended for one specific position to be in the proper occlusion (Fig. 4). If more than one implant is to be placed, a diagnostic wax-up should be used to determine the correct implant locations. At the very least, drawing and measuring on the stone casts will allow for calculations and treatment planning.

Hypothetically, a surgical complication could also occur, but not be realized by the surgeon at the actual time of surgery, especially when plac-

ing multiple implants. For example, Tarnow *et al*⁹ demonstrated in a retrospective study assessing 36 patients, that an implant placed <3 mm away from an adjacent implant can have adequate stability and function but may later result in lateral bone loss. Yet another issue to keep in mind when placing the implant is to measure the vertical distance between the base of the prosthetic contact point and the crestal bone. Tarnow *et al*¹⁰ found that if the distance was 5 mm or less, 98% of the time the embrasure space filled in, but as the distance increases to 6 and 7 mm, the presence of a papilla reduces to 56% and 27%, respectively. de Oliveira *et al*¹¹ found that as long as 5 mm distance is maintained between contact point and alveolar bone crest, it does not make a difference in papilla formation or bone loss, whether the adjacent implants are 1, 2, or 3 mm apart from each other.¹²

Lack of Communication

An informed consent form is an excellent way of communicating potential surgical risks and complications to a patient. Common problems to address include but are not limited to postoperative infection, bleeding, swelling, facial discoloration, transient pain, paresthesia, neuralgia, fracture, joint pain, muscle spasm, tooth looseness and sensitivity, recession, speech change, trismus, and swallowing

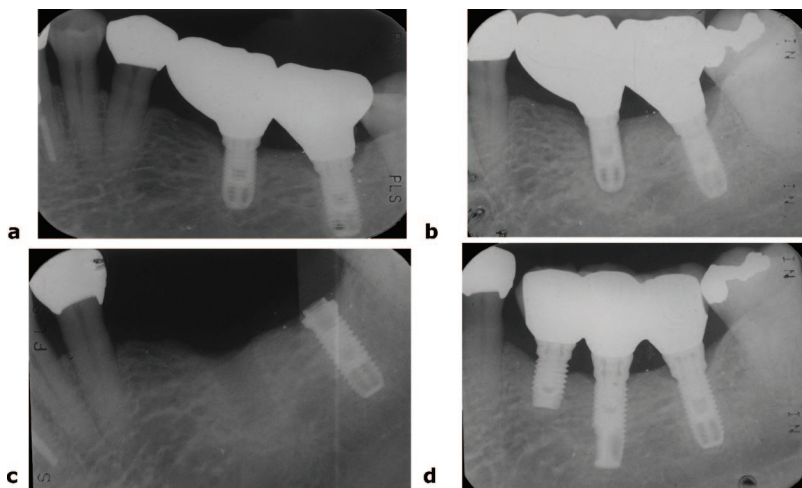


Fig. 4. Example of a poor initial treatment plan. No. 19 implant (a) was placed too far from the second premolar causing the fixed crown to be cantilevered mesially to obtain contact with the adjacent tooth but (b) too much stress may have caused the alveolar bone loss evident at the crest and surrounding the implant body. The mesial implant (c) was removed and replaced (d) with 2 additional implants to alleviate complications.

of foreign objects. Should a complication occur during the post operative healing time, it is recommended to give emergency contact information as well.

In the United States, 12.1% of medical malpractice payment reports were against dentists in 2002.¹³ In dentistry, the main causes for lawsuits are actual body injury (eg, loss of sensation, oroantral fistula, life-threatening bleeding) and major disappointment.¹⁴ This could be avoided if a patient understands the fundamentals of the surgical procedure and what is to be anticipated. A valuable tool used to communicate between surgeons' and restorative doctors is a surgical guide. The sole purpose of fabricating the guide is to identify the correct location and angulation for implant placement which will undoubtedly reduce/eliminate unnecessary surgery/prosthetic complications. Surgical guide designs include the labial outline surgical guide fabricated from a wax arrangement of the intended definitive restoration,¹⁵ a clear vacuum-formed matrix,¹⁶ a duplicate of the existing restoration,¹⁷ a light-polymerized composite material and drill blanks with a diagnostic cast,¹⁸ as well as many other methods.

ANATOMY-RELATED COMPLICATIONS

Nerve Injury

When placing implants in the mandible, proper radiographs and pre-

treatment planning must be done to ensure complete aversion of the inferior alveolar, mental, incisive or lingual nerves. If the mandibular canal cannot be seen on a panoramic radiograph, a computer tomography (CT) scan should be taken to verify the location. The potential risks and complications of injury or damage to these vital structures should be included on the informed consent to avoid liability in cases of lawsuits.

Possible causes of nerve injury include poor flap design, traumatic flap reflection, accidental intraneural injection, traction on the mental nerve in an elevated flap, penetration of the osteotomy preparation and compression of the implant body into the canal.

To circumvent trauma to the inferior alveolar nerve (IAN), some clinicians suggest local infiltrating instead of a mandibular nerve block. This idea is a safety precaution to avoid having the drill approach too close to the canal.¹⁹ Overpenetration occurs when the cortical portion of the alveolar crest puts resistance on the drill, but as it enters the marrow spaces, it drops into the neurovascular bundle. Worthington²⁰ investigated penetration into the IAN canal in human cadavers and recommended reviewing radiographs before surgery using the correct magnification as well as, allowing a 1 to 2 mm safety zone. This distance is to accommodate the Y dimension of the drill (apical extent of the tip which

gets longer as the implant diameter gets wider), where it ranges from 1 mm (3.4 mm drill) to 1.45 mm (4.85 mm drill) as well as 1 mm thickness of cortical plate above the mandibular canal (unpublished data).

Bartling *et al*²¹ observed 405 mandibular endosseous implants placed in 94 patients to determine the incidence of altered sensation using standard neurologic tests over a 6-month period. An incidence of 8.5% was found at the first postoperative appointment. Only 1 patient experienced complete anesthesia for 2 months. This was later resolved by 4 months. Unique to this study was that no permanent altered sensation was found for any of the subjects over the 6 months. Van Steenberghe *et al*,²² also reported a similar incidence rate of 6.5% for altered sensation at 1 year after mandibular implant placement. In contrast, other studies have reported higher rates. Ellies and Hawker²³ found an altered sensation incidence of 36%, of which 10% to 15% of those patients never regained sensation.

Radiographs should be taken if the surgeon has any doubt about where the drill is or if the drill or implant is in close proximity to or invading, neural anatomical structures. If the situation is the latter, the implant needs to be removed, or a shorter body implant should be placed instead. Within days or months, minor trauma injuries usually heal but permanent damage from neuritis can occur. Treatment options include neuronal anti-inflammatory drugs such as clonazepam, carbamazepine or vitamin B-complex,²⁴ although marginal effects have been shown. Referral and treatment for IAN injuries should be done immediately before distal nerve degeneration develops.²⁵ According to Hegedus and Diecidue,²⁶ follow-up appointments should take place at 4, 8, and 12 weeks after placement and each visit should include documentation of subjective symptoms, oral/facial function and atrophic/cutaneous changes. The patient should then be referred for microsurgery if total anesthesia persists, or if after 16 weeks, if dysesthesia is on-going.^{24,27} Timely referral for micro-neurosurgery is necessary to re-establish nerve continuity, improve

sensation and motor skills and to possibly relieve pain.²⁶

Bleeding

Life-threatening events associated with dental implants are rare but major complications such as severe hemorrhage are more common and Goodacre *et al.*,²⁸ found hemorrhage-related implant complications had an incidence of 24%. Potential causes include incision of arteries in soft tissue, osteotomy preparation, and lateral wall sinus lift procedures.

Kalpidis and Konstantinidis²⁹ reported a case involving a perforation of the lingual cortical plate during an implant osteotomy preparation of the first mandibular premolar position. A critical hemorrhage and multiple hematomas immediately occurred after perforation which was verified by a CT scan.

Risk sites³⁰ as described above in the posterior mandible include the sublingual fossa and lingual cortex. A ruptured artery in the area within 30 minutes, can cause a blood loss rate of 14 mL/min³¹ and if >500 mL of blood loss occurs, hypotension can result.³² Life-threatening airway obstruction is a serious threat and early treatment is essential. Treatment involves having the patient stick out their tongue to compress the blood vessels against the body of the mandible. Placing pressure with gauze in the sublingual area does not work as one would intuitively think. Extraoral pressure to the submental or submandibular arteries for 20 minutes against the body of the mandible helps.³³

The posterior superior alveolar and infraorbital arteries are located approximately 19 mm above the maxillary alveolar ridge,³⁴ and the anastomoses of these arteries can pose a risk during sinus lift procedures by lateral window preparation. Bone wax, pressure, crushing, and electrocautery can alleviate hemorrhage. In summary, hemorrhage treatments at implant osteotomy sites include compression, finger pressure, vasoconstriction, cautery, bone graft, bone cement, and ligation of arteries.³³

Cortical Plate Perforation

The buccal cortical plate varies in thickness throughout the mouth and

traumatic dental extractions can cause markedly thin plates or concavities, as well as overall ridge width deficiency.³⁵ When preparing osteotomy sites or placing implant fixtures in areas with minimal labial plate thickness, or if the implant is placed too buccally, a fenestration or dehiscence implant defect is a common finding. A fenestration leaves intact bone coronally with the exposed threads at the apical portion of the crest, whereas a dehiscence defect has the coronal portion of the implant exposed. Tinti *et al.*,³⁶ further classified these defects as Class I if the implant was within the envelope of bone and Class II if it was left staying outside the envelope. Immediate correction with particulate bone grafting with or without a membrane during the time of implant placement, can be done as long as primary stability has been achieved. "Flapless" implant surgeries should be avoided in areas of potential perforation of the buccal or lingual bone.

Sinus Membrane Complications

In the maxillary posterior, the proximity of the sinuses^{37,38} can create a problem for dental implants if there is minimal residual crestal bone (<5 mm) for stability. The maxillary sinus lift technique is an accepted procedure, demonstrated by Tatum,³⁹ to augment vertical height in the severely resorbed posterior maxilla area to facilitate proper implant placement. Sinus complications often occurred when the membrane is perforated at time of surgery. Ardekian *et al.*⁴⁰ found maxillary sinus membrane perforations were more common in areas with minimal amount (<5 mm) of residual alveolar bone but this did not affect the overall implant success rate. No statistical differences were found between the perforation group compared with the intact membrane group. In contrast, Proussaefs *et al.*⁴¹ found implant survival at second-stage surgery was superior for the nonperforated sites (100%) compared with perforated sites (69.6%). Bone density after grafting should be assessed, regardless whether or not a perforation occurs, because poor bone quality often lead to a higher implant failure rate.³⁴

What happens if an implant protrudes into the maxillary sinus cavity

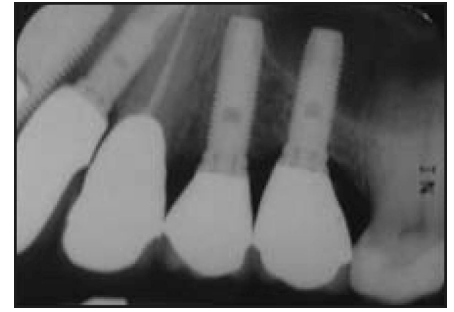


Fig. 5. Implant placed into the maxillary sinus.

(Fig. 5)? Jung *et al.*⁴² reported the risk of maxillary sinus complications in implants which penetrated the bone and mucous membrane of the sinus floor at 2, 4, and 8 mm extensions. After 6 months, radiographic and histologic examinations did not show any signs of pathologic findings in the maxillary sinus of the 8 dogs. Despite the convincing results, the question remains whether 6 months is a long enough follow-up period. Hence, it has been suggested that simultaneous implant placement during sinus lift procedures is not considered a contraindication or less predictable procedure. Nonetheless, careful planning and precise surgery execution are essential to avoid any potential sinus complications.

Lastly, losing an implant into the maxillary sinus is a relatively uncommon surgical complication. However, in cases with less than 5 mm of bone, mastication can cause the implants to move during the graft maturation timeframe.⁴³ Transantral endoscopic surgery is a reliable, minimally invasive method for retrieving displaced objects from the maxillary antrum with minimal complications,^{44,45} but it does require having an endoscope or a referral to an ENT or oral surgeon.

Devitalization of Adjacent Teeth

Adjacent teeth at implant recipient sites should be evaluated before implant placement. Pulpal and periradicular conditions such as small periapical radiolucencies, root resorption and large restorations in/near the vital pulp are often misdiagnosed. Numerous case reports^{33,46,47} describe implant pathosis caused by dormant endodontic problems of adjacent teeth that flare up after implant surgery.⁴⁸ Therefore, it is

worth the time of pulp testing suspicious teeth and completing a thorough radiographic examination. If endodontic pathosis is identified, root canal treatment or extraction should be initiated before implant placement to prevent microbial contamination of the implant⁴⁹ during healing and possible failure.

Dilacerated roots and excessive tilting in the mesiodistal direction that invade the implant space often prevent ideal placement. If a drill and/or implant fixture invades the PDL, hard tooth structure and/or vital pulp, this will lead to endodontic lesions.⁵⁰ Devitalization of an adjacent tooth next to an implant delays treatment and adds additional financial burden for both the patient and surgeon. A proper surgical guide and a careful radiograph analysis are necessary to avoid improper angulation and hidden dilacerated roots.

PROCEDURE RELATED

Mechanical Complications

Situations deeming an implant as “hopeless” are usually associated with surgical trauma during osteotomy preparation with the drill. Ericsson and Albrektsson⁵¹ showed bone resorption occurred at 47°C when drilling was applied for more than 1 minute in rabbits. The result obtained from this study leads to the conclusion that if temperature or duration increases while drilling in bone, necrosis can occur causing detrimental effects for osseointegration. Nonetheless, Ercoli *et al*⁵² later reported that the harmful temperature only occurred when drilling was continuous or when the drill reached beyond 15 mm during 5 osteotomies.

Dense cortical bone (*eg*, type I bone quality), when compared with type III or IV soft cancellous bone, can be overheated when preparing osteotomies because more pressure is needed to advance the drill apically in comparison to soft bone. To reduce frictional heat, high speed handpieces, an up-down motion technique of the bone preparation, and copious irrigation can be used. Misch⁵³ recommends using external and/or internal irrigation, as well as cool saline irrigation, intermittent pressure on the drills,

pausing every 3 to 5 seconds, using new drills, and an incremental drill sequence. Generating less heat by preparing implant sites at 2500 rpm may decrease osseous damage.⁵⁴

Tapping dense cortical bone is suggested. The benefits of tapping include limiting full osteotomy depth, allowing passive implant fit, preventing internal implant-body/implant-bone interface microfracture, and compression necrosis, and removing drill remnants.⁵³

According to Quirynen *et al*,⁵⁵ overpreparation or overheating osteotomies can result in inactive and active retrograde peri-implantitis lesions that can be detected on radiographs as periapical radiolucencies up to a month after insertion.⁴⁷ A good example of an inactive lesion is placing a shorter implant into a larger prepared osteotomy site. Clinically, these lesions are asymptomatic and radiographically, they present as periapical radiolucencies. As long as the radiolucency stays stable in size and the implant is integrated, no treatment is necessary. In contrast, problems with microbial invasion during surgery, such as implant contamination during insertion or placing the implant into an area with previous inflammation (*eg*, endodontic lesion) can lead to active lesions. A risk of successful treatment can be considered in extraction sites with a history of failed endodontic treatment or adjacent teeth with endodontic pathology.⁵⁵

Esposito *et al*,⁵⁶ during a review of literature to find diagnostic criteria for monitoring implant conditions, found that surgical trauma and anatomical conditions both were the most significant etiologic factors for early implant failures in Branemark implants (3.63%). Interestingly, the ITI implants had higher losses due to peri-implantitis and the authors attributed design and surface type as the problem. Early implant failures are due to excessive surgical trauma along with impaired wound healing, premature loading and infection.⁵⁶

Lack of Primary Stability

Lack of primary stability is a surgical complication that should be dealt with at the time of implant surgery. An unstable implant (*eg*, a “spinner”)

should be removed or an attempt to place a larger diameter should be completed. To leave an unstable implant without action can often lead to fibrous encapsulation that causes implant failure.⁵⁷ Nonetheless, bone fill will occur in immediate implants placed into extraction sockets with a marginal defect lateral to the implant wider than 1 mm⁵⁸ but primary stability is still a requirement.

Mandibular Fracture

The mandible is the most frequently fractured facial bone,⁵⁹ many factors have been proposed to contribute to the fractures. These include but are not limited to site, direction and severity of the force as well as impact.⁶⁰ Attempts to place implants in patients with severely atrophic mandibles increases the risk of fracture, especially when monocortical grafts and ridge-splitting surgeries are completed. In patients who present with osteomalacia or osteoporosis, implant placement may subject the brittle bone to splintering because of the loading or frictional forces.⁶¹ Other reasons for mandibular fracture may include using the wrong implant (*eg*, 10 mm site preparation with intent of placing a 12 or 14 mm implant). Checking the implant size/diameter before opening the package is important.

A fracture of the mandible should be restored to maintain form and function. Management should include stabilization with an attempt to also simultaneously eliminate atrophy if indicated. A retrospective study by Eyrich *et al*⁶² found that treatment for mandibular fractures should be based on the type and location of the fracture, as well as the severity of the atrophy. Treatment options included using the wiring of a modified prosthesis, lag screws, wires and plates. The most relevant option of our field includes combined bone augmentation, fixation and simultaneous implant placement. Increasing mandibular height after augmentation may be unpredictable but using implants concurrently may reduce bone resorption. If an implant lies in the line of fracture, osseointegration will still occur as long as there is no mobility or infection.⁶³

Another recommended approach for mandibular fracture is using reduction and

immobilization with monocortical miniplates to avoid any nonunion and malunion healing.³³ Two miniplates or a combination with microplates can obtain stable fixation in severely atrophic fractured mandibles and is a less invasive treatment option.⁶⁴

Ingestion and Aspiration

For the sake of completeness, it should be mentioned that extreme caution should be emphasized when handling small implant components in the oral cavity. Most instruments have a special tip to help ensure screws and abutments transfer directly from the surgical tray into the patient's mouth, but nevertheless, accidents happen. Unfortunately, components winding up on the floor or down a patient's throat can be embarrassing and expensive mishaps, not to mention serious implications could occur if aspiration takes place. For these reasons, preventative measures such as gauze throat screens and floss ligatures on implant pieces are encouraged.

Tiwana *et al.*⁶⁵ found over a 10 year retrospective institutional study, only 36 cases of ingestion were reported and amazingly only one case of aspiration. Fixed prosthodontic therapy reported having the most incidences of ingestion. In particular, cemented single-tooth cast or prefabricated restorations had a higher likelihood of aspiration.

If a patient swallows or aspirates an implant component, they should be referred to the hospital because acute obstruction can be life threatening and prolonging the removal of foreign objects may make a bronchoscopy technically more difficult.⁶⁶ If the foreign object is aspirated it should be removed within 24 hours. Chest radiographs are a diagnostic tool available to rule out ingestion or aspiration.

Other

A study done by the Dental Implant Clinical Research Group⁶⁷ found that inexperienced surgeons (<50 implants) were twice as likely to have implant failures compared with more experienced surgeons. Such a statistic is a good reminder in realizing that some of our literature is based on the work of graduate students who start out as ama-

Accumulate data	Medical history, dental history, radiographs, CT, models
Assemble treatment plan	Exam, discuss all options, review plan with all disciplines (surgical, restorative, patient and lab)
Approve treatment plan	Signed consent. Patient should understand all risks, benefits, complications and fees
Anticipate problems	
Anatomical	Nerves (<1mm from implant), vessels, adjacent teeth (<.5 mm from implant), type IV bone & sinus/nasal floor
Mechanical	Drilling torque, lack of irrigation, incorrect armamentarium, no surgical guide, implant contamination, time constraints
Systemic	Medications, smoking, DM, head & neck radiation, estrogen therapy, osteoporosis
Activate treatment	
Achieve anchorage	No complications, ideal treatment case, primary stability
Analyze compromised situation	Dehiscence, fenestration, improper positioning/angulation,
Accommodate problem	Bone grafting, membranes, sutures, back-up implant, shorter implants, root canal therapy
Abort treatment	Lack of primary stability Over-prepped osteotomy Large dehiscence or fenestration
Auxillary	Nerve trauma Fracture of the mandible Short distance (<1.5 mm from adjacent tooth)
Refer when indicated	
Accomplish treatment	
Post operative instructions	
Post operative medications	Narcotic, antibiotic, sedative, anti-inflammatory

Fig. 6. A+ guidelines for preventing and managing implant complications.

teur implant surgeons hence the data cannot be generalized. The realization also exists that many general dentists starting to place implants may have more failures and complications compared with experienced specialists.

CONCLUSION

Surgical implant complications are not uncommon and should be addressed immediately. Causality may be iatrogenic, due to poor treatment

techniques, or lack of communication between dental disciplines. Time should be spent in the implant "planning" stages, such as tracing preoperative radiographs, measuring models, taking CT scans and making proper surgical guides. Basic anatomy must not be forgotten and should be reviewed by the surgeon in every case. As more surgically inexperienced dental professionals start placing implants an increase in surgical complications will

likely occur. In summary, a competent surgeon should be able to treatment plan a predictable surgery, (Fig. 6) and recognize how to remedy a problematic dental-implant situation.

Disclosure

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REFERENCES

1. McDermott N, Chuang S, Dodson T, et al. Complications of dental implants: Identification, frequency, and associated risk factors. *Int J Oral Maxillofac Implants.* 2003;18:848-855.
2. Moy PK, Medina D, Aghaloo TL, et al. Dental implant failure rates and associated risk factors. *Int J Oral Maxillofac Implants.* 2005;20:569-577.
3. Choi M, Romberg E, Driscoll CF. Effects of varied dimensions of surgical guides on implant angulations. *J Prosthet Dent.* 2004;92:463-469.
4. Wong N, Huffer-Charchut H, Sarment D. Computer-aided design/computer-aided manufacturing surgical guidance for placement of dental implants: Case report. *Implant Dent.* 2007;16:123-130.
5. Jaber M, Sarment DP. Advanced surgical guidance technology: A review. *Implant Dent.* 2006;15:135-142.
6. Williams PL, Warwick R. *Gray's Anatomy.* 36th ed. Edinburgh: Churchill Livingstone; 1980:1281-1287.
7. Tanaka T, Shaw P. Anatomy for implant dentistry: Mandible. *Quintessence Dent Implantol.* 1995;2:10-20.
8. Choquet V, Hermans M, Malevez C, et al. Clinical and radiographic evaluation of the papilla level adjacent to single-tooth dental implants. A retrospective study in the maxillary anterior region. *J Periodontol.* 2001;72:1364-1371.
9. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone. *J Periodontol.* 2000;71:546-549.
10. Tarnow DP, Wagner AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. *J Periodontol.* 1992;63:995-996.
11. de Oliveira RR, Novaes A Jr, Taba M Jr, et al. Influence of interimplant distance on papilla formation and bone resorption: A clinical-radiographic study in dogs. *J Oral Implantol.* 2006;32:218-227.
12. Novaes AB, de Oliveira RR, Taba M Jr, et al. The effects of interimplant distances on papilla formation and crestal resorption in implants with a Morse cone connection and a platform switch: A histomorphometric study in dogs. *J Periodontol.* 2006;77:1839-1849.
13. 2002 Annual Report, National Practitioner Data Bank, US DHHS.
14. Givol N, Taicher S, Chaushu G, et al. Risk management aspects of implant dentistry. *Int J Oral Maxillofac Implants.* 2002;17:258-262.
15. Parel SM, Funk JJ. The use and fabrication of a self-retaining surgical guide for controlled implant placement; a technical note. *Int J Oral Maxillofac Implants.* 1991;6:207-210.
16. Blustein R, Jackson R, Godar D, et al. Use of splint material in the placement of implants. *Int J Oral Maxillofac Implants.* 1986;1:47-49.
17. Neidlinger J, Lilien BA, Kalant DC Sr. Surgical implant stent: A design modification and simplified fabrication technique. *J Prosthet Dent.* 1993;69:70-72.
18. Shotwell JL, Billy EJ, Oh TJ, et al. Implant surgical guide fabrication for partially edentulous patients. *J Prosthet Dent.* 2005;93:294-297.
19. Heller AA, Shankland WE II. Alternative to the inferior alveolar nerve block anesthesia when placing mandibular dental implants posterior to the mental foramen. *J Oral Implantol.* 2001;27:127-133.
20. Worthington P. Injury to the inferior alveolar nerve during implant placement: A formula for protection of the patient and clinician. *Int J Oral Maxillofac Implants.* 2004;19:731-734.
21. Bartling R, Freeman K, Kraut RA. The incidence of altered sensation of the mental nerve after mandibular implant placement. *J Oral Maxillofac Surg.* 1999;57:1408-1410.
22. Van Steenberghe D, Lekholm U, Bolender C, et al. Applicability of osseointegrated oral implants in the rehabilitation of partial edentulism: A prospective multicenter study on 558 fixtures. *Int J Oral Maxillofac Implants.* 1990;5:272-281.
23. Ellies L, Hawker P. The prevalence of altered sensation associated with implant surgery. *Int J Oral Maxillofac Implants.* 1993;8:674-679.
24. Nazarian Y, Eliav E, Nahlieli O. [Hebrew] Nerve injury following implant placement: Prevention, diagnosis and treatment modalities. *Refuat Hapeh Vehashinayim.* 2003;20:44-50.
25. Kraut RA, Chahal O. Management of patients with trigeminal nerve injuries after mandibular implant placement. *JADA.* 2002;133:1351-1354.
26. Hegedus F, Diecidue RJ. Trigeminal nerve injuries after mandibular implant placement-Practical knowledge for clinicians. *Int J Oral Maxillofac Implants.* 2006;21:111-116.
27. Day RH. Microneurosurgery of the injured trigeminal nerve. *Oral Maxillofac Surg Knowledge Update.* 1994;1:91-116.
28. Goodacre DJ, Rungcharassaeng K, Kan JY, et al. Clinical complications with implants and implant prostheses. *J Prosthet Dent.* 2003;90:121-132.
29. Kalpidis CD, Konstantinidis AB. Critical hemorrhage in the floor of the mouth during implant placement in the first mandibular premolar position: A case report. *Implant Dent.* 2005;14:117-124.
30. Longoni G, Longoni S, Sartori M, et al. Lingual vascular canals of the mandible: The risk of bleeding complications during implant procedures. *Implant Dent.* 2007;16:131-138.
31. Flanagan D. Important arterial supply of the mandible, control of an arterial hemorrhage, and report of a hemorrhagic incident. *J Oral Implantol.* 2003;29:165-179.
32. Baab DA, Ammons WF Jr, Selipsky H. Blood loss during periodontal flap surgery. *J Periodontol.* 1977;48:693-698.
33. Park S-H, Wang H-L. Implant reversible complications: Classification and treatments. *Implant Dent.* 2005;14:211-220.
34. Fugazzotto PA, Wheeler SL, Lindsay JA. Success and failure rates of cylinder implants in type IV bone. *J Periodontol.* 1993;64:1085-1087.
35. Katranji A, Misch K, Wang H-L. Cortical bone thickness in dentate and edentulous human cadavers. *J Periodontol.* 2007;78:874-878.
36. Tinti C, Parma-Benfenati SP. Clinical classification of bone defects concerning the placement of dental implants. *Int J Periodontics Restorative Dent.* 2003;23:147-155.
37. Shin HI, Sohn DS. A method of sealing perforated sinus membrane and histologic finding of bone substitutes: A case report. *Implant Dent.* 2005;14:328-335.
38. Kim S-G, Mitsugi M, Kim B-O. Simultaneous sinus lifting and alveolar distraction of the atrophic maxillary alveolus for implant placement: A preliminary report. *Implant Dent.* 2005;14:344-348.
39. Tatum H. Maxillary and sinus implant reconstructions. *Dent Clin North Am.* 1986;30:207-229.
40. Ardekian L, Oved-Peleg E, Peled M, et al. The clinical significance of sinus membrane perforation during augmentation of the maxillary sinus. *J Oral Maxillofac Surg.* 2006;64:277-282.
41. Proussaefs P, Lozada J, Rohrer MD, et al. Repair of the perforated sinus membrane with a resorbable collagen membrane: A human study. *Int J Oral Maxillofac Impl.* 2004;19:413-420.
42. Jung JH, Choi BH, Li J, et al. The effects of exposing dental implants to the maxillary sinus cavity on sinus complications. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2006;102:602-605.

43. Peleg M, Garg AK, Mazor Z. Predictability of simultaneous implant placement in the severely atrophic posterior maxilla: A 9-year longitudinal experience study of 2,132 implants placed into 731 human sinus grafts. *Int J Oral Maxillofac Implants*. 2006;21:94-102.
44. Nakamura N, Mitsuyasu T, Ohishi M. Endoscopic removal of a implant displaced in the maxillary sinus; a technical note. *Int J Oral Maxillofac Surg*. 2004;33:195-197.
45. Varol A, Turker N, Basa S, et al. Endoscopic retrieval of dental implants from the maxillary sinus. *Int J Oral Maxillofac Implants*. 2006;21:801-804.
46. Oh T-J, Joongkyo Y, Wang H-L. Management of the implant periapical lesions: A case report. *Implant Dent*. 2003;12:41-46.
47. Ayangco L, Sheridan PJ. Development and treatment of retrograde peri-implantitis involving a site with a history of failed endodontic and apicoectomy procedures: A series of reports. *Int J Oral Maxillofac Implants*. 2001;16:412-417.
48. Shaffer MD, Juruaz DA, Haggerty PC. The effect of periradicular endodontic pathosis on the apical region of adjacent implants. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 1998;86:578-581.
49. el Askary AS, Meffert RM, Griffin T. Why do dental implants fail? Part I. *Implant Dent*. 1999;8:173-185.
50. Sussman HI. Tooth devitalization via implant placement: A case report. *Periodontol Clin Investig*. 1998;20:22-24.
51. Ericksson RA, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: A vital-microscopic study in the rabbit. *J Prosthet Dent*. 1983;50:101-107.
52. Ercoli C, Funkenbusch PD, Lee HJ, et al. The influence of drill wear on cutting efficiency and heat production during osteotomy preparation for dental implants: A study of drill durability. *Int J Oral Maxillofac Implants*. 2004;19:335-349.
53. Misch CE. *Contemporary Implant Dentistry*. 2nd ed. St. Louis, MO: Mosby; 1999:373.
54. Sharawy M, Misch CE, Tehemar S, et al. Heat generation during implant drilling: The significance of motor speed. *J Oral Maxillofac Surg*. 2002;60:1160-1169.
55. Quirynen M, Gijbels F, Jacobs R. An infected jawbone site compromising successful osseointegration. *Periodontol 2000*. 2003;33:129-144.
56. Esposito M, Hirsch JM, Thomsen P, et al. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. *Eur J Oral Sci*. 1998;106:527-551.
57. Lioubavina-Hack N, Lang NP, Karring T. Significance of primary stability for osseointegration of dental implants. *Clin Oral Impl Res*. 2006;17:244-250.
58. Botticelli D, Berglundh T, Lindhe J, et al. The jumping distance revisited: An experimental study in the dog. *Clin Oral Implants Res*. 2003;14:35-42.
59. Olson RA, Fonseca RJ, Osbon DB, et al. Fractures of the mandible: A review of 580 cases. *J Oral Maxillofac Surg*. 1982;40:23-28.
60. Reitzik M, Lownie JF, Austin J, et al. Experimental fractures of monkey mandibles. *Int J Oral Surg*. 1978;7:100-103.
61. Hohlweg-Majert B, Schmelzeisen R, Schneider E, et al. Significance of osteoporosis in craniomaxillofacial surgery: A review of the literature. *Osteoporos Int*. 2006;17:167-179.
62. Eyrich GKH, Gratz KW, Sailer HF. Surgical treatment of fractures of the edentulous mandible. *J Oral Maxillofac Surg*. 1997;55:1081-1087.
63. Tolman DE, Keller EE. Management of mandibular fractures in patients with endosseous implants. *Int J Oral Maxillofac Implants*. 1991;6:427-436.
64. Mugino H, Takagi S, Ikemura K, et al. Miniplate osteosynthesis of fractures of the edentulous mandible. *Clin Oral Investig*. 2005;9:266-270.
65. Tiwana K, Morton, Tiwana PS. Aspiration and ingestion in dental practice: A 10-year institutional review. *JADA*. 2004;135:1287-1291.
66. Zitman NU, Marinello CP. The aspiration and swallowing of foreign bodies. The management of the aspiration or swallowing of foreign bodies during dental treatment. *Schweiz Mon atsschr Zahnmed*. 2000;110:619-632.
67. Truhlar RS, Morris HF, Ochi S, et al. Second stage failures related to bone quality in patients receiving endosseous dental implants DICRG, Interim report #7. *Implant Dent*. 1994;3:252-255.

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ID Abstract Translations

GERMAN / DEUTSCH

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Komplikationen bei Implantationsoperationen: Ätiologie & Behandlung

ZUSAMMENFASSUNG: In der Zahnheilkundlichen Praxis treten häufig Komplikationen bei Implantationsoperationen auf. Es ist von maßgeblicher Bedeutung, hier über eine mö-

glichst erfolgreiche Problembewältigung Bescheid zu wissen. Die vorliegende Studie zielt darauf ab, die Herausforderungen hinsichtlich der Behandlung von Komplikationen in Verbindung mit dem Behandlungsplan, der spezifischen Patienten-anatomie und dem Behandlungsvorgehen herauszustellen sowie die Ätiologie und die Optionen für Problembewältigung und Behandlung mit dem Ziel eines zufriedenstellenden Behandlungsergebnisses zu diskutieren.

SCHLÜSSELWÖRTER: Zahnimplantate; Implantationskomplikationen; Versagen von Zahnimplantaten.

SPANISH / ESPAÑOL

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Complicaciones de la cirugía de implante: Etiología y tratamiento

ABSTRACTO: Las complicaciones de la cirugía de implante son ocurrencias frecuentes en la práctica odontológica y el conocimiento de la atención de estos casos es esencial. El objetivo de este trabajo es destacar los desafíos en el tratamiento de complicaciones quirúrgicas relacionadas con el plan, con la anatomía y los procedimientos así como explicar la etiología, atención y opciones de tratamiento para lograr un resultado satisfactorio.

PALABRAS CLAVES: Implantes dentales; complicaciones del implante; falla del implante.

PORTUGUESE / PORTUGUÊS

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Complicações de Cirurgia de Implante: Etiologia & Tratamento

RESUMO: Complicações de cirurgia de implante são ocorrências frequentes na prática dentária e o conhecimento da gestão desses casos é essencial. O objetivo desta revisão é realçar os desafios de complicações cirúrgicas relacionadas a planos de tratamento e a anatomia, bem como discutir as opções de etiologia, gestão e tratamento para alcançar um resultado de tratamento satisfatório.

PALAVRAS-CHAVE: Implantes dentários; complicações de implantes; falhas de implantes.

RUSSIAN / РУССКИЙ

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Осложнения, встречающиеся при хирургической имплантации: этиология и лечение

РЕЗЮМЕ. Осложнения при хирургической имплантации являются частым явлением в стоматологической практике, поэтому очень важно знать методы борьбы с такими случаями. Цель этого обзора — показать трудности лечения хирургических осложнений, связанных с планом лечения, анатомией и процедурой, а также обсудить этиологию, методы борьбы и варианты лечения для достижения удовлетворительного результата.

КЛЮЧЕВЫЕ СЛОВА: зубные имплантаты; осложнения при имплантации; неудачная имплантация.

TURKISH / TÜRKÇE

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Oral implantolojide Profilaksi Amacıyla Antibiyotik Rejimi: Nedenler ve Protokol

ÖZET: Oral implantolojide antimikrobiyal ilaç kullanımı, cerrahi yaradaki enfeksiyonları azaltır. Antimikrobiyal profilaksi, tüm Sınıf 2 (temiz-kontamine) cerrahi prosedürleri için endike olup, bunlara dental implantın bakteriyel kontaminasyonu sırasında yeterli düzeyde kan bulunan cerrahi prosedürler ile kemik greft prosedürleri de dahildir. Antibiyotiklerin etkinliği açısından zamanlama ve doz, kritik önem taşır. Antibiyotik genelde prosedür nedeniyle enfeksiyona sebep vermesi en olası olan bakteriye göre seçilir. Yazarlar, diş hekiminin uygun şekilde ilaç reçetelemesine yardımcı olmak üzere prosedüre, yerel konakçıya ve sistemik faktörlere dayanan bir sınıflama ve protokol sistemi geliştirmişlerdir.

ANAHTAR KELMELER: dental implantlar, antibiyotik profilaksi, cerrahi yara enfeksiyonu, farmakolojik protokol, risk faktörleri.

JAPANESE / 日本語

インプラント手術合併症：病因学と治療

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研究概要: 歯科医療においてインプラント手術合併症は頻繁に発生するため、これらのケース処置に関する知識は必須条件である。当報告書は治療プラン関連をはじめ解剖学関連や処置関連などに起因した術後合併症の難点に注目し、さらに満足のでられる治療結果を達成するための病因学、処置と治療オプションについての記述を目的とする。

キーワード: デンタルインプラント、インプラント合併症、インプラント失敗症例

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CHINESE / 中国語

植體手術併發症：病因與治療

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摘要: 植體手術併發症在牙科執業時有所見，因此有必要了解相關病例的管理方式。本評論的目的是強調和治療計畫、解剖學和手術相關的手術併發症有何挑戰，同時也討論其病因、管理和治療選項，以期獲致滿意的治療結果。

關鍵字: 牙科植體、植體併發症、植體失敗。

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KOREAN / 한국어

이식수술 합병증: 원인 및 치료

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초록: 이식수술 합병증은 치과 진료에서 종종 발생하며 이러한 경우의 관리에 대한 지식이 필수적이다. 본 고찰의 목적은 치료계획 관련, 해부학 관련 및 절차 관련 수술 합병증을 조명하고 만족스러운 치료 결과를 위한 원인, 관리 및 치료 방법에 대해 논의하고자 하는 것이다.

키워드: 치과용 임플란트; 이식 합병증; 이식 실패

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