

Case Series

Loss of Pulp Vitality After Maxillary Sinus Augmentation: A Surgical and Endodontic Approach

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Background: Maxillary sinus augmentation is a routine procedure performed in implant dentistry in cases with sinus pneumatization. This study presents a series of clinical cases in which tooth devitalization occurred in conjunction with sinus augmentation.

Methods: In the three cases presented, a sinus-lift procedure was performed that resulted in devitalization of the adjacent teeth. Patients were referred to an endodontist for evaluation and treatment. Vitality of the teeth was determined by the use of a cold test, electric pulp test, and cavity test. The pulp was considered to be necrotic if the tests were negative.

Results: In this case series, loss of pulp vitality of two maxillary left second premolars and one maxillary left first molar occurs after sinus-augmentation procedures. The devitalized teeth were free of caries. In one case, two amalgam restorations were present.

Conclusion: Pulp necrosis may occur in conjunction with a sinus-lift procedure in cases when an adjacent root is in close proximity to the sinus floor and the sinus membrane is elevated over the root apex. *J Periodontol* 2014;85:43-49.

KEY WORDS

Complications; dental pulp devitalization; dental pulp necrosis; sinus floor augmentation.

Maxillary sinus-floor elevation, as first described by Tatum¹ and modified later by others,²⁻⁴ is predictable, with high long-term survival rates for implants placed in conjunction with the procedure.⁵⁻⁸ Based on the systematic review of Aghaloo and Moy,⁹ the “lateral window approach” is a very predictable technique, especially in combination with xenograft augmentation grafting materials. However, little has been mentioned in the literature regarding the effect of Schneiderian membrane elevation and subsequent bone augmentation on the adjacent teeth, especially when their root apices are in close proximity to the maxillary sinus floor.

The innervation of individual roots of all teeth, bone, and periodontal structures in both the maxilla and mandible derives from terminal branches of larger nerves in the region, forming a network known as the “dental plexus.”¹⁰ The superior dental plexus is composed of smaller nerve fibers from the three superior alveolar nerves. Three types of nerves emerge from these plexuses: 1) dental nerves, 2) interdental branches, and 3) interradicular branches. Each is accompanied along its pathway by a corresponding vasculature. The nerve bundles pass upward through the radicular pulp together with blood vessels. Once they reach the coronal pulp, they

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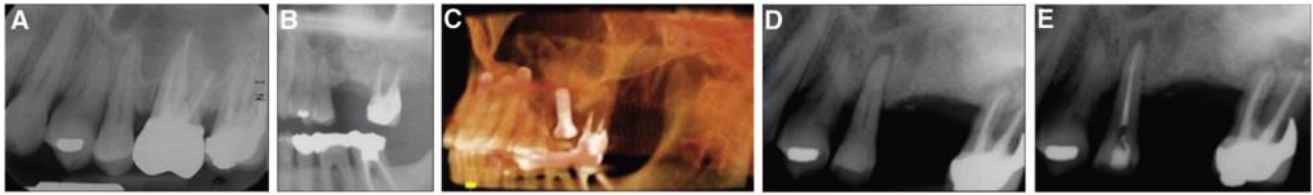


Figure 1.

Case report 1. **A)** Initial radiograph of maxillary left first molar. No periapical pathology was observed on the maxillary left second premolar. **B)** Postoperative radiograph for evaluation of the sinus augmentation immediately after surgery. **C)** Cone-beam computed tomographic scan showing insufficient implant integration. **D)** Periapical radiograph of maxillary left posterior region. Note the periapical radiolucency around the maxillary left second premolar 30 months after the initial sinus augmentation. **E)** Periapical radiograph of maxillary left posterior area after endodontic treatment was performed on the second premolar.

fan out beneath the cell-rich zone, branch into smaller bundles, and finally ramify into a plexus of single-nerve axons known as the plexus of Raschkow.¹¹

The questions that arise include the following: What happens to the adjacent tooth or teeth after a sinus-augmentation procedure in situations where the root apices are close to the sinus floor and innervation and blood supply are disrupted in the course of the surgical procedure? Does the pulp of such teeth become symptomatic or necrotic? Furthermore, if the pulp becomes necrotic, must it be treated endodontically? Can the development of periapical pathosis eventually cause adjacent implant failure? All of these questions should be considered to inform patients adequately about the possible need for later endodontic treatment. Furthermore, if clinicians can recognize situations in which tooth devitalization may occur, they can monitor the vulnerable teeth closely for early diagnosis and treatment.

The purpose of this study is to present tooth devitalization that occurred after maxillary sinus augmentation. In each case, the pulp prognosis was subsequently evaluated by an endodontist.

CASE DESCRIPTIONS AND RESULTS

In each of the following clinical cases, devitalization of an adjacent tooth occurred after a sinus-lift procedure because of the proximity of the adjacent tooth roots to the sinus floor. All patients were treated at the Division of Periodontology at Eastman Institute for Oral Health, University of Rochester, Rochester, New York, and all signed a consent form before their treatment. Cases were retrieved retrospectively, and the study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2000.

Initially, a comprehensive extraoral and intraoral examination was completed. All sinuses were assessed radiographically before and after the surgical procedure. The adjacent teeth presented no caries and were vital, as determined by cold testing. Conventional sinus-lift procedures were performed in

preparation for two-stage implant placement. In each case, the approach was to elevate the membrane up to the medial wall¹² to achieve a total of ≈ 12 mm of native alveolar ridge, including the height of the sinus graft. To achieve that, the membrane had to be elevated from the sinus floor mesially and distally over the root apices of the adjacent teeth to become tension-free and thus avoid any perforation of the membrane. All procedures were performed by DP and multiple unnamed periodontal residents. Implants were placed after healing of the graft.

Case Report 1

A 60-year-old white male presented with a hopeless maxillary left first molar. Endodontic treatment failure resulted in recurrent periapical infection (study dates: March 2008 to April 2011) (Fig. 1A). It was decided to extract the tooth and perform a socket-preservation procedure. A sinus-augmentation procedure was performed 9 months later (Fig. 1B) to prepare the area for placement of a dental implant. After 6 months of healing, a dental implant[¶] was placed. The implant failed to osseointegrate and had to be removed after 4 months (Fig. 1C). Four to 6 months later, ridge augmentation was deemed necessary to enable successful implant placement. The sinus was elevated and 30 months later, a periapical radiograph showed radiolucency and widening of the periodontal ligament space around the maxillary left second premolar (Fig. 1D). Occlusal adjustments were performed to control the tooth mobility. The patient was referred to an endodontist (MJH) for evaluation and treatment, and the tooth responded negatively to a cold test, an electric pulp test (EPT), and cavity testing. The pulp was diagnosed as necrotic, and endodontic treatment was performed (Fig. 1E). Visual evaluation of the pulp during endodontic therapy presented no signs of vital tissue. A new dental implant was finally

¶ SLActive, Standard Plus, wide neck, 4.8 × 12 mm, Institute Straumann, Andover, MA.

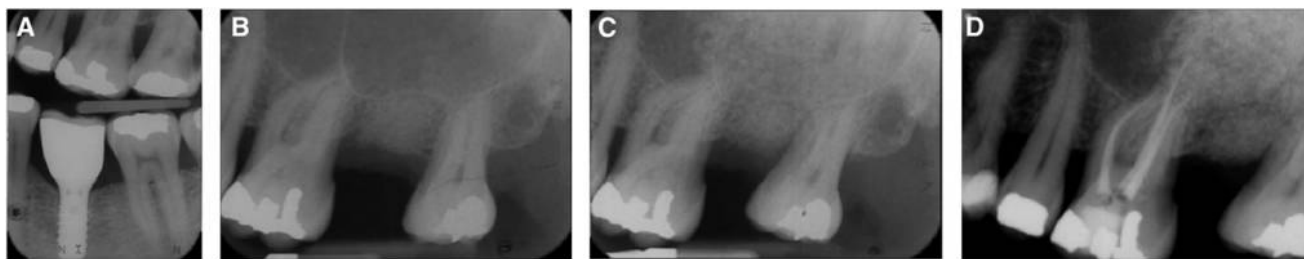


Figure 2.

Case report 2. **A)** Initial bitewing radiograph presenting large caries distal to the maxillary left second molar. **B)** Periapical radiograph of maxillary left posterior area after socket preservation. Note the close proximity of the first and third molar roots to the maxillary sinus floor. **C)** Periapical radiograph of maxillary left posterior area immediately after sinus augmentation. **D)** Periapical radiograph of maxillary left posterior region after completion of endodontic treatment of the first molar.

placed at the maxillary left first molar area, and it osseointegrated without complications.

Case Report 2

A 49-year-old white male presented with pain in the maxillary left posterior area (study dates: April 2010 to January 2011). All his maxillary left premolars and molars had amalgam restorations and were examined for vitality with the cold test. A positive response was elicited in all of the teeth except the maxillary left second molar. In it, the presence of caries was also evident, both clinically and radiographically (Fig. 2A). The patient rejected the option of endodontic and restorative treatment for this tooth. It was then decided to extract the tooth and perform a socket-preservation procedure using freeze-dried bone allograft material[#] and a non-resorbable barrier^{**} (Fig. 2B). A sinus-augmentation procedure was performed 3 months later in the maxillary left second molar area (Fig. 2C) to prepare the area for placement of a dental implant. After 6 months, the maxillary left first molar presented with a negative pulp response to cold, electric pulp, and cavity testing. Therefore, it was diagnosed as having a necrotic pulp, and endodontic treatment was performed by an endodontist (MJH) (Fig. 2D). The inspection of the pulp during endodontic therapy showed no signs of blood circulation according to the endodontist.

Case Report 3

A 57-year-old Asian male presented for comprehensive periodontal and prosthodontic treatment (study dates: April 2010 to October 2010). An extraction of the maxillary left first molar and a sinus-augmentation procedure were performed (Figs. 3A and 3B). Radiographically, the roots of the first and second maxillary left premolars were in close proximity to the maxillary sinus (Figs. 3A and 3B). Three months after the maxillary left sinus elevation, the patient was referred to an endodontist for evaluation of the vitality of the adjacent teeth. During exami-

nation with the cold test and EPT, the maxillary left first premolar was found to be vital. However, the maxillary left second premolar was diagnosed to have a necrotic pulp according to the negative results of cold, electric pulp, and cavity testing. Subsequently, it was treated endodontically (Fig. 3C). Visual evaluation of the pulp during endodontic therapy presented no findings of vital tissue.

In all three cases, any time a vitality pulp testing was performed, a contralateral (control) tooth also received similar testing. All findings are summarized in Table 1.

DISCUSSION

The aim of this case series is to present clinical cases in which tooth devitalization occurred in conjunction with maxillary sinus-augmentation procedures. The authors found no studies (or case reports) of this phenomenon in the literature. Conversely, the close anatomic relationship between the maxillary nerves and vasculature and the maxillary antrum and Schneiderian membrane has been well documented.^{10,13-15} Specifically, the sinus membrane is innervated from the anterior superior alveolar, middle superior alveolar, and posterior superior alveolar nerves, all branches of the trigeminal nerve (division 2). A close proximity of the sinus floor and the root apices of the maxillary posterior teeth may result in their devitalization during the elevation of the sinus membrane if the innervation and blood supply of individual branches are disrupted. Minimally invasive surgical procedures, such as the sinus-elevation osteotome technique,² may also violate the blood and nerve supply of the posterior maxillary teeth, although such complications also have not yet been reported in the literature.

The authors did find publications in which it was recognized that, immediately after segmental osteotomies, teeth failed to respond positively to

[#] Musculoskeletal Transplant Foundation, Edison, NJ.

^{**} Regentex, Cytoplast, Osteogenics Biomedical, Lubbock, TX.

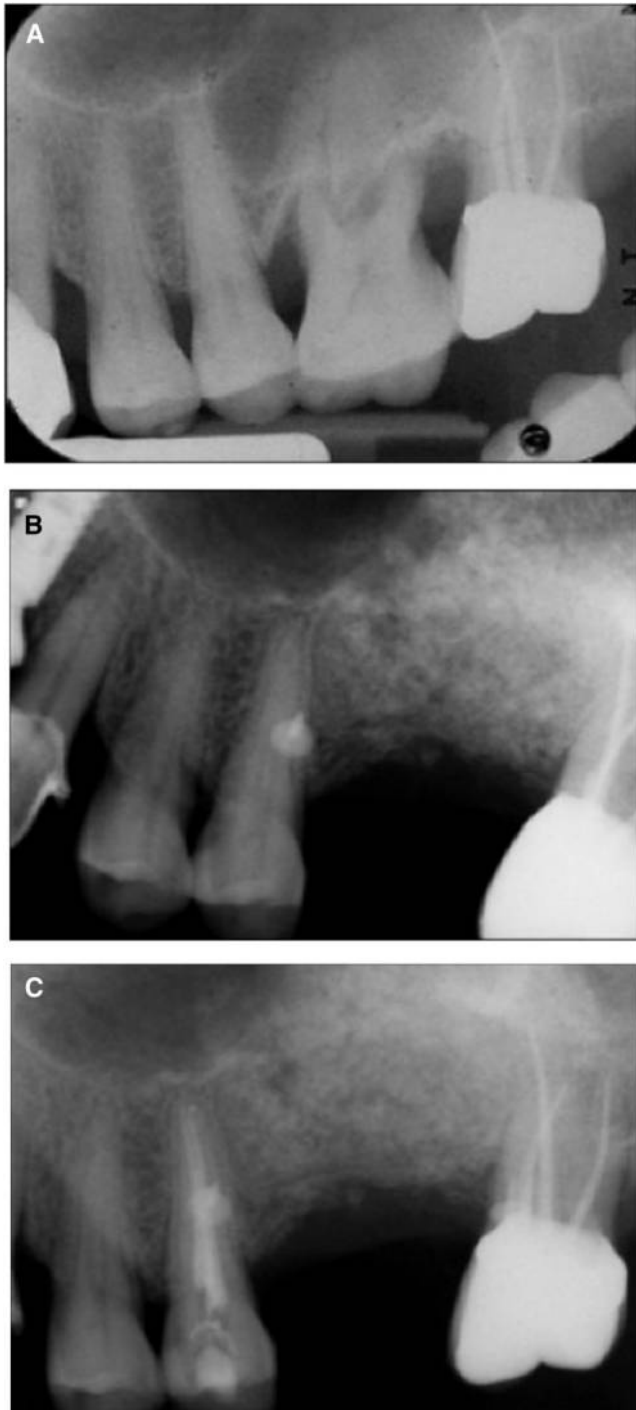


Figure 3.

Case report 3. **A)** Initial periapical radiograph of maxillary left posterior area. **B)** Periapical radiograph of maxillary left posterior region taken 3 months after sinus augmentation. No periapical pathology is evident in the second premolar area. **C)** Periapical radiograph after completion of endodontic treatment of the second premolar.

electrical stimulation. This phenomenon was usually transient, with results returning to normal after 3 to 8 months.¹⁶ It has been reported that regeneration of nerve fibers does not occur after surgical transection of tooth roots in experimental animals.¹⁷ A small dedicated cadre of investigators has debated whether pulpal vascularity is more important than neuronal continuity.¹⁸⁻²² In time, preservation of pulpal circulation generally has come to be considered necessary if normal pulpal anatomy is to be preserved after dento-alveolar surgery.

Human studies have used laser Doppler flowmetry postoperatively to assess tooth vitality after Le Fort I osteotomy of the maxillary central incisors²³ and also bilaterally from the first maxillary premolar to the central incisor.²⁴ These studies have clearly demonstrated that teeth without normal innervation can have an intact blood supply and remain vital.^{21,22} From an endodontic standpoint, common techniques to evaluate the pulp status of a tooth are the thermal pulp test, EPT, and cavity test. The only conclusion a clinician may draw when pulp responds abnormally to a thermal stimulation, either in an exaggerated manner or not at all, is that the pulp is not in good condition.²⁵ The clinical inspection of the pulp in the presented cases during endodontic therapy shows no signs of blood flow. Unfortunately, the status of the pulp tissue can only be quantitatively evaluated histologically; currently, there is no accurate correlation between the objective clinical signs and the pulpal histology.^{26,27} One study that compared the ability of thermal and electric pulp testing methods to register the presence of vital pulp tissue reported the following values for accuracy: 1) cold test: 86%; 2) EPT: 81%; and 3) heat test: 71%.²⁸

The EPT fails to provide any information about the vascular supply of the pulp—the true determinant of pulp vitality. Teeth that temporarily or permanently lose their sensory function (e.g., those damaged by trauma or subjected to orthognathic surgery) will be non-responsive to EPT. However, the vasculature may well still be intact,²⁹ with the vitality consequently preserved.^{21,22} In the wake of oral surgery procedures such as an anterior maxillary osteotomy, if an adequate soft-tissue pedicle is preserved, vessels in the mucosa and periodontium have been found to contribute to periapical vessels and maintain pulpal circulation.³⁰ However, after anterior maxillary osteotomy, some degree of degeneration was observed if the blood supply to the pulp was interrupted; repair of the pulp depends on revascularization.¹⁹

In the present case series, both the cold test and EPT were used as the diagnostic methods and were further corroborated with a cavity test. It has been shown in the literature that if a mature untraumatized

Table 1.**Endodontic Diagnosis of Teeth Adjacent to the Maxillary Sinus-Elevation Areas**

Tooth Examined	Endodontic Diagnosis	Time (in Months) When Endodontic Examination Was Performed, After Maxillary Sinus Elevation
Case report 1		
Maxillary left second premolar	Necrotic pulp	30
Maxillary left second molar	Previous endodontic treatment present	N/A
Case report 2		
Maxillary left first molar	Necrotic pulp	6
Maxillary left third molar	Normal Pulp	6
Case report 3		
Maxillary left second premolar	Necrotic pulp	3
Maxillary left second molar	Previous endodontic treatment present	N/A

N/A = not applicable.

tooth does not respond to both EPT and cold test, the pulp should be considered necrotic.^{25,31} However, a multirouted tooth, with at least one root containing vital pulp tissue, may respond to the cold test even if one or more of the roots contain necrotic pulp tissue.

In this case series, two of the three teeth that are diagnosed to have a necrotic pulp and are treated endodontically are asymptomatic, with no other clinical and radiographic findings. Only in case 1 was periapical radiolucency observed. The three affected teeth may still have had some blood circulation, but this could only be determined with the use of laser Doppler flowmetry.^{21,22} The cavity test is most useful in necrotic teeth in the absence of periradicular lesions and reproducible responses to other pulp tests.³² If a patient fails to feel any sensation during this test, when the bur reaches the dentin, it is a good indication that the pulp is necrotic and endodontic treatment is indicated.²⁵ In the cases presented, any evidence of occlusal trauma, bruxism, or other parafunctional habits was noted in the clinical examination, and additional comprehensive treatment was performed before the decision was made to perform a root canal treatment. The specialist endodontist (MJH) then made that decision. After completion of the dental history (including functional examination), the patients were evaluated with the three diagnostic tests to avoid future development of a periapical infection, which might have negatively affected implant survival.³³

An open question is: How does the dental pulp become septic? Apical periodontitis affects apical periodontal tissues and can be caused by both exogenous and endogenous factors. There is no doubt that in the root canal system, infection of the pulp tissue caused by caries or other pathways is the

primary cause of apical periodontitis.³⁴ In animal models it has been shown that when bacteria are absent from the periradicular area, teeth do not present periapical inflammation.^{35,36} Another question concerns how large the “safety zone” between the root apex and the sinus membrane must be to avoid damage to the blood supply and innervation of adjacent individual teeth. More studies are needed to evaluate this issue at the histologic and clinical level and explain these relationships. However, in the meantime, it may be prudent to perform a more careful and less extensive sinus elevation whenever the root apices of the adjacent teeth are in close proximity to the sinus membrane.

Finally, the subsequent necrosis of the teeth may have been related to other factors, such as occlusal trauma or inflammation that was present before the sinus-floor elevation but was not significant enough to impede vascular flow and/or nerve function at the time of the original pulp testing.^{37,38}

In this case series, the authors try to present the phenomenon of tooth devitalization adjacent to sinus-floor augmentation sites. A limitation of this paper is the limited number of cases presented and the lack of histologic evidence. The primary goal was to familiarize the clinicians with these findings and not to define any incidence rates and guidelines regarding the safety zone that should be taken into consideration when performing these procedures.

Without doubt, there is a need for randomized clinical trials to examine further this phenomenon to be able to provide statistical analyses. Other aspects should also be evaluated, such as the incidence of this complication in conjunction with osteotome or lateral window technique. Animal studies might also be necessary to confirm these findings and to

provide histologic evidence. This may be important for improving clinical outcomes and avoiding complications in sinus augmentations.

CONCLUSION

When the sinus membrane is elevated over the apices of roots that are in close proximity to the sinus floor, pulp necrosis may occur.

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