Review

Clinical Recommendations for Avoiding and Managing Surgical Complications Associated With Implant Dentistry: A Review

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Proposing to place endosseous implants is an integral facet of dental treatment plans. Their insertion is usually associated with a low incidence of untoward events. However, despite careful planning, surgical complications can arise: infection, intraoral hemorrhage, wound dehiscence, postoperative pain, lack of primary implant stability, inadvertent penetration into the maxillary sinus or nasal fossa, sinus lift sequelae, neurosensory disturbances, injuries to adjacent teeth, tissue emphysema, and aspiration, or ingestion of surgical instruments. This article addresses some surgical complications associated with dental implant placement and discusses how to avoid and manage them when they occur. *J Periodontol 2008;79:1317-1329.*

KEY WORDS

Dental implants; intraoperative complications; postoperative complications.

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Most endosseous implant procedures proceed without untoward events. However, surgical complications and unusual sequelae can occur. Being able to understand potential troubles and avoid them facilitates efficient therapy. Similarly, having the capability to recognize and manage unexpected situations is essential for practitioners providing implant services. Therefore, it was deemed important to review some surgical predicaments associated with implant dentistry to provide insight on how to identify, avoid, and handle problems. This article is divided into two parts. The first section focuses on oral soft tissue complications: hemorrhage, neurosensory disturbances, tissue emphysema, infections, wound dehiscence, aspiration or ingestion of surgical instruments, and postoperative pain. The second segment addresses hard tissue dilemmas: periapical implant pathosis and endodontic considerations, lack of primary implant stability, inadvertent penetration into the maxillary sinus or nasal fossa, sinus lift predicaments, and mandibular fracture.

For organizational purposes, it was decided to classify complications into two categories: oral soft tissue and hard tissue. It is recognized that some problems can be associated with soft and hard tissues (e.g., infections); when this occurred, that sequela was discussed in one section.

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Consideration was given to addressing complications in sequence with respect to their prevalence; however, there are insufficient data in the literature to accurately categorize most problems in this manner. This article addresses a large number of issues of potential interest to the implant surgeon; however, it is not possible to comprehensively discuss every subject, because that would require a text too extensive for a single article. When appropriate, references are cited; otherwise, comments should be considered opinions of the authors.

ORAL SOFT TISSUE COMPLICATIONS

Hemorrhage

Petechiae, purpura, ecchymosis, and hematomas. The amount of bleeding associated with a surgical procedure is dependent on numerous factors such as extent of flap reflection, soft tissue management, the patient's anatomy, and systemic health. Accordingly, it is difficult to forecast the amount of hemorrhage a patient will experience based on descriptions of procedures in the literature. In general, several types of hemorrhagic patches can develop as a result of injury: petechiae (<2 mm in diameter), purpura (2 to 10 mm), and ecchymosis (>10 mm).[1] These findings reflect blood within the tissue due to injury of small capillaries and blood vessels in the skin or mucous membranes. These patches are non-elevated, rounded, or irregular and initially are a red-blue or purplish color. Goodacre et al.[2] indicated that postoperatively ~24% of all dental implant sites manifest an ecchymosis. The location of an ecchymosis can be influenced by gravity. It may be noticeable only at the site of injury, or it may extend to the inferior border of the mandible or onto the chest (Fig. 1). This latter finding does not indicate that tissues were bruised, rather it reflects there was bleeding under the flap and blood transcended along fascial planes. The finding of an ecchymosis does not require therapy. Verbal and written postoperative instructions should inform and reassure a patient that this sequela is not a problem.

Figure 1.
Ecchymosis extending to the pectoralis muscles after removal of a maxillary bone cyst.

A hematoma (contusion) is a collection of blood, usually clotted in an organ, space, or tissue, which is due to a break in a blood vessel wall. The excessive fluid may form an elevated, hard lump. If a hematoma develops, ice can reduce the amount of swelling, and it may be advantageous to elevate a bruised site to facilitate blood leaving the area.

Healing of the above conditions follows a predictable pattern of color alterations that is related to hemoglobin breakdown.[3] Initially, lesions are reddish, reflecting the presence of blood. After 1 to 2 days, the sites appear black and blue (purple). By day 6, the color changes to green, and this reflects the presence of biliverdin. At day 8 to 9, the site is yellowish-brownish denoting that bilirubin is present. Discoloration is usually gone in 2 to 3 weeks.

The incidence of hemorrhagic patches can be reduced with careful soft tissue management. When possible, vertical releasing incisions should be avoided because they sever blood vessels and result in increased bleeding. During flap elevation, elevators should rest on bone and not on soft tissue, and suctioning ought to be done on bone as opposed to soft tissue. In addition, after flap replacement, it is advantageous to apply pressure to the tissue for several minutes to minimize blood clot thickness and to ensure bleeding has stopped. These actions will reduce ecchymosis and hematoma formation.

Blood loss during surgical procedures. Baab et al.[4] determined that, on average, 134 ml blood was lost (range: 16 to 592 ml) during one sextant of periodontal surgery. However, no study was found that addressed the amount of hemorrhage that occurred during implant procedures or ridge or sinus augmentations. The amount of blood loss will vary depending on several factors: time to complete the treatment, size of the surgery, vasoconstrictor use, blood pressure, medications, inflammation of tissues, and health status of the patient. In general, the amount of bleeding should be considered in the context that the average person has ~5,000 ml of blood. When donating blood, a pint (473 ml) is usually given. Clinicians should be aware that when blood pressure decreases 20 mm Hg during a procedure, blood loss is >500 ml, or the patient experiences an increased heart rate of 20%, enhanced medical management may be needed (e.g., intravenous solution), which could include referral to a hospital.[5]

Caution needs to be exercised when placing implants in the presence of a submandibular or sublingual

recess in the mandible; if there is a large undercut the lingual plate can be inadvertently perforated, resulting in hemorrhaging. Lingual concavities with a depth of 6 mm were reported in 2.4% of assessed jaws (computerized tomography [CT] scans).[6] Arterial trauma can result in development of a sublingual or a submandibular hematoma. The submental and sublingual arteries are blood vessels that may be injured in the floor of the mouth. The submental artery (2 mm average diameter)[7] is a branch of the facial artery, and the sublingual artery (2 mm average diameter) arises from the lingual artery and is found coronal to the mylohyoid muscle.[8] The sublingual artery is the main nutrient vessel in the floor of the mouth. The submental artery usually courses anteriorly and inferiorly to the mylohyoid muscle; however, in one study,[7] it perforated through the muscle to the superior aspect in 41% of 34 dissected cadavers. Hofschneider et al.[7] also noted that the sublingual and submental arteries may traverse anteriorly very close to the lingual cortical plate, and branches of these arteries may enter accessory foramina along the lingual cortex (Fig. 2).

It was reported that 420 ml blood can be lost in 30 minutes from an artery 2 mm in diameter with an estimated blood flow of 0.2 ml per beat (70 beats per minute).[9] The bleeding can cause swelling, and the tongue may be displaced superiorly and posteriorly, obliterating the airway and resulting in upper airway embarrassment.[10] Airway loss is manifested as tachypnea (increased rate of breathing), dyspnea (labored breathing), cyanosis, decreased phonation, and hoarseness. Clinicians should be aware that there may be a latency period after arterial trauma, and hemorrhage can occur several hours later.[11]

Figure 2.
Accessory blood vessel canal communication with the floor of the mouth.

Avoiding hemorrhage in the floor of the mouth. To avoid the above dilemma, the authors suggest the following recommendations. When there are concerns regarding the topography of the mandible, obtain a CT scan. Digitally palpate the submandibular and sublingual areas before and after flap elevation to determine the extent of the undercut. After the lingual flap is elevated, consider placing a periosteal elevator into the undercut on the lingual. The elevator should not be pushed very far apically; it is being used to provide guidance with regard to the degree of undercut present in the submandibular space. Drill osteotomies parallel to the elevator if prosthetically practical; this will preclude perforating the lingual cortex.

Management of hemorrhaging and airway obstruction. Bleeding during implant placement can emerge from soft tissue or bone. To control bleeding from soft tissue, inject an anesthetic with epinephrine and apply direct pressure. If bleeding is from an arteriole and a fine spray is emitted from the tissue, apply pressure and the bleeding will usually subside. To halt hemorrhaging from the bone, the clinician can inject anesthetic with epinephrine directly into a nutrient canal and/or twist gauze and hold it in place with a periosteal elevator, burnish the bone to try to occlude it, or place a bone graft material into a defect to obtund bleeding. Although epinephrine can be an aid in controlling bleeding, its use in patients with cardiac disease is limited.[12] Furthermore, there is the potential of rebound bleeding after the drug wears off. Therefore, definitive measures (e.g., direct ligation of the damaged blood vessel, deep sutures, and flap adaptation) provide the most reliable method to control bleeding. Other agents[‡§] can be applied, such as thrombin. Bleeding from an osteotomy site can be managed by placing a direction indicator into the site or placement of an implant into the completed osteotomy.

If hemorrhage develops in the floor of the mouth apply firm pressure with gauze. When performing gauze tamponade, place one thumb inside and the index finger outside the mouth and apply prolonged pressure. Ligation of the bleeding blood vessel is the preferred treatment and provides the most dependable result. Whenever the facial artery is believed to be involved (submental branch), press on the antegonial notch (located 1 inch anterior to the gonial angle and directly in front of the masseter muscle). Once hemorrhaging is controlled, consider transferring the patient to a hospital setting for monitoring and possible airway management. If bleeding persists, call for help (medical center), because direct ligation of the blood vessel may be needed. Furthermore, if hemorrhaging continues, an airway crisis can develop, and the

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patient may require aggressive medical and surgical management.[10]

Nerve Injury

Neurosensory alterations may occur subsequent to implant therapy.[13] Intrusion into the inferior alveolar or mental canal during osteotomy development can cause transection, tearing, or laceration of nerves (Fig. 3). Implant insertion can also result in bone compression on the nerve.[14] In addition, within the soft tissue, the lingual or mental nerve may be injured by compression, stretching, the scalpel, or needle penetration. Three levels of increasing severity for nerve injuries have been classified.[15] Neurapraxia denotes a mild injury that can be caused by compression or prolonged traction of the nerve. Because the axons are intact, temporary loss of feeling is reversed within 4 weeks after surgery.[16] In contrast, severe compression or traction of a nerve may result in axonotmesis, which connotes possible intrafasicular edema, ischemia, or demylination. There can be damage to some of the axons, but the overall structure of the nerve remains intact. Postoperatively, at 5 to 11 weeks, there may be signs of returning feeling that continue to improve over the next 10 months.[17] The most severe injury, neurotmesis, indicates that there has been disruption of the nerve, and no impulse can be propagated along the nerve. Transection of the nerve requires microsurgical intervention, and the prognosis for recovery is not good.[17]

Neurological sequelae of nerve injury. After nerve injury, the patient will manifest one or more of the following symptoms: paresthesia (numb feeling, burning, and prickling), hypoesthesia (reduced feeling), hyperesthesia (increased sensitivity), dysesthesia (painful sensation), or anesthesia (complete loss of feeling of the teeth, the surrounding skin, and mucosa).[17]

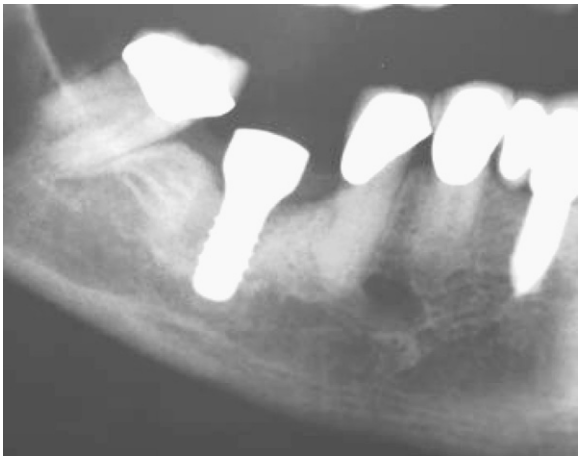

Figure 3.
Dental implant penetrating into the inferior alveolar canal.

Postoperative management after neurosensory alteration. Whenever there is concern that nerve damage occurred during osteotomy development and the implant was inserted, radiographs should be taken to ascertain the implant's position. If it is intruded into a nerve canal, the authors suggest that the implant be slightly withdrawn a couple of turns or removed altogether. The next day, if a patient relates symptoms of altered perception, it needs to be determined whether they are due to the presence of the implant or sequelae of soft tissue manipulation or edema. Whenever it is believed that the implant is the problem, it should be removed. If the twist drill or the implant did not encroach upon the canal, it is possible that bone was compressed, thereby placing pressure on the nerve. The implant should be slightly withdrawn several turns. In the event of uncertainty with regard to implant penetration into a nerve canal, a CT scan may be needed to provide additional information.

After nerve injury, it is important medicolegally to document the level of neurosensory dysfunction. Several tests can be used to evaluate neural impairment (Table 1).[18] The clinician should ascertain the depth and extent of the sensory dysfunction. Altered sensation regarding the lip and tongue and drooling should be documented. Numbness for 16 weeks suggests that the nerve sheath was disrupted, and the patient should be referred for possible microsurgery.[15] When an implant is not within a nerve canal, Kraut and Chahal[17] suggested that altered sensation can be due to an inflammatory reaction; they prescribed steroid therapy or anti-inflammatory medication (ibuprofen, 800 mg, three times a day) for 3 weeks. They recommended referral to a microsurgeon if improvement was not seen at 2 months.

Incidence of neurosensory dysfunction. After implant placement, the frequency of sensory alterations varied among studies[13,19-21] because there are

Table 1.

Tests to Discriminate if Neurosensory Damage Has Occurred

1. Light touch test: a soft brush is applied to the lip, and the patient is asked in which direction the stimulus was applied.[18]
2. Pain test: a 27-gauge needle can be used to determine whether the patient perceives pain.[18]
3. Two-point discrimination test: calipers are opened progressively at 2-mm increments until the patient is able to discriminate the caliper ends as two separate points of contact.
4. Ice or a heated mirror handle (43°) can be used to determine whether the patient is able to discriminate between hot and cold.[18]

numerous variables: osteotomy sites, surgical methods, study design, sensitivity of evaluation techniques, choice of outcome variables, and jargon used to relate sensory disturbances. Because changed sensation of the lower lip and adjacent tissue is a possible treatment complication, patients must be advised of this risk before implant placement.[21] Ultimately, it is prudent not to use a specific location that has a high potential risk for nerve injury because implant insertion is an elective procedure.

Avoiding nerve injuries. To avoid nerve injuries, the location of the inferior alveolar nerve and mental foramen must be determined prior to osteotomy development. Evaluate periapical and panoramic films; if needed, a CT scan should be obtained. The appropriate magnification correction factor should be used, and drill guards can be placed on burs to avoid unintentional overpenetration of the drill.[22] A safety margin of 2 mm between the entire implant body and any nerve canal should be maintained.[13,22] With regard to the anterior loop of the mental foramen, it may be present; however, its prevalence and length are debatable. It should also be noted that radiographs under- and overestimated loop length (range: 0 to 7.5 mm).[13,23] Furthermore, the correlation between identification of the loop upon cadaver dissection and radiographs is consistently weak.[23,24] Similarly, with regard to the presence of an anterior loop, false positive and negative results were detected on radiographs.[23,25] If there are doubts concerning the mental foramen's position or the anterior loop's presence or unease about a 2-mm safety zone, patients should be referred for a CT scan to obtain additional information or the roof of the mental foramen should be exposed during surgical implant therapy (Fig. 4). A measurement from the roof of the mental foramen to the alveolar crest should be recorded, and the amount of available bone for implant placement should be ascertained.[13,26]

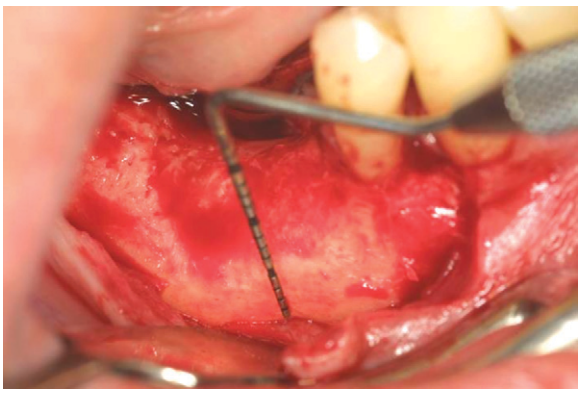

Figure 4.
Measurement from the alveolar crest to the roof of the mental foramen.

Branches of the mental nerve that emerge from the mental foramen provide sensation to the lips and adjacent mucosa and must be managed differently depending on the patient's anatomy and type of surgical procedure to be performed. For example, in preparation for implant surgery with a relatively normal ridge height and width, a midcrestal incision is made, and the nerve branches are protected within the mucoperiosteal flap.[27,28] If detection of the mental foramen is desired, wet gauze can be used to aid in dislodging the flap without inducing nerve damage.[27] When there is extensive resorption of the alveolar ridge, the initial incision is made more to the lingual, and a full-thickness flap is elevated until the nerve foramen is identified.[28] In addition, in the mental foraminal area, clinicians must avoid compressing the mental nerve when retracting the flap. Otherwise, a transient paresthesia may occur as a result of swelling around the mental nerve.

The lingual nerve. During implant procedures in the posterior mandible, the lingual nerve can be damaged if the lingual flap is not retracted carefully. Clinicians should be aware that 15% to 20% of the time the lingual nerve is found at or coronal to the crest of bone lingual to the mandibular third molar.[29] On average, the lingual nerve is located 2 mm horizontally from the cortical plate in the flap and 3 mm apical to the crest.[30] Furthermore, the lingual nerve is in contact with the cortical bony plate 22% of the time.[30] Therefore, to avoid lingual nerve damage, the elevator should be used to protect the nerve located in the flap underneath the periosteum, and the elevated tissue should be managed gently to avoid inducing a transient traction injury. Whenever possible, lingual vertical releasing incisions should be avoided.

The infraorbital nerve. The infraorbital nerve is located on the inferior aspect of the infraorbital ridge and can be damaged during surgical procedures. In particular, this may occur during the flap elevation prior to creating a window for a sinus lift. The infraorbital foramen can be palpated externally to the cheek, and flap elevation should terminate inferior to this landmark. Clinicians need to be aware that the height of the maxillary sinus ranges from 35 to 45 mm;[31] therefore, window preparation extending ~15 mm from the crest of the alveolar ridge will provide wide latitude of safety before approaching the infraorbital nerve. If extensive resorption of the maxilla has occurred, caution needs to be exercised not to encroach on the infraorbital nerve.

Tissue Emphysema Induced by Dental Procedures (crepitus)

Tissue emphysema is caused by inadvertent introduction of air into tissues under the skin or mucous membranes. Air from a high-speed handpiece, air/water

syringe or air polishing or air abrasive device can be forced into a sulcus, surgical wound, or a laceration in the mouth (Fig. 5).[32] The air can follow the fascial planes and create a unilateral enlargement of the facial and/or submandibular regions.[32] The clinical presentation is typically a facial or cervico-facial swelling coincident with dental treatment.[33,34] Swelling can close the eye,[33] and it can appear several hours after therapy.[34] When the skin is palpated, it usually produces a crackling sensation as the gas is pushed through the tissue. This is referred to as crepitus. The crackling sound is pathognomonic for tissue emphysema, and pain is not a usual feature of tissue emphysema.[34]

It is also possible to have tissue emphysema and no crepitus.[35] If the cause of the swelling is not apparent, a differential diagnosis based on the appearance of the tissues should include angioedema, soft tissue edema, and infection.[36] Treatment of tissue emphysema usually consists of antibiotic and mild analgesic therapy, close observation, and reassurance. Antibiotics are prescribed because bacteria may have been introduced into the tissue with the compressed air. Symptoms usually subside in 3 to 10 days.

Once a large amount of air is projected into the tissues, it may tract into the mediastinum and pleural space.[33] The possibility of mediastinal involvement should be recognized, and the patient should be monitored appropriately.[37] If a patient reports any airway distress, he/she needs to be sent to a hospital, be provided intravenous antibiotics, and be monitored closely.[35]

Infections

It is recognized that infections after oral surgery may involve soft tissue and bone (e.g., periapical lesions and osteomyelitis) and are addressed in the first section of the paper.[38] The prevalence of infections after a variety of periodontal procedures ranged from 1% to 5.4%; in the same studies,[39,40] patients not receiving antibiotics before, during, or after surgery had an infection rate that ranged from 2.33% to 5.4%. With regard to the prevalence of infections after implant therapy, Powell et al.[41] noted a 1.14% (two of 175 procedures) chance of developing a problem after stage 1 and stage 2 therapies, and Gynther et al.[42] found a 0.7% rate of infection. Because the infection rate is so low after implant surgery, it is questionable whether the clinician needs to administer antibiotics for 1 week postoperatively. A recent report[43] suggested that amoxicillin, 2 g, 1 hour before a procedure, is adequate prophylaxis. Additional corroboration for this recommendation was published by Hossein et al.[44] They also demonstrated that a 1-day dose of antibiotics achieved the same benefit as medication for 1 week. Conversely, there are numerous scenarios in which a judgment must be made by the clinician as to the necessity of prescribing antibiotic coverage for an extended period of time (e.g., if a surgical procedure is complicated, multiple implants are placed, implant placement takes a prolonged period of time, bone grafts were placed, or the patient was medically compromised).[45]

Infections associated with placement of dental implants are treated similarly to other dento-alveolar infections.[38] This includes treatment of descending necrotizing mediastinitis, a rare but dangerous complication that was reported after the placement of dental implants.[46] An extensive review on antimicrobial therapy in the treatment of peri-implant diseases that occur after implants are placed was recently published by Heitz-Mayfield and Lang.[47]

Figure 5.
Soft tissue emphysema after irrigation of pocket with 3% hydrogen peroxide under pressure.

Wound Dehiscence

After flap closure, incision line breakdown sometimes occurs during the first 10 days.[48] When the wound becomes dehisced (opened), it heals by secondary intention.[48] The wound closes as new granulation tissue is formed and epithelialization occurs. Epithelium has a 12-hour lag time and then 0.5 to 1 mm of healing occurs daily;[49] connective tissue heals at a rate of 0.5 mm/day.[50] The most common postoperative complication for submerged implants is wound dehiscence.[51] The prevalence of this problem ranged from 4.6%[52] to 13.7%[53] around submerged implants. Factors that could contribute to wound opening include infection, faulty suturing, flap tension, and poor flap design. Infections along the suture line can be attributed to contamination, retained sutures, and loose cover screws.[54] Wound dehiscence can be avoided if flaps are passively coapted and are tension-free.[55] Two other common causes of wound opening are trauma from inadequately relieved dentures and antagonistic

teeth (Fig. 6).[56] To circumvent these problems, dentures should be relieved and relined with a soft denture liner or tissue-conditioning material,[57] and these agents should undergo periodic replacement.[58]

An increased prevalence of soft tissue dehiscences (30%) was noted when barriers were placed as part of guided bone regeneration procedures (Fig. 7).[59] To decrease this occurrence, it is prudent to release the flap so that the buccal margin can be advanced over the lingual margin by 2 to 3 mm to facilitate tension-free closure. Mattress sutures in conjunction with interrupted sutures can be used to offset muscle pull and possibly inhibit wound dehiscences.

Management of wound dehiscence. There are two approaches to the management of a soft tissue dehiscence: resuturing or chemotherapy. When the dehiscence is small and occurs within 24 to 48 hours, the clinician can immediately resuture the dehiscence.[57] Once the wound is large (2 to 3 cm) or the time elapsed is >2 to 3 days, it was suggested that the margins of the wound be excised and resutured.[57] However, this is problematic and frequently does not work well. If the patient has traumatized wound margins, it is in the anterior part of the mouth, or a membrane was used, consider using chlorhexidine rinses twice a day and/or systemic antibiotics.

Figure 6.
Trauma to soft tissue from antagonistic teeth.

Figure 7.
A soft tissue dehiscence after guided bone regeneration procedure using an expanded polytetrafluoroethylene membrane.

Aspiration or Ingestion of Foreign Objects

Intraoperative ingestion or aspiration of a dental screwdriver or an implant can present a life-threatening complication.[60,61] If a device is aspirated, it is necessary to refer the patient to an otolaryngologist for evaluation and treatment. Usually aspiration of a foreign body will be accompanied by coughing; however, it is possible for a patient to aspirate an object without coughing.

Worthington[62] reported a situation in which a screwdriver was swallowed, resulting in potentially serious consequences, including infection and blockage. It was noted that the instrument may pass naturally; however, these patients should be referred to a gastroenterologist for evaluation and possible endoscopy to remove the object. In this regard, Munter[63] indicated that once an object is past the esophagus and is <20 mm in length, it has a 90% chance of passing uneventfully.

In general, these types of mishaps can be avoided if a piece of silk suture is tied to the screwdriver or another device before it is inserted into the mouth. This provides the clinician a fast way to identify and retrieve a dropped instrument. In addition, it is sensible to place a large piece of gauze into the patient's mouth so that when an object is dropped, it is easily retrieved.

Pain Control

A patient's postoperative discomfort after dental implant insertion can be reduced if incisions are neat, the periosteum is reflected intact, tissues are handled gently, and flaps are sutured so healing occurs by primary intention. Pain can also be decreased by creating osteotomies with sharp burs and avoiding excessive pressure while drilling. If the temperature exceeds 47°C for 1 minute and the bone is burned (brown color seen), the patient may experience postoperative discomfort because there will be bone necrosis.[64] Sometimes, color changes cannot be seen because the thermal insult is occurring in the deeper portions of the osteotomy. Careful attention to irrigation protocols and intermittent drilling pressures are important facets with respect to limiting postoperative pain. It is recognized that careful manipulation of hard tissue (i.e., bone) also reduces postoperative pain.

HARD TISSUE COMPLICATIONS

Periapical Implant Pathosis and Endodontic Considerations

Several situations can arise with regard to induction of periapical lesions around teeth or implants. Incorrect

positioning of an implant, which results in striking an adjacent tooth or impinges on the tooth's blood supply, or overheating of the bone during the osteotomy can cause an adjacent tooth to become non-vital (Figs. 8 and 9).[65] If this occurs, the damaged tooth will need endodontic therapy, an apicoectomy, or an extraction.[66] Furthermore, a periapical lesion that develops as a result of devitalization and encroaches upon the implant may contaminate it and cause loss of the implant.[67]

Other explanations for the initiation of periapical pathosis around an implant are microbial contamination at the time of placement, bone necrosis due to overheating of bone during osteotomy development, and residual foreign bodies in the bone. Quirynen et al.[68] reported that 1% of implants placed during a 5-year period developed periapical pathosis. The condition is also referred to as a retrograde peri-implantitis, and defects can be classified as active (symptomatic) or inactive.[68]

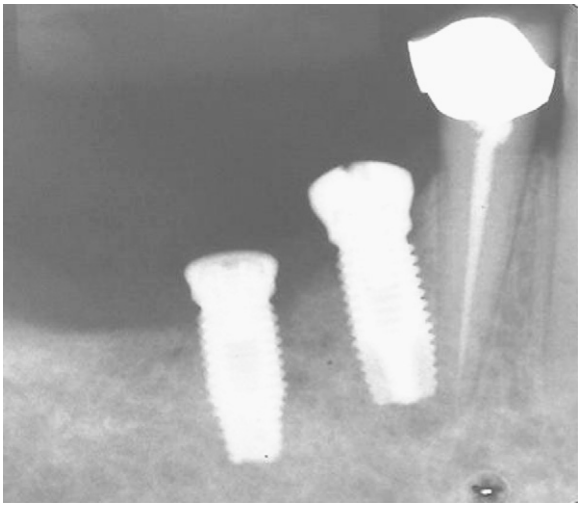

Figure 8.
Malposed implant hitting adjacent tooth.

Figure 9.
Implant thread markings on a tooth.

Avoiding development of periapical pathosis. To avoid devitalizing an adjacent tooth during osteotomy development, the angulation of adjacent teeth and dilacerations of roots need to be radiographically assessed prior to implant placement. Ideally, 1.5 to 2 mm of bone should be present between an implant and the adjacent tooth. Furthermore, inspection of a radiograph with a guide pin at a depth of 5 mm will facilitate osteotomy angulation corrections.

To reduce the potential of developing retrograde peri-implantitis, it is advisable to avoid immediate placement of an implant into an infected site or when there is a radiographic indication of pathosis.[69] Conversely, thorough debridement and irrigation may be sufficient to provide a proper environment, because it seems that retrograde implantitis only occurs 1% of the time.[68] Implant packages should be opened immediately before placement and should not touch anything other than the bone to avoid transferring contaminants.[69] Osteotomies ought to be flushed and suctioned prior to implant insertion to remove debris. In addition, teeth adjacent to an implant site that need endodontic treatment should be treated prior to implant placement.[69]

Therapy for retrograde peri-implantitis. Inactive lesions are asymptomatic and, according to Quirynen et al.,[68] require no therapy when the radiolucency size remains stable. In contrast, Flanagan[69] suggested that any periapical implant radiolucency should be surgically debrided to preclude exacerbation of the lesion and implant loss. This latter perspective may result in overtreatment. If a site is infected, the patient may present with pain, tenderness, swelling, and a fistulous tract.[70,71] Periapical lesions around implants that are symptomatic need to undergo surgical debridement and antibiotic therapy.[68-71] Whenever the apex cannot be completely debrided, it should be resected, and a bone graft may assist in preventing collapse of a bioabsorbable barrier.[70]

Mandibular Jaw Fracture

A potential, although uncommon, complication of implant placement is fracture of an atrophic mandible (Fig. 10).[72,73] Tolman and Keller[73] concluded that fractured mandibles detected shortly after implant placement were due to stress fractures at weakened sites where implants were placed. Fractures have also been reported when nerve transposition was done in conjunction with implant insertion, because removing buccal bone to expose the nerve canal may weaken the mandible.[72-74] To maintain structural integrity of the atrophic mandible, Karlis et al.[72] suggested that it is reasonable to engage the inferior border of the mandible for stability with an implant; however,

Figure 10.
Mandibular fracture adjacent to removed implant site.

implants should not disrupt it because that may weaken the mandible.

There are several factors that predispose a patient to mandibular jaw fracture associated with implant placement: osteoporosis (reduction of bone mass), stress at the implant location, and trauma.[73,74] In this regard, insertion of long and wide implants in an atrophic mandible may further weaken the jaw.[74] Therefore, consideration should be given to how much bone is present to maintain the strength of the mandible when implants are placed. Park and Wang[75] cautioned that there is increased vulnerability to fracture once the resorbed mandible has <7 mm of bone height and 6 mm of width.

When a fracture occurs, Laskin[74] suggested that the degree of displacement is the critical determinant in selecting the appropriate treatment. If the fracture manifests minimal mobility or displacement, the implant should be maintained.[74] However, if there is a large amount of displacement, the surgeon needs to decide whether a closed or open fracture reduction is needed with or without retention of an implant along the fracture line.[74]

Lack of Primary Implant Stability

There are several options available to correct lack of primary stability after an implant is placed. When there is adequate apical bone height, the osteotomy can be made deeper, and a longer implant can be inserted. However, if there is no additional available bone apically, then a wider implant might be able to be inserted. Another method that may increase stability is to add bone with an amalgam plugger, condense it, and then insert the implant.[76] The authors suggest using an osteotome one size smaller than the implant to be placed to compress the bone prior to implant insertion. If the implant is still loose, it needs to be removed, and the site should be augmented with bone and reentered in several months.

Inadvertent Penetration Into Maxillary Sinus or Nasal Fossa

Unintentional penetration into the maxillary sinus or the nasal cavity with the twist drill is a minor problem if there is adequate length of bone to place a stable implant. Insertion of an implant several millimeters into the sinus or nasal cavity is usually well tolerated.[77] However, in these situations it is prudent to prescribe an antibiotic and a decongestant.

Complications Associated With Sinus Elevation

There are numerous surgical predicaments associated with a maxillary sinus elevation that can impact implant survival. The most common problem is perforation of the Schneiderian membrane during its elevation (occurrence: 25%[78] to 40%[79]). Perforations should be occluded with a bioabsorbable barrier prior to placing graft material.[78,80] If a tear in the membrane occurs along the periphery of the osteotomy and it is difficult to reengage the membrane, this situation can be managed by extending the osteotomy outline several millimeters past the original window and reestablishing contact with the membrane (Figs. 11 and 12). Several investigators[79,81] concluded that intraoperative complications, such as membrane perforation, did not detrimentally influence implant survival.

Excessive bleeding when developing an osteotomy can occur because of several reasons: it is possible to sever a blood vessel that runs along the membrane or cut an intraosseous artery in the lateral wall of the sinus. Bleeding from the membrane can be managed by placing gauze that is saturated with anesthetic solution (contains 1/50,000 epinephrine) directly onto the membrane. Bleeding from the bone requires direct pressure with an instrument (e.g., a hemostat), and it can be touched with a cautery unit. If the osteotomy is developed, another way to manage an intraosseous arterial bleeder is to displace the membrane and clamp the bone with a mosquito hemostat, thereby crushing the bone and occluding the bleeding blood vessel (Fig. 13). Pertinently, Elian et al.[82] recently reported that 20% of the time intraosseous arteries are <16 mm from the crest of the ridge and may present a complication during lateral window preparation.

Septa may be encountered in the maxillary sinus and complicate membrane elevation. They have been

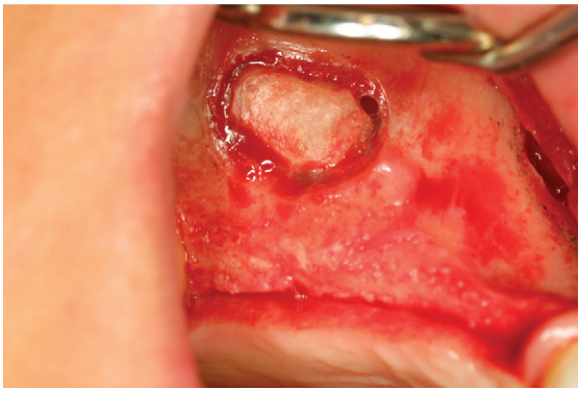

Figure 11.
Perforated Schneiderian membrane.

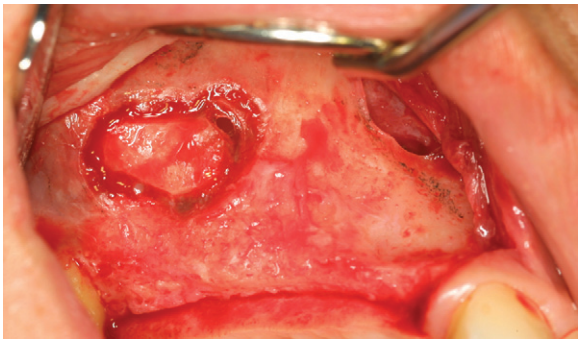

Figure 12.
Extension of an osteotomy to recapture perforated membrane.

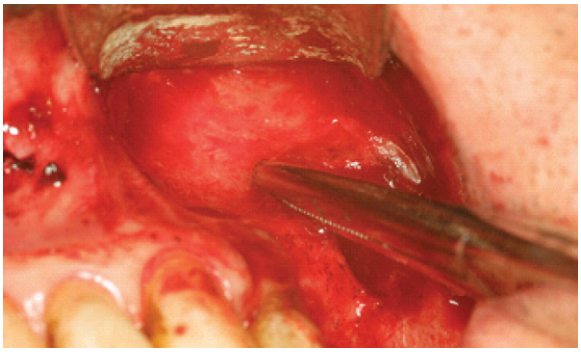

Figure 13.
Hemostat used to clamp the bone after the Schneiderian membrane was displaced.

detected in 31.7% of patients, and most were found between the second premolar and the first molar.[83] When septa are encountered on the antral floor, Boyne and James[84] recommended cutting them with a narrow chisel and removing them with a hemostat, so the bone graft can be placed over the entire antral floor without interruption. If the membrane is to be elevated over partial septa, they should be released laterally to medially, because septa often enlarge medially. Membrane elevation attempted anteriorly to posteriorly over septa is more prone to being perforated. Another option is to create more than one lateral window as part of the antral opening to accommodate the septa.[83]

During implant insertion, if an implant is inadvertently displaced into the sinus cavity, it must be removed. This is accomplished by creating a window into the sinus to retrieve the implant.[85] After a sinus lift, if an infection develops (pain, redness, and tenderness) without fluctuance, antibiotics are administered. Once there is fluctuance, incision and drainage are performed in conjunction with prescribing systemic antibiotics.[78,86] It is prudent to culture the infection to determine whether the appropriate antimicrobial therapy is being used. A persistent infection dictates that the graft material be removed and the sinus flushed out.[87] Symptoms of sinusitis may include fever, facial pain (that increases on leaning forward), and yellow to green purulent discharge from the nose, which may drain posteriorly causing a cough and malaise.[88] Related symptoms include popping of the ears and muffled hearing. There may be swelling of the periorbital tissues and referred pain to the maxillary teeth.[88] Sinus infections can have serious consequences. Uncommonly, they can progress to unilateral or bilateral pan-sinusitis or to cavernous sinus involvement.

Other complications associated with sinus lift procedures include detection of lesions within the sinus (e.g., polyps, cysts, and mucocele) and overfill of the sinus. CT scans are an important diagnostic aid in predetermining the dimensions of the maxillary sinus and the presence of unexpected findings (e.g., tumors and intraosseous arteries). Knowledge of the anatomy of the sinus is important. For example, its mean height is 36 to 45 mm, its mean width mesiodistally is 25 to 35 mm, and the mean depth is 38 to 45 mm (laterally–medially).[31] The ostium is located on the superior aspect of the medial wall of the maxillary sinus above the first molar. The linear distances between the most inferior point of the antral floor and the normal ostium are ≥20 mm (mean, 28.5 mm).[89] This information can be used to avoid overfilling the sinus, which can result in occluding the ostium and inducing sinusitis.

Medical Conditions and Therapies Affecting the Success of Dental Implants

A number of medical conditions pose absolute and relative contraindications with regard to placing implants, because they can be associated with an

increased incidence of complications.[90-92] In particular, clinicians should be aware of potential problems associated with prior therapy with bisphosphonates (osteonecrosis)[93-95] and radiation therapy of the head and neck (osteoradionecrosis).[96-99] Information related to these issues have been reviewed by others,[93-99] and they are not discussed in this commentary.

CONCLUSIONS AND FINAL RECOMMENDATIONS

Fortunately, serious complications associated with dental implant placement are uncommon, and less severe situations can often be avoided. Preplanning using diagnostic radiographs, wax-ups, and attention to detail before and during implant procedures can help to avoid problems. Other methods that can be used to enhance success include the following: create a checklist of things that might be overlooked, confirm equipment is working before it is needed, carry out routine tasks with care and attention, follow procedures as planned and modify as required, check and recheck procedures for possible errors, and assess completed work with respect to what was planned. Recognition of a developing problem and prompt management reduce postoperative complications. Finally, proper training should be obtained before advanced surgical or prosthodontic procedures are undertaken.

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