Management of Endodontic Disease for Odontogenic Sinusitis

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KEYWORDS

• Odontogenic sinusitis • Pulpal necrosis • Apical periodontitis • Root canal treatment
• Gutta percha • Extraction • Oroantral fistula

KEY POINTS

- Root canal treatment (RCT) and dental extraction are viable primary treatment options for odontogenic sinusitis (ODS) due to endodontic disease, both to address ODS symptoms and prevent future extrasinus infectious complications.
- While there is more published evidence on extraction success for ODS, extraction compromises dental function and potential quality of life, so RCT should be considered the primary dental treatment of choice (if available).
- RCT preserves the natural dentition, however, root canal anatomy is complex and requires specialized microsurgical techniques and instrumentation to optimize technical success; subsequent coronal restorations must then prevent leakage and recontamination of the root canal space.
- Both RCT and dental extraction alone can resolve ODS, particularly when limited to the maxillary sinus; disappearance of foul smell within 2 weeks of extraction significantly increases the likelihood of full recovery without requiring endoscopic sinus surgery.
- More studies are needed to understand patient and disease factors placing patients at risk for primary dental treatment failure when managing ODS.

INTRODUCTION

One of the most common causes of odontogenic sinusitis (ODS) is endodontic infection, stemming from pulp necrosis extending out root portals of exit into the surrounding support tissues to cause apical periodontitis (AP) and/or periapical abscess (PAA).

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This may then lead to maxillary sinus inflammation and possibly ODS. Endodontic disease can usually be managed by definitive endodontic treatment, most commonly nonsurgical root canal treatment (RCT) (Fig. 1A–C). Occasionally, follow-up apical surgical root canal treatment (SRCT) is required to address treatment objectives that cannot be achieved by RCT. This involves apical resection of root(s) with preparation and reverse-filling of the communicating portals of exit and connecting grooves associated with microleakage of pathogens and inflammatory mediators (Fig. 2A–G) Endodontic treatment can potentially resolve both the AP and ODS.[1] If endodontic disease is unrecognized in the setting of maxillary sinusitis, patients may undergo multiple unnecessary medical or sinus surgical interventions aimed at treating non-odontogenic rhinosinusitis until the dental source is addressed (Fig. 3A–E).[2] In such ODS cases, eliminating the infectious endodontic source is necessary for ultimate resolution of ODS and prevention of recurrence. However, more evidence exists on the success of dental extraction to treat ODS, where pulpal and periapical disease can be entirely eradicated with the removal of the tooth.

For ODS caused by endodontic pathosis, the primary treatment recommendation should be RCT if the tooth is restorable, and it has a favorable endodontic prognosis. RCT involves thoroughly cleaning and shaping the internal root space so that necrotic infected pulp tissue can be definitively removed, along with the sealing of significant root portals of exit. This predictably leads to resolution of AP, and often PAAs. If RCT and revision RCT fail to eliminate the AP/PAA, SRCT or dental extraction should be considered. It should also be noted that RCT may not be possible in patients with anomalous root anatomy, or in cases with teeth that are non-restorable or have poor periodontal support. Additionally, cost of endodontic treatment may be prohibitive for some patients, or patients may not have access to endodontic specialists, and extraction may be their only option. This article will highlight technical aspects of RCT and extraction, and their successes in managing the endodontic disease and ODS. Multidisciplinary care between otolaryngologists and dental specialists will also be highlighted through case scenarios, showing the dynamic interplay between dental treatment and endoscopic sinus surgery (ESS).

ROOT CANAL TREATMENT PRINCIPLES

The primary goal of endodontic therapy is to restore and maintain the health of the root attachment apparatus (cementum, periodontal ligament, dense cortical lining bone).

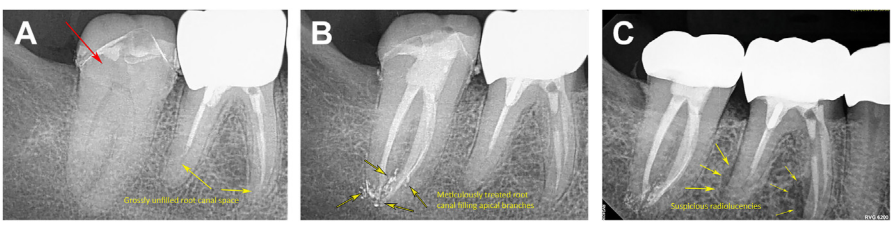

Fig. 1. (*A*) Preoperative radiograph before root canal treatment (RCT) of a mandibular second molar (*red arrow*). Also note the inadequately treated first molar with unfilled root canal space. (*B*) Immediate post-treatment radiograph showing complete filling of the root canal space without voids and treatment of all exiting branches at the root apex. (*C*) A 3.5-year post-treatment radiograph showing unremarkable healing of the treated second M and periradicular radiolucencies consistent with recurrent endodontic disease associated with the first molar.

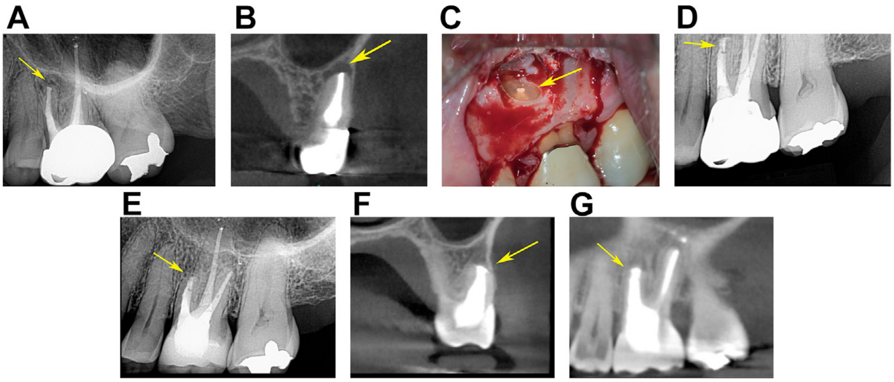

Fig. 2. Surgical endodontic treatment (apical surgery, apicoectomy) eliminates a blocked, inaccessible, infected periapical space at the root terminus. (*A*) Preoperative periapical radiograph showing a maxillary first molar with a periapical radiolucency on the mesiobuccal (MB) root (*yellow arrow*). (*B*) Pretreatment cone beam computed tomography (CBCT) frontal capture image showing a definitive periapical radiolucency over the MB root (reversed from image in *A*). (*C*) Intraoral photo showing the surgical access, clearance of periapical disease, and apical root resection (*yellow arrow*). The root canal terminus was later microsurgically prepared and filled with a bioceramic putty. (*D*) Immediate post-treatment periapical radiograph showing the apically resected and reverse-filled root end (*yellow arrow*). (*E*) A 3-year post-treatment radiograph showing osseous regeneration and healing of the periapex (*yellow arrow*). (*F*) A 3-year CBCT coronal image showing osseous regeneration of the resected and reverse-filled MB root apex. (*G*) A 3-year CBCT sagittal image showing osseous regeneration over the resected and reverse-filled MB root apex.

Schilder introduced a technique designed to address complex root anatomy by cleaning, shaping, and filling root canals in 3 dimensions.[3] One must ensure sealing of all apical and lateral root portals of exit as well. He described 5 mechanical objectives of cleaning and shaping as follows:[4] (**Fig. 4**).

1. The root canal preparation should develop a continuously tapering cone from the root apex to the coronal access (occlusal surface of tooth).
2. The cross-sectional diameter should be narrower at every point apically and wider at every point as the coronal access is reached.
3. The root canal preparation should flow with the shape of the original canal.
4. The apical foramen should be maintained in its original spatial location and not transported (ie, its original shape and location must not change).
5. The apical diameter should be prepared as small as is practical, but large enough to prevent blockage and accumulation of apical debris.

It should be noted that RCT has historically improved, and should be performed as a microsurgical procedure, requiring an advanced specialty skillset (**Fig. 5**).[5] Unfortunately, the majority of RCTs are performed by non-specialists without a microscope, and this can lead to significantly higher failure rates. Of note, microscope use during RCT training is now required in accredited endodontic specialty programs.

Cracks, caries, and other defects should also be microscopically explored. Internal posts and crowns should be dismantled when necessary. If a root curve is blocked or a false preparation path is created, the root apical terminus may become inaccessible for proper debridement and filling, necessitating either apical or extraction.

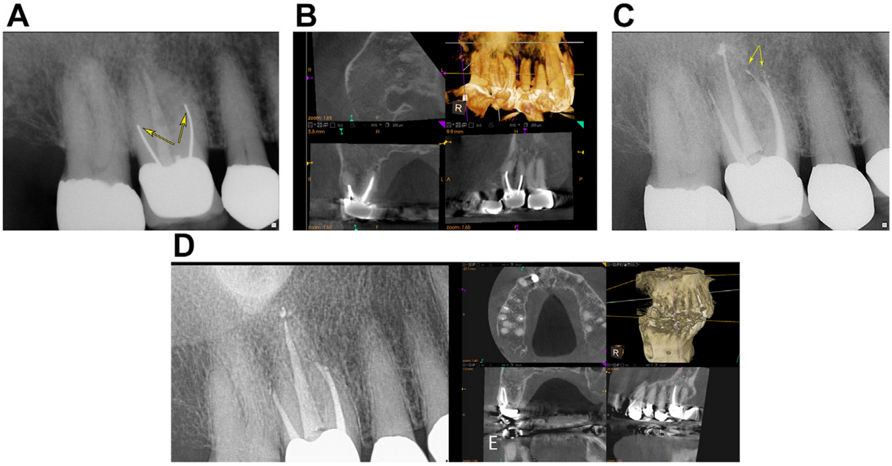

Fig. 3. Example of a patient with odontogenic sinusitis (ODS) due to a molar with apical periodontitis after prior RCT. This patient had right-sided sinusitis symptoms and underwent multiple sinus surgeries over years, and had not been referred to an endodontist to evaluate the prior RCT. (*A*) Preoperative radiograph showing an incomplete RCT with silver points partially filling the buccal canals (*yellow arrows*), and this was a likely source of recurrent or ongoing endodontic disease. (*B*) Preoperative CBCT showed right maxillary sinus opacification consistent with ODS (confirmed purulence endoscopically). (*C*) Periapical radiograph immediately following RCT, showing complete filling of the root canal spaces. The two *yellow arrows* show a filled apical bifurcating root canal terminus that was previously not sealed with a single "floating" silver point. (*D*) Periapical radiograph 6 years post-treatment showing a stable complete RCT, and patient was asymptomatic. (*E*) Six-year follow-up CBCT showing successful RCT and complete osseous integrity of the periapical region, but persistent maxillary sinus opacification. The patient was referred back to the otolaryngologist for sinusitis management.

Root Canal Cleaning and Shaping

RCT may begin with administration of a local anesthetic, but may be unnecessary for necrotic teeth. Rubber dam isolation of the tooth is critical to ensure an aseptic field and prevent saliva and oral bacteria from entering the working field, as well as to protect the patient from aspirating endodontic instruments and materials. Strategic understanding of root canal system anatomy allows preparation through the occlusal surface of the crown (ie, endodontic access). Precise uncovering of the pulp chamber ceiling and development of a “convenience form” allows identification and easy entry of endodontic files into root canal orifices and preparation of grooves harboring debris and a septic substrate (see Fig. 4A–C). Care is taken to avoid over-enlarging and compromising structural dentin necessary for long-term tooth strength. Use of the dental operating microscope is critical during endodontic access preparation to avoid iatrogenic damage, while strategically extending the internal walls of the access to uncover potential canal orifices and isthmuses (communications) often found between primary canal systems.

After the floor of the pulp chamber is accessed and root canal orifices are identified, the root canal spaces must be debrided and disinfected, which is a critical determinant of RCT success. Copious irrigant flushing is important during the cleaning and shaping of the root canal system.[6] Sodium hypochlorite is the primary irrigant used to disinfect and digest pulpal soft tissue. Ethylenediaminetetraacetic acid, a chelating agent, is often used to remove calcific debris in the pulp spaces. Several commercially available products activate with negative pressure irrigation, ultrasonic, and laser energy. Of

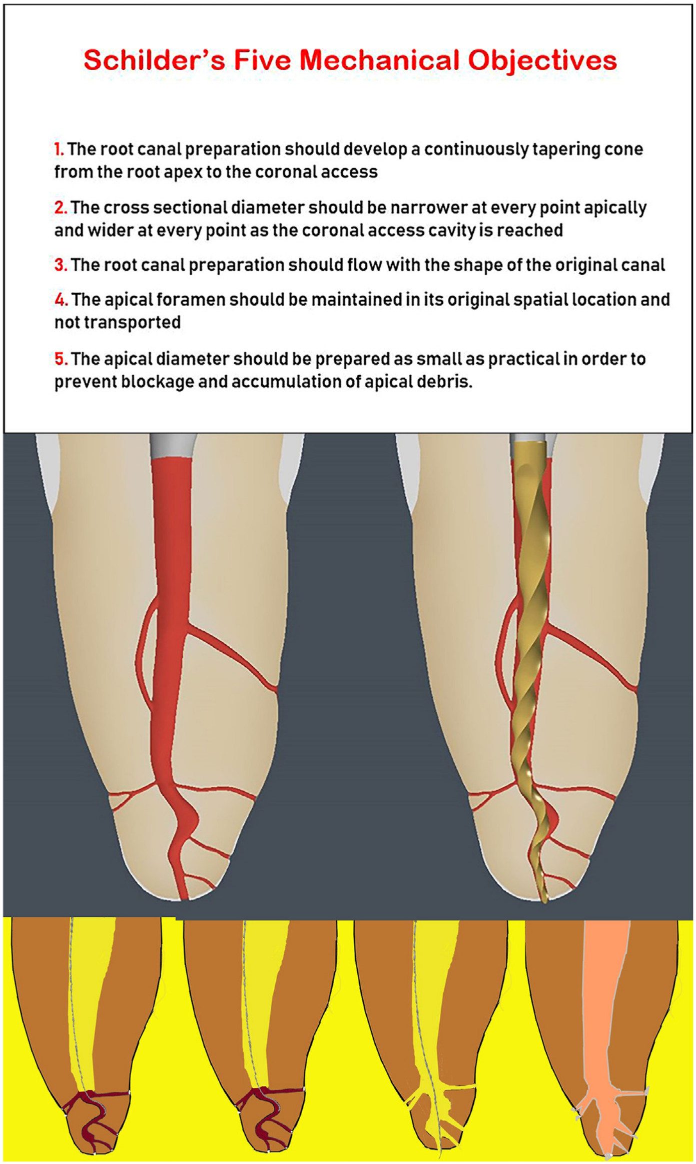

Fig. 4. Schilder's 5 mechanical objectives of cleaning and shaping. Engine-driven rotary files are used to efficiently clean and shape the simpler coronal two-third of a root. Hand files are required to clean and shape the more complex apical terminus of the root.

note, the disinfecting solutions being flushed into the complex root spaces require sufficient time to activate and penetrate deeply into the roots. Regardless of technology used, RCT must be performed meticulously with patience.

Filling the root canal system

Once the root canals have been cleaned and shaped optimally, they must be filled with a substance that seals all ports of exit (apical and lateral root surfaces). Gutta percha with

Fig. 5. Example of microscope-assisted RCT, which should be considered standard-of-care in the modern era.

microfilm of sealer arguably remains the "gold standard" endodontic filling material. It has clinical advantages for placement in prepared root canal systems as it can be softened, deformed, and hydraulically compressed (Fig. 6). Calcium silicate-based root filling materials are also commonly used due to some advantageous bioactive properties. These bioactive materials induce bone formation, reattachment of tissues to the roots, and establish a high pH gradient which decreases inflammation. Bioceramics

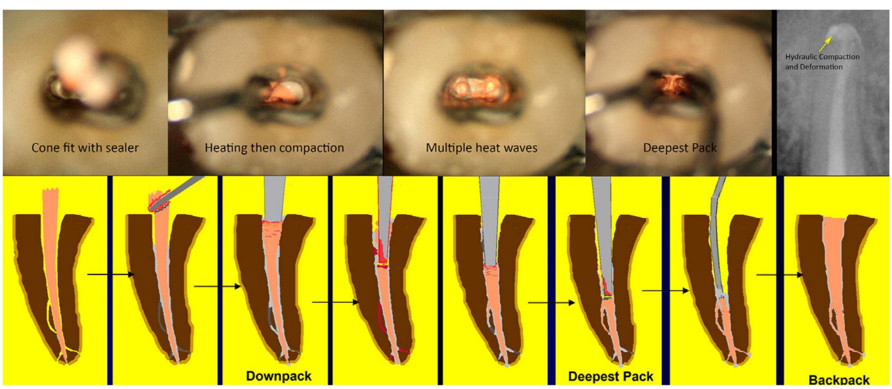

Fig. 6. Ideal apical filling created by heating and subsequent compaction of gutta percha cones coated with zinc oxide/eugenol sealer. At least 5 waves of heating and compaction are performed to push and deform gutta percha into the apical terminus.

are used for repairing root perforations, filling irregularly large ports of exit caused by root resorption, and are frequently used during surgical or nonsurgical treatments (**Fig. 7**A–D). One disadvantage with bioceramics is that they cannot be dissolved with a solvent should retreatment be necessary.

RCT routinely results in some filling material (usually sealer) exiting the root portals of exit (overfilling). It is generally of no clinical concern as long as all portals of exit are sealed.[3,7] While this may cause focal maxillary sinus mucositis (mucosal thickening on CT scan),[8] it would not usually cause bacterial ODS. However, if gutta percha is injected through sinus mucosa into the lumen, it could lead to either bacterial ODS, or may act as a nidus for non-invasive fungal ball formation.[9]

Root canals with minute branching ramifications are filled by the hydraulic flow of low-viscosity sealer used to coat the gutta percha cone during heating and compaction. Root canals may exhibit complex apical branching ramifications, and are filled by this hydraulic flow (**Fig. 8**A, B). The gutta percha cone is generally confined to prepared portion of the root canal system to which it is fit, and is deformed into the apical terminus with alternate heating and compaction with a plugger/condenser. Failure to heat and hydraulically compress the gutta percha into the apical root leaves space(s) that can harbor septic debris (**Fig. 9**A–D). The quality of root filling and sealing of ports of exit are important, but the preparation and debridement/disinfection of the root canal spaces prior to filling is the critical, technique-sensitive determinant for preventing

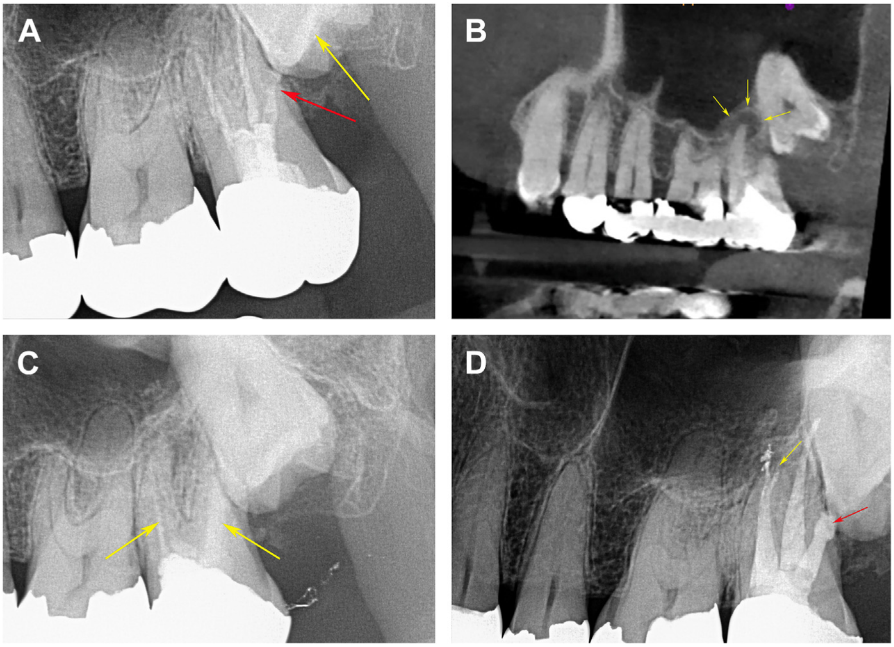

Fig. 7. Failing previous RCT on a maxillary second molar with a periapical abscess and external root resorption. (*A*) Preoperative periapical radiograph showing external resorption of the distobuccal root (*red arrow*) due to an impacted third molar (*yellow arrow*) (*B*) CBCT showing the periapical radiolucency at the mesiobuccal root apex (*yellow arrows*). (*C*) Periapical radiograph after the first visit showing removal of the previous root filling and placement of intracanal calcium hydroxide (*yellow arrows*). (*D*) Immediate post-RCT radiograph showing a filled, previously missed MB2 canal system (*yellow arrow*) and the resorbed distobuccal root filled with a bioceramic filling (*red arrow*).

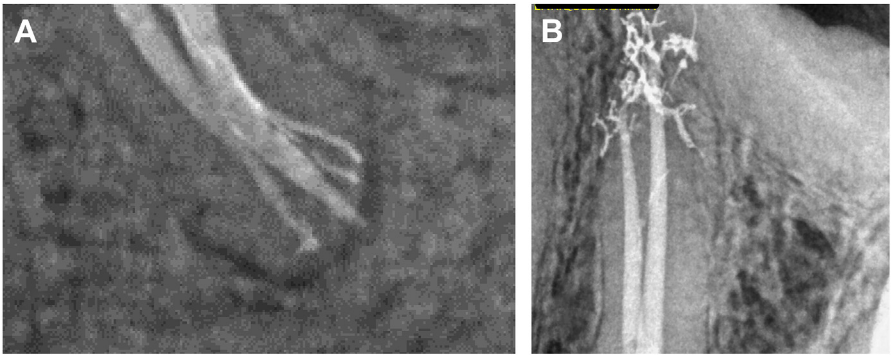

Fig. 8. Root canal anatomy tends to become more complex toward the apex with branching and curvatures. (*A*) Filled apical delta branching network. (*B*) Two-roots of a maxillary bicuspid showing primary, secondary, and tertiary apical root canal branching (branches off of branches).

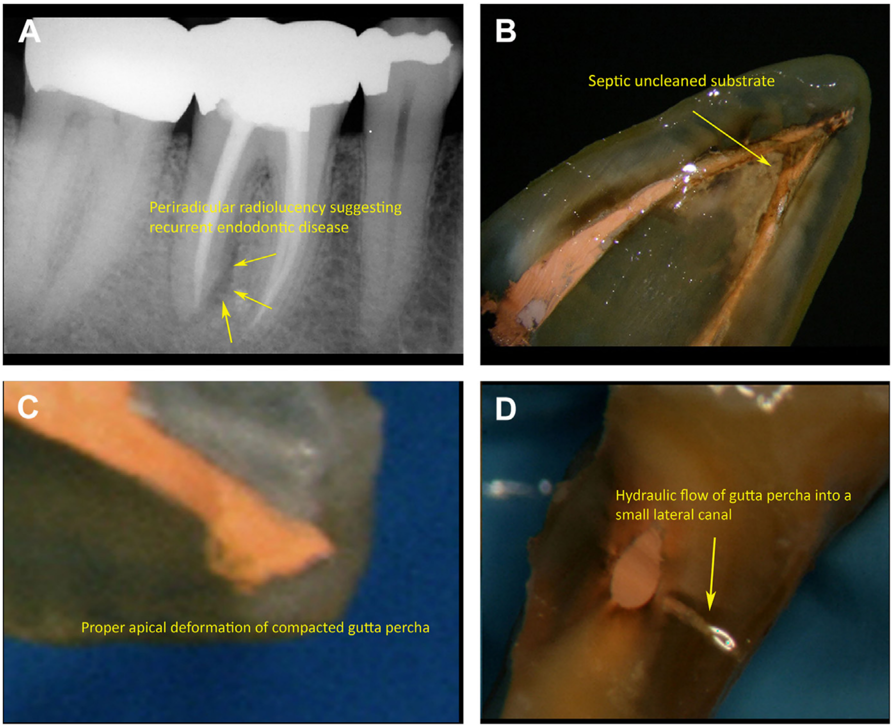

Fig. 9. (*A*) Periapical radiograph suggesting an adequately treated first molar with failed RCT. (*B*) The mesial root apex of the extracted root canal–treated tooth showing poorly condensed gutta percha cones mixed with septic debris at the apex. (*C*) For reference, this is a different extracted root canal–treated tooth with properly condensed gutta percha and apical splaying. (*D*) The extracted tooth in (*C*) showing a hydraulic flow of filling material into the lateral canal with no voids.

reinfection. The final RCT objective is to disinfect and completely fill the entire root space sealing all root portals of exit from each root apex to the pulp chamber. A well-sealing restoration is placed from the pulp chamber floor to the tooth's occlusal surface (access restoration) after root filling.

RESTORATIVE CONSIDERATIONS

The access restoration should be placed immediately under aseptic conditions with rubber dam isolation. There are several core options depending upon required retention, strength, and sealing of the post-treatment restoration. Resin-bonded composites are the most commonly placed access restorations. An endodontist may commonly place a temporary access restoration with patients referred back to their general dentist for final restoration (including crown placement). A delay in access restoration is not ideal especially if a rubber dam is not used. It is critical that the pulp chamber be completely sealed because an unsealed pulp chamber and an ill-fitting crown have been shown to increase the risk of recurrent endodontic disease due to migration of bacterial and inflammatory mediators through restorative gaps in the crown or filling and through ports of exit or the surrounding periodontium, and into the into the root canal system.[10] If a previous crown is accessed to perform an RCT, and the crown is loosened, this can also lead to recurrent caries, bacterial migration, and subsequent root canal reinfection.

Fracture resistance is an important consideration after endodontic treatment. Molars that have undergone RCT should generally have restorations that cover the cusps which prevents unfavorable wedging forces during chewing that can split or crack the root(s). Teeth with single roots and narrow cervical diameters benefit from placing a resin-bonded carbon fiber post in the coronal portion of the canal which disperses chewing forces longitudinally, providing horizontal fracture resistance.[11]

ROOT CANAL TREATMENT SUCCESS FOR APICAL PERIODONTITIS (± PERIAPICAL ABSCESS) AND REASONS FOR FAILURE

The literature may roughly imply 80% success of RCT cases for AP/PAA,[12–14] but this is misleading and failure is multifactorial being impossible to attribute to RCT per se. A variety of RCT success rates have been published, ranging from 30% to 87%.[15] This broad range is unfortunately due to varying stringent to lenient success criteria, imaging methods, and other variables that influence outcomes, including materials, techniques, and operator skill. This has been presumed to imply that technical nuances are extremely important to appreciate, hence the recommendation that specialists perform RCTs microscopically to optimize technical success.[5,16] The aforementioned study limitations combined with extraordinary variations in root canal anatomy and technical sensitivity have prevented endodontic outcome studies from having prognostic value. Most published outcome studies have also failed to follow endodontic treatments after 10 years. Future studies require more rigorous study designs controlling for techniques from the RCT to the coronal restoration, and long-term recall will be prudent. Until then, providers should collect their own data on success.

Successful RCT requires control of numerous factors that affect structural integrity, which include a lasting coronal seal, caries prevention, periodontal health, and esthetics. Rarely does a patient present for treatment with a tooth in pristine condition. A tooth with endodontic disease often presents with a history of restorations, cracks, root fractures, previous failed RCTs, or other complexities. Specific to a patient presenting with a prior RCT, one must recognize radiographic determinants of inadequate RCTs before considering SRCT or dental extraction, since revision RCT could be curative (**Fig. 10**).

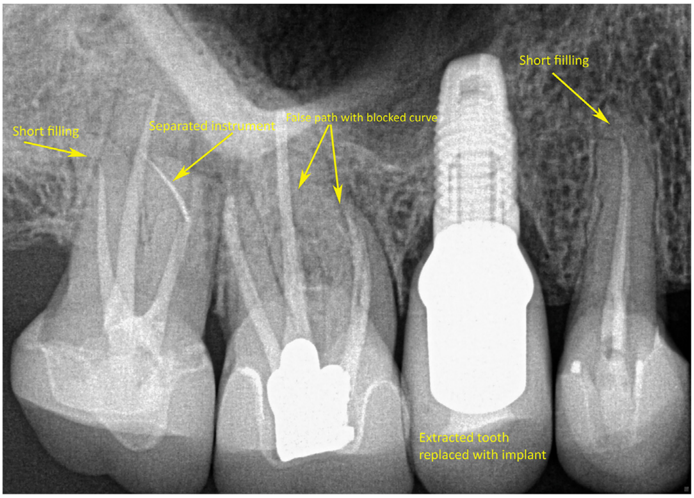

Fig. 10. Multiple teeth with various RCT procedural errors: separated instrument filled short, false paths. A tooth rendered untreatable with too many complexities is often extracted and replaced with an implant, though in some cases this could be corrected with appropriate RCT techniques.

Endodontic specialists using a microscope tend to spend much of their practice time retreating endodontic procedures performed by non-specialists without a microscope.[5] Since patients may or may not be symptomatic after a failed RCT, imaging is critical in these situations. A periapical radiograph or cone-beam computed tomography (CBCT) may show a root canal filling ending short of the root terminus, often with voids and poor condensation. When these findings are associated with a periapical or lateral radiolucency, endodontic retreatment may be necessary (Fig. 11A–F). Another very common and important reason for RCT failure is an untreated or missed root canal. If a canal is untreated, the space remains infected, and pathogens eventually

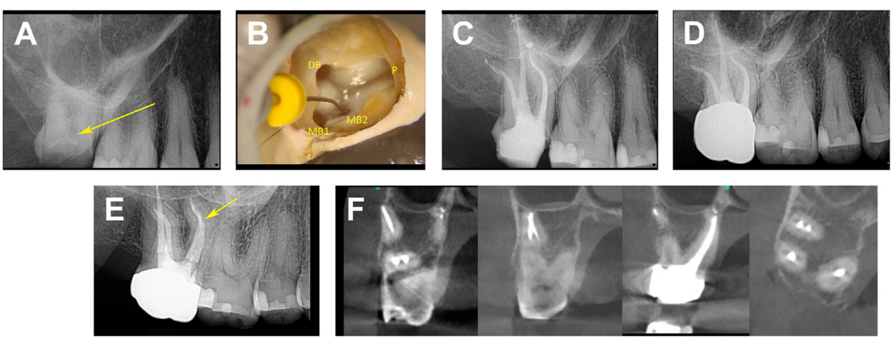

Fig. 11. (*A*) Preoperative radiograph of a maxillary second molar (*arrow*) needing RCT. (*B*) Clinical microphotograph showing the identification and treatment of MB1 and MB2 (with file) canals (*C*) Immediate post-RCT radiograph showing 3-dimensional filling of complex branching root canal anatomy. (*D*) A 6-year post-treatment periapical radiograph showing stable completed RCT with a crown restoration. (*E*) A 6-year post-treatment off-angle radiograph showing the 2 MB canals merging at the apex (*arrow*). (*F*) Coronal and axial CBCT cuts showing complete root canal filling and normal periapical and periodontal osseous integrity.

migrate out root portals of exit to infect the periodontium. Maxillary molars have a high frequency of 2 canals existing in the mesiobuccal root, with the second smaller canal being termed the MB2 canal. The MB2 is the most frequently missed canal during maxillary molar RCT,[17] and this could lead to failed resolution of both AP/PAA and ODS (**Fig. 12**A–F). The utility of CBCT scans cannot be overstated, as they facilitate identification of missed canals and small periapical radiolucencies that would otherwise be hidden on traditional radiographs. CBCT findings help explain the reasons for RCT failure and can guide appropriate successful retreatment or clearly indicate a need for extraction.

Endodontic Treatment Success for Odontogenic Sinusitis

In the setting of ODS, dental pulp is generally completely or at least partially necrotic, and will frequently have associated PAAs. These teeth are usually asymptomatic, and do not require emergent RCT. Notably, maxillary molars are the most common source of endodontic ODS, and these molars are particularly challenging to treat due to complex root anatomy,[18–20] with recommendations being that endodontists manage them rather than general dentists.[16] One important concept to appreciate with RCT for ODS is that one must assess for success at resolving the AP/PAA separate from the sinusitis. Based on the literature, if one speculates RCT to be roughly 80% successful for AP/PAA, and dental extraction to be 60% successful for resolving ODS, the combined probability of success for RCT alone would be predicted to be 48%.[21] While this probability is speculative and problematic due to low quality of RCT literature, it is reasonable to presume it would offer lower ODS resolution rates than extraction.

To date, very few studies have assessed the success of primary or revision RCT in resolving purulent ODS, with most studies reporting results of RCT for AP and adjacent

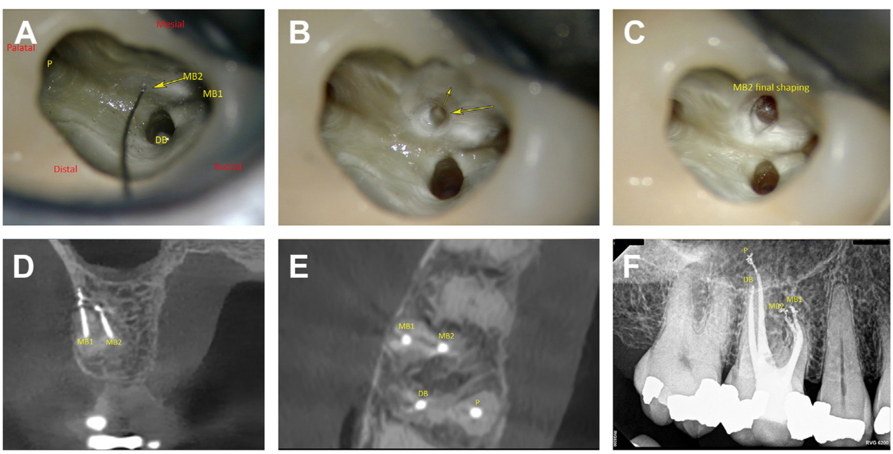

Fig. 12. Discovery and treatment of a second mesiobuccal (MB2) canal system in the right maxillary first molar (*A*) Initial MB2 canal orifice discovery with a 60-micron diameter endodontic file after cleaning and shaping of the larger first mesiobuccal (MB1), distobuccal (DB), and palatal (P) root canal systems. (*B*) Mesial extension (*arrows*) of the access cavity preparation to allow deeper file entry into the MB2 canal. (*C*) Final extension and completed cleaning and shaping of the MB2 canal. (*D*) Coronal CBCT showing the MB1 and MB2 roots with separate apical portals of exit. (*E*) Axial CBCT through the tooth's mid-portion, showing the 4 filled canals at that level. (*F*) Post-treatment periapical radiograph showing completed treatment with a 3-dimensionally filled root canal system.

maxillary sinus mucositis, without true purulent sinusitis. For example, Siqueira and colleagues reported that RCT resolved maxillary sinus inflammation or infection in 14 patients with endodontic disease.[22] However, only 2/14 patients had complete maxillary sinus opacification on CT, and none had nasal endoscopy to assess for middle meatal purulence. Therefore, the majority likely did not have purulent ODS. Another case series reported success of RCT for ODS in 2 patients, but these patients also had mucositis, and not purulent sinusitis.[23] The only sizable study to date on RCT for purulent ODS came from Kwiatkoska and colleagues who showed only a 13% success rate at resolving ODS with RCT alone. Of note, they also included some patients with mucositis alone. Additionally, there was heterogeneity in their sample due to the retrospective study design, where some patients had had RCTs months to years prior to evaluation as opposed to some who had it performed immediately after otolaryngologic evaluation. These patient populations could have differed. Additionally, their strict study criteria requiring full AP and sinusitis resolution by 12 months may have yielded the low success rate, as some periapical radiolucencies remain for years on imaging without being infectious or symptomatic.[24] RCT alone can definitely resolve some cases of purulent ODS, but larger well-designed prospective studies are needed to determine prognostic variables for RCT treatment success in ODS. Specifically, dental providers studying RCT success for ODS should report the frequency of PAAs in the setting of PALs on imaging, and they must distinguish mucositis from purulent ODS. Such studies would most optimally be conducted through collaboration with otolaryngologists.

Also interesting, no study has explored whether oral antibiotics following RCT for ODS could improve rates of sinusitis resolution. While current recommendations based on the endodontic literature is to not prescribe antibiotics after RCT for pulpal and periapical disease, the purulent sinusitis of ODS could potentially respond to antibiotics once the infectious dental source is eliminated. Future studies should explore whether antibiotics improve ODS treatment success after endodontic treatment alone.

COLLABORATIVE CASE SCENARIOS FOR ODONTOGENIC SINUSITIS DUE TO ENDODONTIC DISEASE

The following cases highlight important scenarios that can arise when managing ODS due to endodontic disease with RCT. Each scenario involves answering the following questions, which often requires multidisciplinary communication.

1. Did the patient have purulent ODS prior to the RCT?
2. Was the RCT technically successful?
3. Did the RCT resolve the endodontic disease?
4. Did the RCT resolve the ODS?

Case 1 (Failed Root Canal Treatment with Progression of Maxillary Sinus Mucositis to Odontogenic Sinusitis)

This 54-year-old male had undergone RCT of the first maxillary molar to treat pulpal necrosis and AP 10 years prior. Note that at that time his CT scan showed only left-sided maxillary sinus floor mucosal thickening (reactive mucositis), and he had no sinusitis symptoms (**Fig. 13**A–D). Over time, he developed worsening left-sided sinusitis symptoms, no dental symptoms, and CT showed complete maxillary sinus opacification, and nasal endoscopy revealed middle meatal purulence, confirming purulent ODS (see **Fig. 12**C, D). Due to his symptom burden, he elected to have ESS next, and wanted

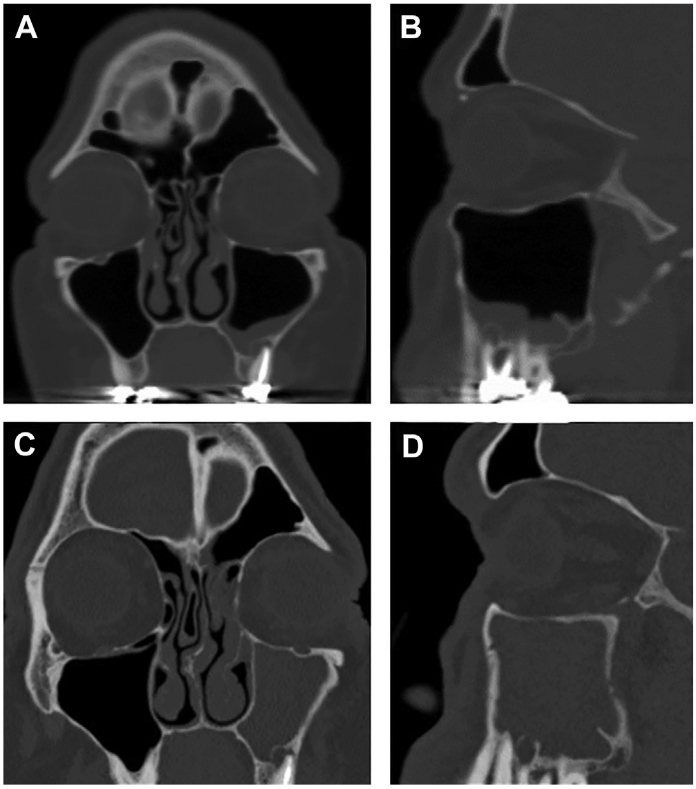

Fig. 13. Example of a patient with left-sided ODS that developed over years following a prior RCT of the first maxillary molar. (*A, B*) Computed tomography (CT) scans showing left maxillary sinus mucosal thickening (reactive mucositis) after an RCT of the first maxillary molar which had apical periodontitis with a periapical radiolucency and bone erosion. (*C, D*) Ten years later, the patient had been developing left-sided sinusitis symptoms and CT showed complete maxillary sinus opacification with the persistent periapical radiolucency with bone erosion which gradually caused a purulent ODS over time. The patient underwent endoscopic sinus surgery (ESS) for symptomatic control, and eventually he decided to have the tooth extracted as well.

to wait on his dental condition. Eventually, he decided to have a dental extraction because he had persistent maxillary sinus inflammation, and while no infectious symptoms, he was advised that his persistent dental and sinus disease could cause complications in the future.

Case 2 (Successful Root Canal Treatment for Apical Periodontitis and Odontogenic Sinusitis)

This 62-year-old male presented asymptomatically after an incidental finding of left maxillary sinus complete opacification on CT, which was found to be due to second M with a large periapical radiolucency and bone erosion (Fig. 14A, B). ODS was confirmed endoscopically by purulence draining from the middle meatus. Given his absence of sinusitis symptoms, he elected to undergo primary RCT which completely resolved the ODS (Fig. 14C, D). Note that while the periapical radiolucency was still present 6 months after RCT, this is common, and does not connote RCT failure. The

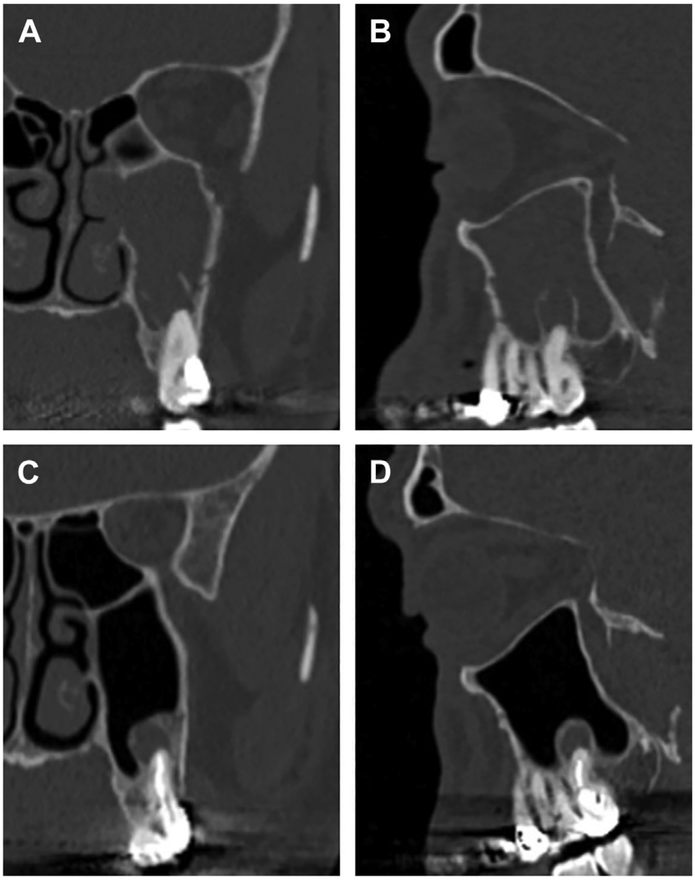

Fig. 14. Example of a patient with purulent left-sided maxillary ODS that resolved with RCT alone. (*A, B*) Coronal and sagittal CT scans showing left maxillary sinus complete opacification and a second maxillary molar with apical periodontitis and a large periapical abscess with bone erosion. (*C, D*) Six-month post-treatment CT scans showing complete resolution of the maxillary sinus disease, and successful RCT with significant regression in size of the periapical radiolucency.

radiolucency had already decreased substantially in size, but can take months to years to completely resolve. This would be followed by the endodontist with serial imaging to ensure no disease recurrence.

Case 3 (Successful Root Canal Treatment for Apical Periodontitis, but Not the Odontogenic Sinusitis)

This 56-year-old female presented with minimal left-sided sinusitis symptoms, no dental pain, but both CT and nasal endoscopy findings being consistent with ODS due to AP of the first maxillary molar. She elected to undergo primary RCT of the molar to treat the ODS. Despite the RCT being technically successful at resolving the endodontic disease, it did not resolve the purulent sinusitis, and the sinusitis actually worsened over time symptomatically and with spread to the ethmoid and frontal sinuses (Fig. 15A–C). She then underwent successful ESS. However, her tooth was preserved without needing extraction.

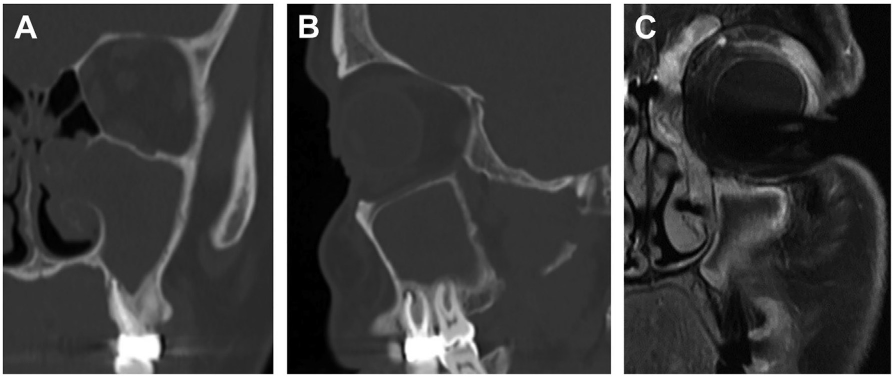

Fig. 15. Example of persistent left-sided ODS affecting maxillary, ethmoid, and frontal sinuses despite successful RCT. (*A*) Coronal CT showing complete maxillary sinus opacification, and an adjacent molar that had a successful RCT to attempt treating the ODS (pre-RCT CT not shown). (*B*) Sagittal CT showing a complete RCT and the prior periapical radiolucency regressed to almost nothing. (*C*) Post-treatment MRI (obtained for non-sinusitis reasons), showing persistent inflammation and infectious secretions in the maxillary, ethmoid, and frontal sinuses. The patient underwent successful ESS to resolve this.

Case 4 (Root Canal Treatment Unsuccessful for Apical Periodontitis and Odontogenic Sinusitis)

This 39-year-old female developed moderate right-sided sinusitis symptoms over 4 months, and no dental symptoms. Nasal endoscopy confirmed purulence in the middle meatus, so was diagnosed with ODS due to AP (likely PAA) of a maxillary molar. She did not want ESS, so underwent RCT. On follow-up, she still had sinusitis symptoms and purulence in the middle meatus, and CT still showed maxillary sinus opacification and adjacent molar with RCT and PAL over the palatal root with bone erosion (Fig. 16A, B). Additionally, the RCT was deemed unsuccessful, but there was concern that a revision RCT would be challenging with high likelihood of failure. She opted next for ESS, which successfully resolved her sinusitis symptoms, then eventually had the tooth extracted because it began causing focal pain. She has had no sinusitis recurrence to date.

UTILITY OF DENTAL EXTRACTION FOR ODONTOGENIC SINUSITIS

To date, only a few studies have analyzed the influence of dental extraction alone on resolving ODS due to AP/PAA. Yoshida and colleagues (n = 31) and Tsuzuki and colleagues (n = 32) retrospectively assessed outcomes after dental extraction alone for ODS, and reported ODS resolution in 62.5% and 52% of cases, respectively.[25,26] Mattos and colleagues and Tomamatsu and colleagues also studied primary dental treatment for ODS, but had heterogeneous populations of extractions, RCTs, and oroantral fistula (OAF) closures. When pooled together, their success rates for primary dental treatment were 51% to 52%, respectively.[27,28] Yoo and colleagues prospectively followed 33 ODS patients who underwent mostly dental extraction alone (27 extractions, 4 RCTs) plus 3 to 4 weeks of oral antibiotics, and demonstrated 67% success at resolving the ODS. They also showed preoperative smoking and higher Lund–Mackay scores to be negative predictors of dental treatment success.[29] Of note, in each of the aforementioned studies, extramaxillary spread into ethmoid and frontal sinuses increased the likelihood of dental treatment failure.[25–27,29]

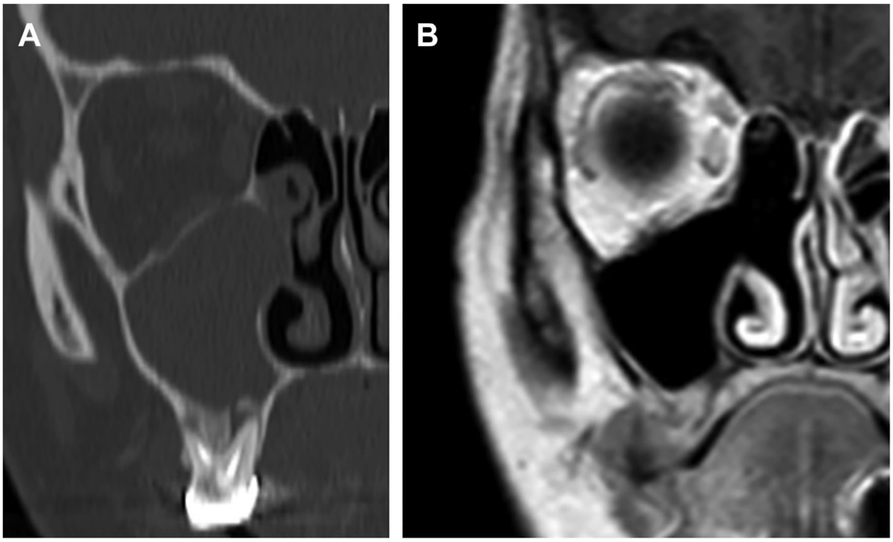

Fig. 16. Example of persistent right-sided ODS affecting maxillary and ethmoid sinuses following an RCT that failed to resolve both the apical periodontitis of a maxillary molar and the ODS. (*A*) Coronal CT showing complete maxillary sinus opacification after prior RCT, and the molar still demonstrated a periapical radiolucency with bone erosion (though no dental symptoms). The patient was miserable from sinusitis symptoms, so underwent ESS next, followed by molar extraction because the RCT was deemed not revisable. (*B*) MRI (obtained for non-sinusitis reasons) showing a widely patent maxillary antrostomy and anterior ethmoidectomy, and absent molar.

The largest prospective study on this topic was conducted by Simuntis and colleagues, in which 96 patients underwent dental extraction alone for ODS due to AP.[30] Of these patients, 77.1% completely resolved without ESS, with 22-item sinonasal outcome test (SNOT-22) scores decreasing from 48.0 $\pm$ 18.5 before extraction to 3.3 $\pm$ 4.1 6 months after extraction. (**Fig. 17**A, B) shows a representative case of an ODS patient who resolved after dental extraction alone. On the contrary, 22.9% of patients experience a minimal decrease in SNOT-22 following extraction. If patients failed to resolve symptomatically after 6 months, they were offered ESS. The minimal clinically important difference (MCID) in SNOT-22 was calculated to be a 36.6% reduction by 2 weeks following extraction. Additionally, they showed that if malodor disappeared in the first 2 weeks post-extraction, the odds for full recovery without needing ESS were 38.5 times higher, whereas if malodor failed to resolve in that timeframe, patients were significantly more likely to require ESS.[30] However, importantly, all patients in this study had varying degrees of mucosal thickening on CT (not opacification), without reporting of preoperative nasal endoscopies, so some cases may not have been purulent ODS. Additionally, patients with extramaxillary extension were excluded, so the disease burdens were also lower than other dental extraction-related studies for ODS. Larger studies of patients with only purulent ODS will be needed to determine the success of dental extraction alone, but until then, the mean published success rate for ODS has been about 60%.

One important limitation in studies on primary dental extraction for ODS is that they have not reported time to resolution of sinusitis symptoms. Craig and colleagues showed in a prospective study that of 11 patients who had primary dental treatment,

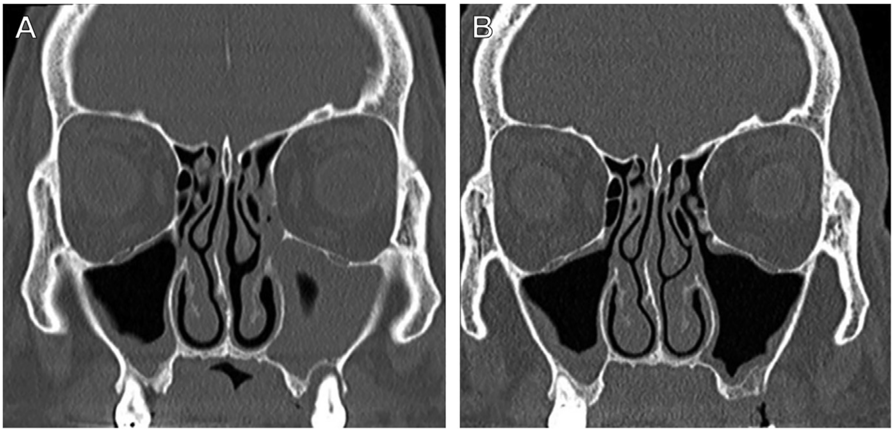

Fig. 17. Left-sided ODS caused by apical and marginal periodontitis (endo-perio lesion) of the left second maxillary molar. The patient presented with malodor, left cheek pressure, and postnasal discharge. (*A*) CT showed subtotal maxillary sinus and osteomeatal complex opacification and an adjacent molar with a periapical radiolucency. Molar extraction resulted in the disappearance of all clinical symptoms within 2 weeks. (*B*) CT after 6 months showed only minor mucosal thickening on the sinus floor.

4 improved during the study period, with their symptoms taking 35 to 56 days to resolve. In the 27 primary ESS patients, all patients' symptoms improved within 7 to 12 days.[31] The sample sizes of both treatment groups were small, but provided evidence that symptomatic burden should be considered when educating patients on primary dental treatment versus ESS. When patients have a high sinusitis symptom burden, some may wish to undergo primary ESS followed by dental treatment.

One final point to note is that there are potential long-term side effects from extraction when compared to tooth-preserving endodontic procedures. First, extraction leads to alveolar bone atrophy at the extraction site over time with the remaining teeth shifting into the gap, leading to malocclusion and a collapsed bite. Also, increased occlusal forces on remaining teeth can lead additional loss of teeth from cracks or root fractures. In addition, missing teeth affect facial esthetics and make chewing healthy, fibrous foods difficult affecting quality of life. Furthermore, replacement costs with a dental implant and associated bone grafting or sinus elevation procedures in this region can exceed those of endodontic treatment. Interestingly, a recent study showed that for ODS, primary RCT led to similar overall expected costs as that of primary dental extraction plus various reconstructive options, and ESS when indicated. This was based on probabilities of needing all dental and ESS treatment options based on rates reported in the literature.[21] This suggested that overall costs were similar between RCT and extraction because of the costs of reconstruction after extraction. And if patients select dental implants, their costs will usually exceed RCT.

PREVENTION OF OROANTRAL FISTULA DURING EXTRACTION

Maxillary dental extraction in the setting of ODS due to AP/PAA can be complicated by an OAF, especially with prominent periapical lesions. When a periapical lesion perforates the cortical plate of the maxillary sinus floor, extraction of the causative tooth may cause an oroantral communication (OAC) that may become an epithelialized OAF if it does not heal. No studies have demonstrated the incidences of OACs or

OAFs after extraction for ODS. One study reported OACs occurring after maxillary molar dental extractions in only 0.5% to 5% of cases, but did not report the incidence of subsequent OAF formation.[32] Another study showed that while OACs occurred in only 0.5% to 1% of all maxillary extractions posterior to canines, OAFs occurred more commonly in abscessed teeth (53% of all OAFs).[33] This would be consistent with ODS where many of the causative teeth have periapical abscesses with bone erosion. Additionally, if maxillary purulence drains through an OAC, presumably that would inhibit healing and increase the risk of OAF formation.

No studies have explored how to reduce OAF formation after OACs during dental extractions. Some surgeons use a high-speed drill or saw to excise the maxillary dentition piecemeal, as this ensures minimal force being applied to the overlying maxillary sinus mucosa (presuming there is not a premorbid mucosal perforation). Additionally, whether patients should receive oral and/or intraoral antibiotics before the extraction, or after OAC development to reduce OAF risk requires further study. The duration of antimicrobial therapy would be important to study as well.

CLINICS CARE POINTS

- All otolaryngologists and dental specialists managing endodontic-related ODS should be aware of the different dental treatment and sinus surgical options available to treat both the infectious dental and sinus disease. Multidisciplinary collaboration facilitates this.
- In patients with ODS due to AP/PAA who undergo primary dental treatment, dental specialists should discuss the benefits and risks of endodontic treatments and extraction, and the needs for potential subsequent dental or sinus surgical treatments should they fail to resolve either the infectious dental or sinus disease.
- More evidence is currently available for dental extraction, showing that it resolves ODS in roughly 60% of cases, with extramaxillary extension being a negative predictor of success; early disappearance of malodor in first 2 weeks may be a positive indicator that ESS will not be necessary.
- Endodontic treatments in the setting of ODS should be performed by specialists using microsurgical techniques. More research is necessary to determine RCT success in managing ODS, but regardless of its success in resolving the sinusitis, patients have a greater chance of saving their native tooth, avoiding the possible complications of extraction, and the need for subsequent reconstruction.

DISCLOSURE

J.R. Craig: research consultant for Aerin Medical, Inc.

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