Piezosurgery in Dentistry: A Review Article.

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ABSTRACT

Aim: This review aims to explore the development, clinical applications, and biological implications of piezosurgery, with emphasis on its role in modern dental and maxillofacial practice.

Methodology: Relevant publications were identified from peer-reviewed journals covering experimental, clinical, and comparative studies on piezoelectric bone surgery. Articles discussing periodontology, implantology, oral and maxillofacial surgery, and allied specialties were critically evaluated, particularly those contrasting piezosurgery with conventional rotary or oscillating techniques.

Results: Findings consistently demonstrate that piezosurgery enables precise and selective cutting of mineralized tissues while safeguarding soft structures. Its use in sinus floor elevation, ridge expansion, and bone harvesting has been associated with fewer complications, such as Schneiderian membrane perforation and neurosensory disturbances. Laboratory and histological data reveal improved osteoblast viability, reduced thermal damage, and favorable expression of bone-regenerative markers. These biological advantages translate into promising clinical outcomes, including enhanced implant stability. However, limitations remain, notably increased operative time, a learning curve for practitioners, and the relatively high cost of equipment.

Conclusion: Piezosurgery represents a significant advancement in minimally invasive oral surgery, combining surgical precision with biological safety. With continued refinement and integration into digital workflows, its role in contemporary surgical dentistry is expected to expand further.

Keywords: Piezosurgery, ultrasonic osteotomy, implantology, periodontology, bone healing, minimally invasive surgery

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INTRODUCTION

Over the past two decades, dentistry has integrated advanced technologies aimed at improving precision, safety, and healing in surgical procedures. Among the most transformative innovations is **piezosurgery**, a technique that uses ultrasonic microvibrations to selectively cut mineralized tissues while sparing adjacent soft tissues. Since its introduction by Vercellotti in the late 1990s, piezoelectric bone surgery has become increasingly important in periodontology, implantology, oral and maxillofacial surgery, and allied fields such as otolaryngology and craniofacial surgery [1,2,3].

The rationale behind piezosurgery lies in minimizing surgical trauma while enhancing accuracy. Compared to traditional rotary instruments and oscillating saws, piezoelectric devices provide **micrometric precision, selective cutting,**

cavitation-enhanced visibility, and reduced intraoperative bleeding [4,5]. Clinical evidence confirms that the technology facilitates bone harvesting, sinus augmentation, ridge splitting, nerve transposition, orthodontic microsurgery, and maxillofacial osteotomies with improved safety and predictability [6,7,8].

This review summarizes the available literature on piezosurgery, focusing on its **historical background, mechanism of action, clinical applications, biological and biomechanical effects, advantages, limitations, and future perspectives**.

2. Historical Background

The foundation of piezosurgery is the **piezoelectric effect**, first described by Pierre and Marie Curie in 1880. In dentistry, Catuna pioneered the use of ultrasonics in 1953 with the design of an ultrasonic drill for cavity preparation [10]. Richman extended its application to endodontics and apicoectomies in 1957 [11]. Further progress came from Mazarow (1960) and McFall et al. (1961), who reported ultrasonic devices for bone cutting [12,13]. Horton and colleagues (1975, 1981) evaluated ultrasonic osteotomy in alveolar bone defects and confirmed its favorable healing profile compared to burs [14,15].
The modern clinical application of piezosurgery was developed by **Tomaso Vercellotti**, who in 1999 collaborated with Mectron Medical Technology to design the first dedicated piezosurgery unit. His initial clinical report in 2000 described ridge expansion for implantology [5] .By 2001, the device was applied for sinus membrane elevation [6] .In 2005, the **U.S. Food and Drug Administration (FDA)** approved piezoelectric devices for bone surgery, cementing their role in surgical dentistry [16].

Since then, piezosurgery has been widely adopted for procedures ranging from impacted canine exposure to complex maxillofacial osteotomies [7,8,17,18].

3. Mechanism of Action

Piezosurgery works through **ultrasonic vibrations at frequencies between 24–36 kHz**, generated by piezoelectric transducers that convert electrical energy into mechanical oscillations [19]. These micrometric vibrations (60–200 µm) are transmitted to surgical tips specifically designed for tasks such as osteotomy, osteoplasty, sinus lifting, or graft harvesting.
A defining feature of piezosurgery is **selective cutting**. Bone is cut effectively at lower ultrasonic frequencies, whereas soft tissues such as nerves and vessels require frequencies above 50 kHz, ensuring they remain unaffected [20,21].

The **cavitation effect**, produced by irrigation in the oscillating field, leads to imploding microbubbles that clear the surgical site of blood and debris, improve visibility, and contribute to bactericidal effects [17]. Controlled irrigation also prevents thermal injury by dissipating heat, a major concern with rotary drills[22,23]

A typical system consists of a **main unit with control panel**, a peristaltic pump for irrigation, and a lightweight handpiece with interchangeable tips [24,25]

4. Clinical Applications

4.1 Periodontology

Piezosurgery has been applied in crown lengthening, flap surgery, and regenerative procedures. Vercellotti demonstrated enhanced outcomes in osseous resective therapy using piezoelectric instruments compared with burs [26]. Orthodontic microsurgery using piezosurgery allows precise cortical bone cuts to accelerate dental movement with minimal trauma [27].

4.2 Implantology

Implant dentistry represents one of the most significant fields for piezosurgery:

- **Bone harvesting**: Autogenous bone blocks and chips obtained with piezosurgery show higher cell viability and better morphology than those harvested with burs [19,28,29] .
- **Ridge expansion and split-crest techniques**: Studies have reported high implant survival rates with ultrasonic ridge splitting [8,30,31] .
- **Sinus floor elevation**: Piezosurgery reduces Schneiderian membrane perforation rates compared with conventional instruments, as confirmed by Wallace et al. and Barone et al. [32,33].
- **Implant site preparation**: Randomized trials indicate that piezosurgery can improve implant stability compared with rotary techniques [34,35].

4.3 Oral and Maxillofacial Surgery

Applications include mandibular sagittal split osteotomy, cyst removal, nerve transposition, and TMJ ankylosis surgery. Geha et al. reported reduced neurosensory complications after sagittal split osteotomy using piezosurgery [36]. Robiony et al. demonstrated its application in multipiece maxillary osteotomies [37], while Kotrikova et al. highlighted its safety in cranial osteoplasty [38].

4.4 Other Surgical Fields

Beyond dentistry, piezosurgery has expanded to **ENT surgery** for rhinoplasty and otologic interventions [39,40], and to craniofacial and neurosurgery, where soft tissue preservation is crucial [3].

5. Biological and Biomechanical Effects

Histological and cellular studies have demonstrated favorable biological responses with piezosurgery. Preti et al. reported earlier expression of bone morphogenetic proteins and transforming growth factor β2 compared to rotary osteotomy [41]. Chiriac et al. and Sivolella et al. confirmed superior osteoblast viability in bone harvested with piezosurgery [28,29].

Animal models showed reduced osteonecrosis and improved lamellar bone formation in piezoelectric osteotomy sites compared to burs [42–44]. Studies on intraosseous temperature rise demonstrate that piezosurgery, when combined with irrigation, results in less thermal damage than conventional drilling [22,23,45,46].

Biomechanically, randomized clinical trials have shown that implants placed in piezosurgery-prepared sites achieve stability comparable to, or better than, rotary-prepared sites [34,35].

6. Advantages

The main advantages of piezosurgery include:

- **Micrometric precision** in bone cutting [1,4,20].
- **Selective action**, sparing nerves and vessels [32,33,38].
- **Improved surgical visibility** due to cavitation [17,21].
- **Enhanced biological response**, including higher cell viability and accelerated bone healing [28,41].
- **Reduced postoperative morbidity**, with fewer neurosensory complications [36].

7. Limitations

Despite its benefits, piezosurgery presents challenges:

- **Longer operative times**, especially in dense bone [23,37]
- **Learning curve** for clinicians unfamiliar with ultrasonic devices [47].
- **High equipment cost**, which may limit accessibility [16].
- **Reduced efficiency** in cutting highly mineralized bone [22,46].

FUTURE PERSPECTIVES

Next-generation piezosurgery devices offer higher power, ergonomic improvements, and multipurpose applications [24,25]. Integration with **computer-guided surgery, navigation, and robotics** could further improve precision.

Emerging research indicates that ultrasonic osteotomy may positively modulate molecular pathways involved in bone regeneration, including growth factor expression and angiogenesis [41]. With expanding applications in ENT, craniofacial, and orthopedic surgery [3,39,40], piezosurgery is poised to become an even more versatile surgical tool.

CONCLUSION

Piezosurgery represents a paradigm shift in oral bone surgery by combining selective cutting, improved surgical control, and favorable biological outcomes. Evidence across periodontology, implantology, and maxillofacial surgery demonstrates its superiority over traditional instruments in terms of safety, healing, and patient outcomes. Although cost, operative time, and technical demands remain limitations, ongoing technological improvements and broader adoption suggest that piezosurgery will continue to play a central role in minimally invasive surgical practice.

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