

Piezosurgery in Oral and Maxillofacial Surgery

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40.1 Introduction

The term “piezo” has been derived from the word “Piezien,” which implies pressure in the Greek language. Piezoelectric effect was first described by Jacques and Pierre Curie in 1880 and involves the appearance of an electric charge across certain crystals when they are under mechanical pressure. Inversely, when an electric current is applied across them, they deform. This phenomenon of deformation when under alternating current creates microvibrations or oscillations of ultrasonic frequency [1]. Although ultrasonic microvibration technology was experimentally used earlier, it was in 1988 that Italian oral surgeon Tomaso Vercellotti developed the first commercially available Mectron® piezoelectric bone surgery unit to cut bone tissue while minimizing the limitations of conventional tools [2, 3]. The first use of piezoelectric surgery was for osteotomies by oral and maxillofacial surgeons and later on used for neurosurgical and orthopedic procedures. This revolutionary tool not only lowers the chance of damage to adjacent vital soft-tissue structures such as nerves and vessels during osteotomies, but also preserves osteocytes, which in turn complements bone healing [4, 5].

40.2 Equipment and Principles of Use

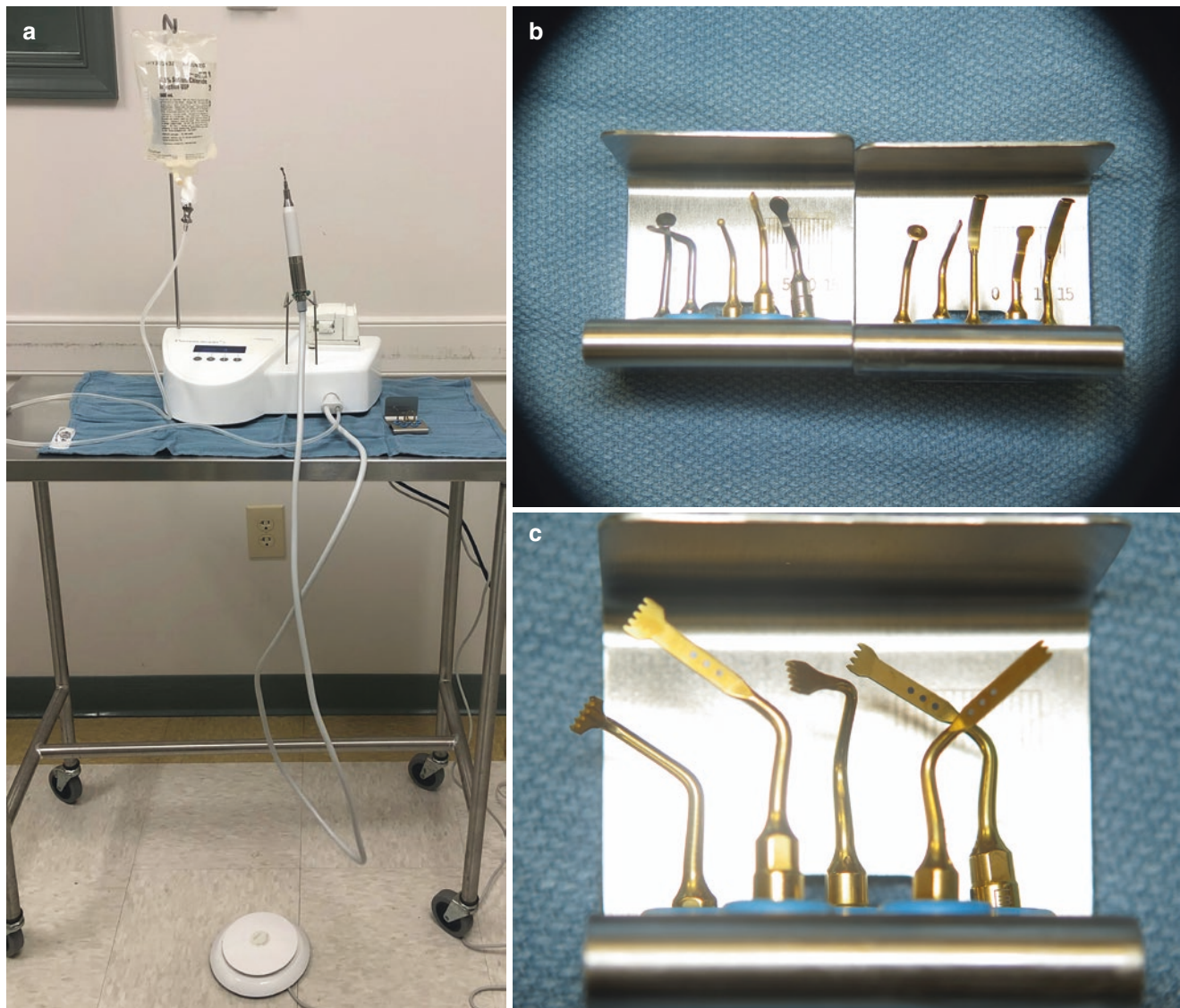
Piezoelectric surgery devices are generally small portable units comprising a handpiece with a working tip and a foot control switch, which are connected to the main power-generating unit. The main power unit also features holders for the handpiece and irrigating/cooling fluid (Fig. 40.1a–c). The handpiece is the critical part of this device, containing within it the ceramic chips where the microvibrations are created and later transmitted to the working tip. Commonly

used ceramic chips in Piezoelectric surgery units are Barium Titanate or an equivalent material. The amount of deformation in the crystals within the handpiece and resultant vibrations in the insert depend on the power applied [6].

The working tips of a piezoelectric system used for surgical purposes are interchangeable inserts, which can be of different shapes, sizes, and cutting edges based on the intended clinical applications. These inserts can be made of different materials and be coated with titanium or a diamond layer to improve the cutting efficiency. To create a cutting effect rather than a debriding effect, the vibrations of the insert enter into a resonance with the ceramic chips, which increases the energy output. This, combined with the form of the insert, acts like a micrometric oscillating saw. The main energy unit has an interactive touchpad, which allows the operator to control the frequency of vibrations, power of the unit, and the amount of irrigating or coolant fluid. The pressure applied on the insert can also be manually controlled by the operator and can affect the frequency delivered to the target tissue, which in turn affects the cutting efficiency. When higher pressure is applied at the tip, it impedes the cutting efficiency of the insert and releases the energy as heat, which is detrimental to the bone as well as adjacent soft tissue [6, 7].

The Piezoelectric unit also allows for election of modes of operation, which are preset power modes with varying frequencies to match the clinical application. The frequency is usually set between 25 and 29 kHz, which can create micro-oscillations of 60–210 μm amplitude, providing the handpiece with power exceeding 5 W. The vibrations produced in the “Low mode” result from average ultrasonic powers, without frequency overmodulation, and allow the operator to perform endodontic procedures. On the contrary side, the “high mode” and the “boosted mode” are characterized by vibrations with higher ultrasonic power and frequency overmodulation, which allows cutting of mineralized tissue. The “boosted mode” has frequency overmodulation with an increased rate that is most efficient for osteotomy and osteoplasties in surgical procedures, while the “high mode” is less

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Fig. 40.1 (a) The Piezosurgery® unit from Mectron® is made of a power supply unit, a handpiece, its holder, an irrigant solution holder, foot control switch. (b, c) Inserts or working tips of a piezosurgery unit. (b) shows working tips for Sinus lift and (c) shows osteotomy tips

efficient but more helpful in periodontal procedures and bone smoothening [6–8].

The device includes an irrigating system for cooling that creates an adjustable jet of coolant solution through a peristaltic pump at rates between 0 and 60 ml/min and helps remove debris from the cut surface and helps maintain hemostasis because of its cavitation effect. This enhances visibility, particularly in difficult-to-reach anatomical zones, by scattering coolant liquid as an aerosol. The irrigation liquid should be refrigerated at 4 °C for effectual cooling [6, 8, 9].

For optimal use and maximum efficiency, the operator could select the proper power based on the surgical tissue, apply light pressure with the tip, and adjust the rate of deliv-

ery of the irrigating solution to avoid overheating the tissue and decrease the chance of damage to soft tissues. Although the device has a safe frequency range along with the cooling irrigation liquid, there is a possibility of damage to soft tissues due to high pressure and overheating [10].

40.3 Advantages

Used in many therapeutic surgical procedures, piezosurgery has several advantages when compared to traditional methods of surgical instrumentation used for osteotomies or osteoplasty. These are as follows:

- *Decreased risk of damage to adjacent soft tissues:* This is the major advantage with use of a piezoelectric surgical unit. When used as recommended, at the appropriate frequency, the micrometric oscillating motion decreases the chance of damage or cutting of adjacent soft tissue while cutting through hard tissues. For example, it allows improved Schneiderian membrane preservation during osteotomy of the maxillary lateral wall during a sinus lift and preservation of the inferior alveolar nerve (IAN) during mandibular osteotomy.
- *Improved visibility:* With use of piezosurgery, better visibility is secondary to the decreased amount of bleeding and the phenomenon of cavitation. Cavitation refers to the phenomenon of “microboiling” occurring in liquids in a solid-liquid interface at intermediate frequencies of vibration secondary to the creation of imploding bubbles when the irrigating solution contacts the insert. Improved visibility helps the operator to place the osteotomy in the preferred location with increased accuracy [6].
- *Increased patient comfort:* Due to the micrometric nature of the vibrations and decreased noise, use of a piezosurgery device improves patient comfort and decreases anxiety during procedures done under local anesthesia. When used for bone harvesting, it also reduces the need for use of chisels, which can help improve the patient experience and reduce stress.
- *Improved survival of osteocytes:* Bone harvested with various techniques, including rotary instruments, chisels, rongeurs, and a piezosurgery device, was studied with histomorphometry evaluation by Berengo et al. The piezosurgery device was shown to be one of the best methods of harvesting bone along with gouge chisels, back action chisels, and rongeurs in terms of the viability of the harvested bone and number of osteocytes. Bone harvested with rotary instruments, including burs and safe scrapers, was noted to be completely nonvital with an absence of osteocytes. In another histomorphological study done with the placement of porous titanium implants in minipig tibias, neo-osteogenesis was noted to be consistently more active in bony samples from implant sites that were prepared using piezoelectric surgery, and there was an earlier increase in BMP-4 and TGF-2 proteins and fewer proinflammatory cytokines in bone around the implants [5, 11].

40.4 Disadvantages/Limitations

Although piezosurgery has numerous advantages as listed here, it is associated with some drawbacks as follows:

- *Low efficiency/increased operating time:* One of the major drawbacks with ultrasonic/piezo surgery osteotomes is the increased time required for the procedure. The cutting

efficiency of a piezosurgery device has been reported to be 3–4 times less than that of conventional osteotomes for some procedures [12, 13]. For example, in a randomized prospective crossover clinical study done by Stefano Sivoletta, piezoelectric osteotomy of a lower third molar took 9.4 min longer than rotary tools to complete [14].

- *Expense:* The cost of equipment is sometimes an additional burden to the provider. Each individual cutting tip in a piezosurgery equipment setup is generally more expensive than traditional cutting tools such as burs, chisels, or saw blades. These tips can also potentially break or fracture when improperly used, which can again increase the need for more equipment.
- *Learning curve:* Use of piezo requires a short learning curve to attain maximum efficacy, which could be frustrating to the operator. The digital pressure applied by the surgeon while using conventional tools such as saws and drills is quite different from piezoelectric surgery as it mandates less pressure and failing to calculate the pressure according to the speed of the insert prevents microvibrations of the insert. When the microvibrations are prevented due to excessive pressure on the working tip, energy not used for cutting will be transformed into heat, which, if it continues for long time, would damage the tissue.
- *Pacemakers and defibrillators:* Piezosurgery is *relatively* contraindicated for use in patients with pacemakers, although there is no evidence of electromagnetic interactions produced by piezoelectric devices according to one in vitro study [15].

40.5 Applications for Piezosurgery

40.5.1 Dentoalveolar Procedures

Piezosurgery can be applied toward multiple dentoalveolar procedures where there is a requirement for meticulous bone preparation, atraumatic tooth extraction/exposure, and when the location of the surgical site is in proximity to vital anatomical structures. Example of applications in dentoalveolar surgery include ankylotic tooth root extraction, impacted third molar extraction, surgical exposure of impacted teeth, and extractions in patients with a thin periodontal biotype. In all of these indications, piezosurgery has the potential to limit bone loss and maximize maintenance of alveolar bone integrity, especially when the alveolar bone is thin and the procedure requires a high degree of precision. A split-mouth design, randomized, clinical trial conducted by Mantovani et al. studied differences in postoperative pain, orofacial swelling and duration of the procedure when using a rotary bur for third molar osteotomy versus a piezosurgery device. They found that, although the duration of the procedure was longer, the postoperative pain and swelling were less in the piezosurgery group [16].

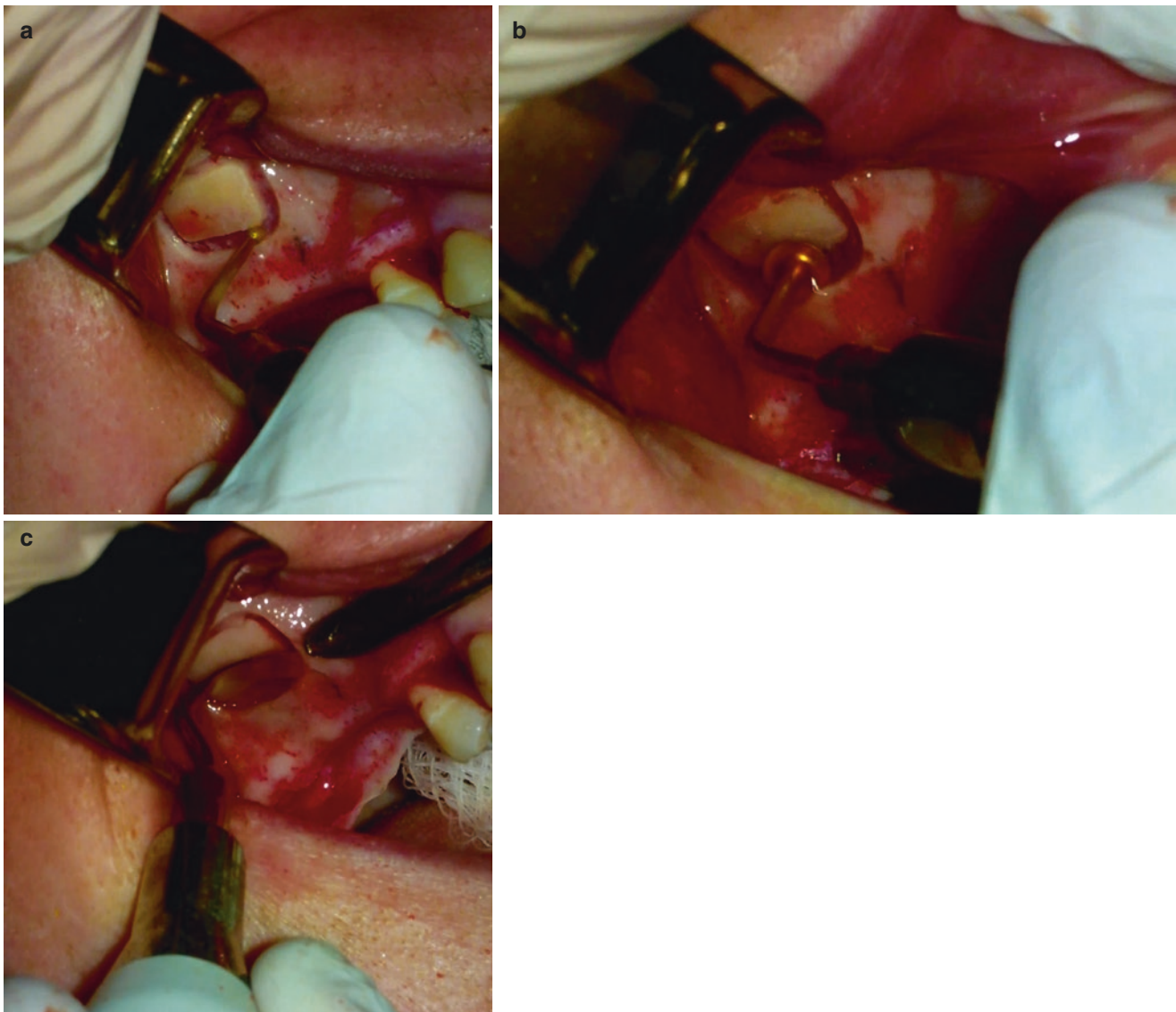
40.5.2 Dental Implant Surgery

40.5.2.1 Sinus Floor Elevation

Perforation of the Schneiderian membrane during lateral wall osteotomy, and/or while raising the maxillary sinus floor manually, is a common complication, which can affect the bone grafting procedure. Use of piezosurgery in sinus lift procedures not only minimizes the chance of perforation during osteotomy but also eases the separation of the membrane as well (Fig. 40.2a–c). In the commonly used lateral approach technique for sinus lift, piezoelectric devices have a superior action in each technique or step compared to

traditional instruments. The chance of membrane perforation with conventional techniques is reported to be 14–56%, while studies on the use of piezosurgery devices report it to be 5–7% [8, 17, 18].

- **Thinning buccal wall:** With traditional instruments, it is difficult to thin the buccal wall with good control. Piezoelectric device makes precise osteoplasty easy and the bone fragments produced during osteoplasty can be used as grafting material.
- **Bony window/osteotomy:** Piezosurgery makes the frame of the bony window optimal with respect to the sinus



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Fig. 40.2 (a) Piezosurgery insert used to perform outline of the lateral wall osteotomy to thin the wall. (b) Blunt piezosurgery insert used to infracture the window wall and initiate the separation of the Schneiderian membrane from the sinus wall. (c) After the lateral sinus wall oste-

otomy completed, membrane separation initiated a third insert shaped as an elevator used to continue the separation of the membrane to create required space for the bone graft for augmentation

anatomy with decreased chance of membrane perforation.

- Sinus membrane separation: Most commercially available piezosurgery devices have special inserts that make the separation around the perimeter of bony window easier and decrease chance of tear or perforation during the manual lifting process.

40.5.2.2 Implant Site Preparation

Implant site healing and ultimate osseointegration of implants is negatively influenced by the high temperatures created during site preparation. Results of an in vitro study done by Heinemann et al. in 2012 on porcine jaws comparing piezosurgery, Sonicflex®, and rotary instruments showed the highest temperature rise with use of piezosurgery, although the trabecular bone and osteocytes were still intact [19]. On the contrary, a recent randomized, controlled clinical trial by Da Silva Neto et al. in 2014 compared implant stability at various times postoperatively in osteotomies performed by conventional rotary instruments versus piezosurgery devices, and found implant stability to be higher with Piezosurgery [20]. The use of piezoelectric devices facilitates the use of selective enlargement of only one socket wall and Vercellotti called this: “differential ultrasonic socket preparation.” [4].

40.5.2.3 Alveolar Ridge Splitting

Ridge-splitting techniques for alveolar augmentation is indicated when there is adequate height of bone for implant placement but inadequate ridge thickness. The conventional ridge-splitting procedure uses chisels, rotary instruments, or saws, all of which have a high risk for damage to soft tissue, undesired propagation of the osteotomy and bone fracture, as well as prolonging treatment time due to the need for second-stage surgery to place the implants. (Fig. 40.3a, b) With use

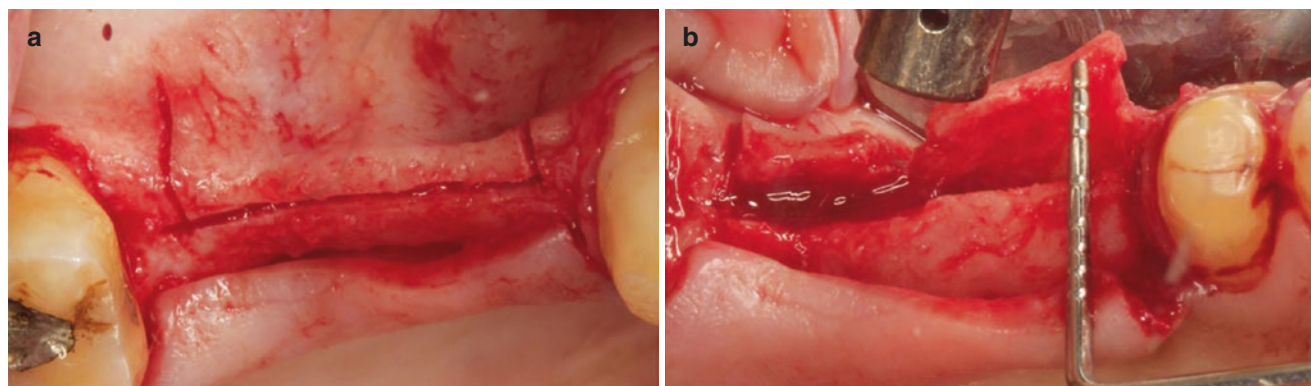
of piezosurgery, one can decrease the chance of the damage to adjacent structures during the osteotomy as well as reduce the risk of bone thermonecrosis, while simultaneously providing better control of propagation of the ridge split osteotomy. Although ridge splitting was traditionally used in the maxillary arch, piezoelectric bone surgery allows ridge expansion even in highly mineralized tissues like the mandible with ease [21, 22]. Blus et al. conducted a study on ridge splitting for more than 200 implants placed in 57 patients and reported 96.5% success rate with a 36-month follow up [23].

40.5.2.4 Lateralization of the Inferior Alveolar Nerve

In order to place implants in atrophic edentulous mandibles, IAN lateralization can be used as an alternative to bone augmentation procedures (Fig. 40.4a–c). Bovi, in 2005, first reported a technique for IAN mobilization with simultaneous implant placement utilizing a piezoelectric device. He reported that IAN mobilization with a piezoelectric device minimizes the risk of irreversible damage to the IAN and enables the surgeon to make a smaller bony window, which, in turn, decreases overstretching of the mental nerve [24]. In an in vitro study, Metzger compared transposition of the IAN with use of a piezoelectric device versus conventional burs. His study also supported the lower rate of nerve injury from use of piezosurgery [25].

40.5.3 Bone Graft Harvesting

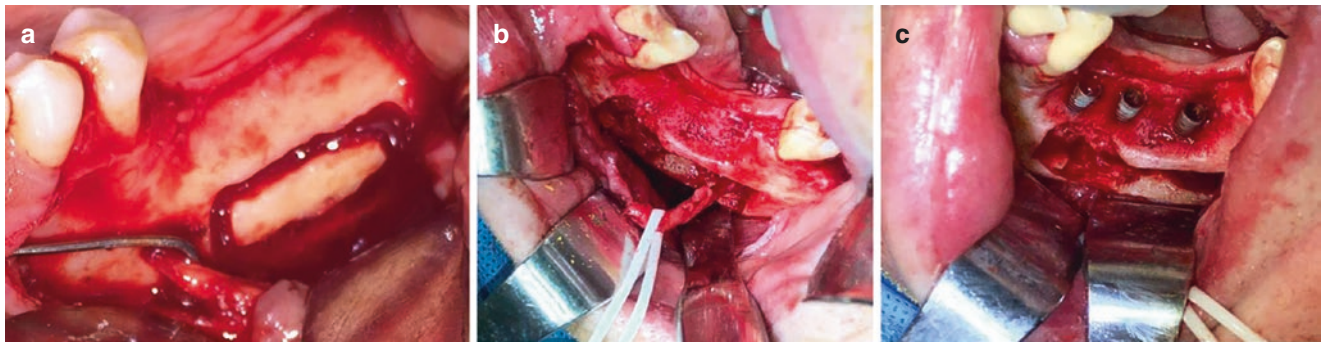
For bone augmentation, bone grafts in the form of chips or blocks can be used. Bone chips are primarily indicated in guided bone regeneration where the stabilization of the graft is not an issue, such as multiwalled defects. On the other hand, when the bony defect is large or stabilization is diffi-



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Fig. 40.3 (a, b) Ridge split technique with piezo surgery. Bony osteotomies performed with piezoelectric device then ridge expanded to desired dimensions. From: Tarun Kumar, A., Triveni, B., Priyadharshini,

M., & Mehta, G. (2016). Staged Ridge Split Procedure in the Management of Horizontal Ridge Deficiency Utilizing Piezosurgery. *Journal of Maxillofacial and Oral Surgery*, 15(4), 542–546 (Springer)



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Fig. 40.4 (a–c) Inferior alveolar nerve (IAN) lateralization for placement of implant

cult, block grafts must be utilized to augment vertical or horizontal dimension. Piezosurgery is used for harvesting all types of bone grafts, including autologous free block grafts, microvascular free flaps, and bone chips.

For example, piezosurgery is commonly used to harvest mandibular ramus block grafts. This requires use of two types of piezosurgery inserts. One is the standard saw-shaped right angle insert, which is used in an area, which can be viewed directly to make the depth cut and vertical cuts, while a second, dual-angled, insert is used specifically to make the inferior horizontal bone cut. In bone graft harvesting, piezosurgery allows better visibility, precise cuts, and good adaptation of the grafts along with better survival of bone cells. In a study by Happe in 2007 on 40 patients, bone grafts harvested from the mandibular ramus by piezosurgery resulted in 93% uneventfully healed donor sites and 96% uneventfully healed graft sites [26]. There was also minimal resorption of the graft. Shaping of block grafts can be better controlled with piezosurgery, although this can take longer than rotary instruments. In microvascular free bone flaps harvested with piezosurgery, the surgeon can decrease the chance of injury to the vascular bundle along the surface of bone. With the use of piezoelectric surgery, the clinician can cautiously osteotomize the fibula or other bone without any periosteal/pedicle dissection. In addition, the piezoelectric method also allows shaping and handling the pedicle while it is still attached to the donor site.

40.5.4 Orthognathic Surgery

Piezoelectric devices are increasingly being used in orthognathic surgery due to its precise cutting and lower risk of damage to adjacent teeth and nerves. Landes et al. performed a large study on 90 patients in whom orthognathic surgery was performed with piezosurgery. This study demonstrated decreased

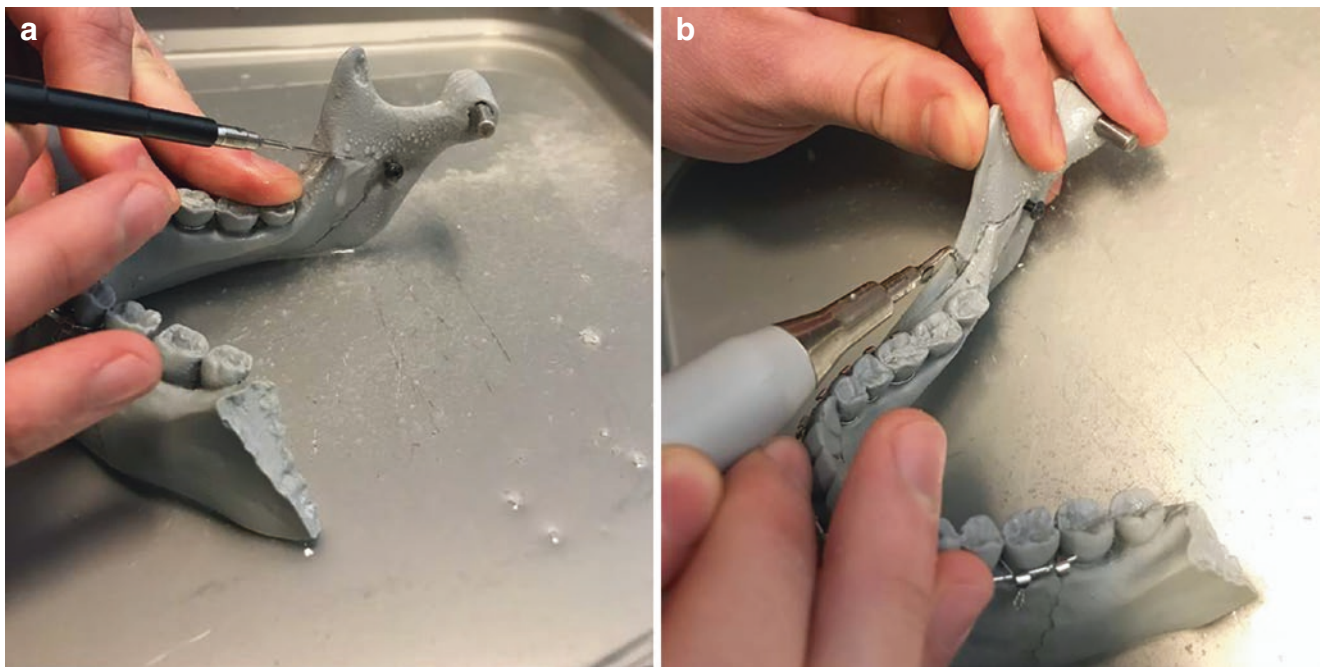
blood loss compared to conventional surgery but no significant difference in surgical times. Lefort I osteotomy only required the use of chisels in about 33% of cases [5, 27, 28]. In the same study, among patients who underwent bilateral sagittal split osteotomy (BSSO), inferior alveolar nerve sensitivity at 3-month follow up was retained in 98% of the cases, compared with 84% after conventional BSSO (Fig. 40.5). When performing surgically assisted rapid maxillary expansion (SARME), the advantage of using piezoelectric surgery is that it minimizes potential damage to the descending palatine artery while separating the pterygomaxillary junction, the nasopalatine artery while making the midline maxillary cut, and it lowers indirect thermal damage to the bony surfaces and adjacent structures, including teeth [29].

40.5.5 Aesthetic Facial Surgery

Conventionally, chisels are used for osteotomy of the lateral nasal bone during rhinoplasty, which transmit significant force to the surrounding soft tissues in a blind manner, and increases the risk for bleeding from injury to the adjacent vasculature. A study done by Robiony et al. assessed use of chisels versus piezosurgery and found a decreased risk of injury to adjacent soft tissues with use of piezosurgery. Use of chisels also may create inaccuracy due to blind use and the ungaurded nature of the instrument. On the other hand, use of piezo will not incur this issue and gives the operator more control and accuracy [30].

40.5.6 Distraction Osteogenesis

Distraction osteogenesis (DO) is indicated when there is a need for significant amounts of bone augmentation or lengthening, or when the soft tissues that cover the bone will not



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Fig. 40.5 (a, b) Orthognathic surgery using Piezo. Figure shows steps in a BSSO. Variations in the blade design can be used based on desired osteotomy

allow for osseous augmentation. The use of piezosurgery permits the initial osteotomy to be made delicately and accurately while minimizing injury to the soft-tissue flap and surrounding hard tissue, allowing maintenance of the vascularity needed for successful new bone formation [31]. Distraction Osteogenesis (DO) can be used for distraction of either the alveolar bone or the basal jawbone. DO with a piezoelectric device ensures the preservation of original bone structures, specifically the cancellous bone, which favors the healing process due to its high healing potential. In a recent article, DO with microdistractors using a piezoelectric device has shown favorable results in patients with Pierre Robin Sequence [32].

40.5.7 Temporomandibular Joint Surgeries

Osteotomies and osteoplasty in the temporomandibular joint (TMJ) region involves risk to the facial nerve as well as major vessels such as the internal maxillary artery and the masseteric artery. Due to anatomical complexity, the use of conventional bone-cutting tools such as burs and saws may put these vital structures at risk of injury or permanent damage. Given the advantages of piezosurgery as discussed previously in the chapter, its use in this specialized surgery is reasonable and advisable. In 2014, Anson Jose observed less

bleeding along with minimal postoperative complications while treating TMJ ankylosis with piezosurgery [33].

40.5.8 Inferior Alveolar Nerve Preservation

The IAN is at risk whenever there is the need to extract impacted mandibular molars, enucleate large cysts, or remove benign mandibular tumors. In 2009, Dr. Kagan Degerliyurt presented an article describing a procedure called the “bone lid technique,” which is performed by using a piezosurgery device when there is a definitive risk of damage to IAN [34, 35].

40.5.9 Trauma

Piezoelectric devices can be used for reconstruction in multiple trauma cases, such as comminuted frontal bar fractures, to cut and shape the inner table of a calvarial bone graft, to osteotomize a healing fracture while reducing the chance of adjacent tissue injury. Using piezosurgery in post-traumatic cases can help preserve bone, protect adjacent soft tissues, decrease blood loss, improve visibility, and ensure a better overall outcome [36].

40.6 Conclusion

Piezosurgery is a promising surgical tool for safe and effective use in various surgeries. For an oral and maxillofacial surgeon, piezosurgery allows safer and effective osteotomy or osteoplasty compared to conventional rotating instruments such as burs and saw blades, even in complex anatomical areas. Over the past decade, it has not only been increasingly used in OMFS but has been adapted for use in neurosurgery, orthopedic surgery, and otorhinolaryngology. In addition to the surgical advantages, it helps the patient by reducing procedural stress, postoperative swelling, pain and overall improves the surgical experience. The major drawback of piezosurgery is the lack of efficiency or cutting speed, which can be balanced by improved clinical outcomes. Future generations of ultrasonic devices may bring about better efficiency and ultimately replace all conventional cutting tools.

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