Technological innovations in tissue removal during rhinologic surgery

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ABSTRACT

Background: The modern rhinologist has a wide variety of technological innovations at his/her disposal for the removal of soft tissue and bone during endoscopic surgery. We identified and critically evaluated four leading tissue removal technologies that have impacted, or are poised to impact, rhinological surgery.

Methods: A literature review was conducted.

Results: Technological functions, strengths and limitations of microdebriders, radio frequency ablation, endoscopic drills, and ultrasonic aspirators were explored. The primary drawback of powered instruments continues to be the higher costs associated with their use, and their main advantage is the ability to accomplish multiple functions such as tissue removal, suction, and irrigation, all with one tool. The effective and safe use of any powered instrument requires an intimate understanding of its function, capabilities, and limitations.

Conclusion: Powered instrumentation continues to play a significant and evolving role in soft tissue and bone removal during rhinologic surgery.

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INSTRUMENTATION FOR SOFT TISSUE REMOVAL

Soft tissue removal is a common challenge in rhinologic surgery, owing to the propensity for bleeding from tissues such as adenoids, polyps, and tumors. Bleeding during an endoscopic procedure, especially one performed using the customary one surgeon two-handed technique, is problematic because the surgeon only has one free hand with which to contend with the bleeding. Furthermore, even small amounts of bleeding during endoscopic surgery can obscure the surgeon's view of an already small and complex operative field, thereby increasing the risk of complications.¹

Microdebrider

Introduced to rhinology in the 1990s,^{2–4} microdebriders are the most commonly used powered instrument in endoscopic sinus surgery (ESS). Available in a variety of designs, these cylindrical shavers have become wildly popular for ESS (especially for nasal polyps) because they provide a tool that precisely shaves tissues and also continuously suctions blood away from the surgical field (Table 1).⁵ Suction draws soft tissue into the aperture of a hollow shaft and an oscillating inner cannula (moving back and forth across the opening) cleaves the tissue that is then evacuated along with blood into a suction canister. The tissue is morselized, but histologically preserved for pathological examination.⁶ The edges on both the inner and the outer cannulas can be either straight or serrated (for better gripping of tissues). Blades can be set to rotate or oscillate. Oscillation typically runs at a slower speed (up to 5000 rpm), allowing the blade to remain

open longer, drawing in more tissue as for routine use during ESS. Forward rotation settings are used with blades modified to resemble drill burrs that permit the instrument to function like a drill. However, because of their relatively low revolution speed (maximum, 15,000 rpm), these are less efficient at removing thick bone than high-speed otologic drills (that function at 80,000–100,000 rpm). A recently developed “universal” console allows for both microdebriders and high speed drills to be plugged into the same console, minimizing hardware in the operating suite.

Microdebrider blades are also available with a variety of angles as well as rotating ports. This allows for improved dissection in difficult-to-access areas.⁵ Specialty blades have been developed for specific tasks including adenoidectomy and inferior turbinate (IT) reduction. The IT blade is 2.9 mm in diameter (compared with the standard 4.0 mm), and some models also have a beveled guard on the back of the blade to assist in penetrating through and dissecting beneath turbinate mucosa. By sparing the surface epithelium, less crusting and synechiae formation occur postoperatively than with cautery or surface-damaging techniques.⁷

Other recent advancements in microdebrider blade design include blades that clog less (a significant issue with earlier iterations) and automatically close on release of the foot pedal, to reduce suction-related damage during removal of the instrument from the nose.⁸

The tip of microdebrider blades can also now be tracked by image-guidance systems. This was initially and most simply accomplished by optical-based navigation platforms that now permit calibration using universal adapters that can be affixed to any rigid surgical instrument to enable tracking. With this remarkable innovation, the surgeon can accurately navigate with any microdebrider blade, of any angle, from any manufacturer. Electromagnetic-based systems can still only track a small number of specific, proprietary instruments, although a few trackable microdebrider blades have recently been introduced (Fig. 1). These blades are precalibrated and automatically recognized by the system when brought into the operative tracking field.

Advantages of microdebriders are that they spare adjacent mucosa, remove tissue more quickly, and provide improved precision through better visualization. There are, however, only a few studies supporting these contentions.^{2,3,5} Sauer and colleagues conducted a prospective, double-blinded, and randomized control trial comparing ESS

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Table 1 Advantages and disadvantages of instrumentation used for tissue removal

Technology	Advantages	Disadvantages
Microdebrider	Greatest experience of all powered instrumentation Continuous suction for visualization Multiple angled and specialty blades available Spare adjacent mucosa Relatively low cost Trackable with navigation Bipolar feature available for hemostasis	Very low revolution speeds for drilling so limited capability of (significant) bone removal Some concern over rapid progression of complications when they occur
Radiofrequency ablation	Decreased thermal damage compared with (monopolar) electrocautery Relatively low cost Bipolar function may be useful for skull base procedures	Not able to remove any bone Slower tissue removal than microdebrider Limited experience with technology in rhinology (other than IT procedures)
Endoscopic drills	Fastest and most controlled bone removal: still most effective tool for larger bony lesions, frontal drill out, etc. Modest cost and widely available	Can be challenging to use in difficult to reach areas Heat transmission of concern Mechanical damage to adjacent mucosa and critical structures possible No angled burrs available (e.g., for frontal work) Ergonomics and modifications for endonasal approaches still lacking
Ultrasonic aspirator	Effective bone removal Spare adjacent mucosa and soft tissues very effectively, limited collateral damage	Slower bone removal compared with high speed drills Very limited experience with technology in rhinology Heat transmission concerns High cost

IT = inferior turbinate.

Figure 1. Medtronic Straightshot Microdebrider with an angled, and navigation-tracked blade. Image courtesy of Medtronic (Jacksonville, FL).

performed with a microdebrider on one side with surgery done using standard instruments on the other side. They noted an improvement in symptom and endoscopic scores at 3 weeks in the microdebrider group but no other differences were found. Operating room times and blood loss were not reported.⁹

Despite the robust proliferation of microdebriders and their effectiveness at continuously clearing blood from the field, current devices have a major shortcoming: they do nothing to actually stop bleeding. The most recent innovation in microdebrider technology now permits the added ability to control bleeding while retaining the shaving and suctioning capabilities characteristic of this class of instrument. The PK Diego (Gyrus ACMI-ENT Division, Bartlett, TN; Fig. 2) has the

ability to deliver bipolar energy to the distal tip of its blades. This bipolar function can be set to low, medium, or high power (corresponding to 10, 20, and 40 W, respectively) for additional titration depending on the degree of bleeding encountered. Kumar and Sindwani compared 40 patients who underwent ESS using a conventional microdebrider with 40 patients who underwent similar operations with a PK Diego bipolar microdebrider. They found a statistically significant difference in blood loss when the bipolar microdebrider was used (86 mL versus 123 mL, respectively). A significant decrease in operative time was also noted, which was felt to be related to improved visibility. No major complications occurred in either group.¹⁰

The application of the bipolar-equipped microdebrider also appears well suited for submucosal IT reduction where bleeding from the turbinate interior as well as the entry site can be easily controlled and for endonasal removal of a variety of vascularized tissues. The fact that bipolar energy is used (as opposed to monopolar) is also noteworthy, because this limits the transmission of heat to adjacent intraorbital and intracranial structures. This important characteristic, along with the wide selection of angled blades, is also useful in removing tissues and controlling bleeding during complex skull base procedures, given that currently available bipolar systems are limited by ergonomics and the varying geometry of the skull base.

Like any other instrument, microdebriders have certain limitations that must be recognized.⁵ Importantly, they offer very little tactile feedback. Severe intracranial and orbital complications attributed to the use of a microdebrider have been reported.^{11,12} Although major complications from ESS are fortunately rare, complications that do occur related to microdebrider use may progress more quickly because of the powered nature and continuous suction of this device.⁵ Finally, microdebriders carry the cost of the system and ongoing expense of disposable blades.

Figure 2. PK Diego microdebrider with an inferior turbinate blade inserted. Inset 1 shows the PK Diego handpiece attached to a universal tracking adapter for an optical-based image-guidance system. Inset 2 shows a diagram of the PK Diego microdebrider bipolar tip. Image courtesy of Gyrus (Bartlett, TN).

Figure 3. Coblator II base unit. Images courtesy of Arthrocare Corp. (Austin, TX).

Radiofrequency Ablation

Radiofrequency ablation uses radiofrequency energy to energize electrolytes within a conductive medium such as saline, theoretically creating a plasma field that disrupts the molecular bonds of soft tissue. This occurs at much lower temperatures (40°C) than traditional electrocautery (400+°C). Some have argued that decreased thermal damage during Coblation (Coblator; Arthrocare Corp., Austin, TX) has more to do with vaporization of the saline than creation of a plasma field, which can only exist in a vacuum.¹³ Whatever the mechanism, there does appear to be significantly less penetration of thermal energy into surrounding tissue with this technology.^{14,15}

There are a number of Coblation wands available (Fig. 3). These include needle-tipped wands to be inserted into soft tissue for ablation and broader tips that use continuous suction and irrigation for expedited tissue removal. These broad-based tips also provide bipolar energy delivery for hemostasis.

Coblation is gaining popularity in rhinologic surgery for IT reduction, in particular. Radiofrequency energy is applied at several marked depths to create a series of ablated pockets submucosally, which provides volume reduction. This tissue will continue to scar down during healing, potentially resulting in further reduction over time. Back and colleagues¹⁶ showed significant subjective improvement in nasal symptoms using a visual analog scale after Coblation-mediated IT reduction. Given the ability of this technology to remove tissues with little bleeding, other rhinologic applications of Coblation are currently being explored, including polypectomy. A recent study compared operating room time and estimated blood loss of patients who underwent a Coblator-assisted polypectomy with those who underwent a microdebrider-assisted polypectomy. There was no dif-

ference in disease severity between the two groups. The estimated blood loss was 307 mL in the Coblation group compared with 627 mL in the microdebrider cohort. The average length of surgery was also shorter in the Coblation group. A subgroup analysis revealed that the difference in blood loss was only significant in revision cases.¹⁷ More recently, an article has also indicated the use of the Coblation system for the endoscopic resection of encephaloceles. The use of this technology resulted in less operative time when compared with traditional bipolar cautery, with no statistical increase in complications.¹⁸

A major limitation of radiofrequency ablation for ESS for chronic rhinosinusitis with or without nasal polyps is its inability to address the bone encountered in the ethmoid sinus or other areas of the sinonasal tract. In addition, there have been no studies examining the extent of heat generation or transmission to adjacent structures during prolonged use of this instrument as would be necessary for tumor or polyp removal.

INSTRUMENTATION FOR BONE REMOVAL

The sinonasal cavity is comprised of bony partitions and is surrounded by fixed bony boundaries. All surgery on the sinuses or extending beyond the confines of the sinonasal tract into the intracranial cavity or orbit, therefore, requires the controlled take-down of varying amounts of bone. The bone encountered is of very different qualities, ranging from the thin bone of the ethmoid labyrinth or lamina papyracea to the more formidable frontal beak or clivus. A consideration in all settings, however, is how to best remove the bone expeditiously while avoiding injury to adjacent vital structures.

Figure 4. eMax 2 Plus with Handpiece; MA-D20, 20° Angle Driver. Image courtesy of Anspach Effort, Inc. (Palm Beach Gardens, FL).

Figure 5. Sonopet Omni base unit and hand piece. Images courtesy of Stryker Corp. (Kalamazoo, MI).

Endoscopic Drills

Endoscopic drills are far less commonly used than microdebriders, given that microdebriders are able to effectively handle the thin bone encountered during routine ESS. For areas of thicker bone, a variety of drills and burs have been developed. Conventional hand instruments may be used for cases requiring significant bony removal, but the greater force needed to take down thick bone can result in poorly controlled movements that risk injury. The advantage of drills is that they permit expeditious and more controlled bony removal. Unlike otologic drills, drills intended for endoscopic use have a slimmer profile permitting them to be passed readily through the nostrils (Fig. 4). Other modifications aimed at addressing some of the unique ergonomic and length concerns for endonasal drilling include longer sheaths, extended drill attachments for the skull base, telescoping drill bits, and angulated handpieces. Some drills also offer a protective guard for the burr, which protects adjacent tissues from the spinning drill burr. The built-in suction feature constantly removes blood and debris while continuous irrigation cools the burr and the tissue interface reducing heat transmission to adjacent vital structures. The use of suction irrigation and some of these other endonasal modifications, however, do come at the expense of a wider diameter that can encroach on endoscopic work space and visualization. There are still great strides to be made in the arena of endoscopic drills.

The number of flutes on a burr determines how aggressively the drill will function. Fewer flutes will result in faster and more aggressive takedown of bone, as will increasing the speed of rotation. Diamond burs are much less aggressive than cutting (fluted) burs in general and are preferred to slowly thin down bone over critical structures. A variety of procedures may be augmented with the use of endoscopic drills, including endoscopic dacryocystorhinotomy,¹⁹ frontal drill-out surgery,²⁰ and a variety of skull base approaches.⁵ Limitations of the use of these drills in sinonasal techniques include associated costs, persistent ergonomic issues related to their adaptation for endonasal surgery, damage to adjacent mucosa, and concerns over heat transmission.

Ultrasonic Aspirator

Although previously used for soft tissue cavitation, recent advances in ultrasonic technology now permit aspirators to expeditiously remove bone while still being respectful of nearby soft tissues.²¹ Ultrasonic aspirators operate on the converse piezoelectric effect, whereby application of an electric charge to certain crystals creates a reversible mechanical deformation. Piezoelectric crystals are stacked in the handpiece of the instrument, and the rapid expansion and contraction of the crystals causes high-frequency vibration of the

instrument tip, which denatures proteins and emulsifies bone. The resulting emulsified tissue is removed by continuous irrigation and suction. The frequency of vibration can be optimized for either bone or soft tissue removal (Fig. 5). In addition, the ultrasonic aspirator reportedly generates less heat compared with conventional drills. Power can be adjusted on the ultrasonic aspirator, with greater power resulting in increased amplitude of tip stroke and more aggressive takedown of tissues.²¹

The key advantage of the bone-cutting ultrasonic aspirator is tissue selectivity. It vibrates, rather than spinning like a drill burr or microdebrider blade, which results in effective bone removal while being relatively atraumatic to the surrounding soft tissue. The lack of a spinning burr also reduces the risk of skipping or chatter associated with a conventional drill, providing more control. The use of bone-cutting ultrasonic aspirators has been described in a variety of neurosurgical procedures, and they have been praised for their ability to minimize damage to nearby vasculature and dura while removing thick bone in confined spaces. The endoscopic use of these instruments was first described in otolaryngology by Antisdal and colleagues,¹⁹ who reported their experience using the ultrasonic aspirator for the creation of the bony rhinostomy in endoscopic dacryocystorhinostomy. The authors reported that inadvertent or even purposeful contact of the back of the vibrating tip with a mucosa-lined structure such as the nasal septum or middle turbinate did not cause any identifiable injury. The use of the ultrasonic aspirator has since been reported for removal of the bony portion of the IT²² and for transnasal osteoma removal.²³ The ability of this technology to selectively remove bone while being respectful of nearby mucosa and soft tissue holds considerable promise for endoscopic procedures requiring significant bony removal.

Presently, literature available supporting the use of this technology or describing rhinologic applications is extremely limited. The cost of the unit itself is substantial and it carries the ongoing costs of disposable tips. This instrument does remove bone more slowly than a high-speed drill and, importantly, data on heat generation at the tip during bone emulsification are lacking.

CONCLUSION

The microdebrider has continued to improve in function and design. More recently, several other innovative power tools such as the Coblator, endoscopic drill, and the ultrasonic aspirator have been developed. Powered instrumentation continues to play a significant and evolving role in soft tissue and bone removal during rhinologic surgery.

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