Piezosurgery: Transforming Periodontal Procedures with Precision and Safety

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ABSTRACT

Piezoelectric surgery is a boon to periodontics, providing increased control and safety during various periodontal surgeries. Piezoelectric devices perform selective hard tissue cutting while the surrounding soft tissues experience minimal trauma due to ultrasonic vibrations. The current development and progression of piezosurgery in periodontal therapy have been thoroughly discussed in this paper. This review explores piezoelectric technology and examines its effects on clinical outcomes, including patient comfort, hospitalization duration, healing time, and procedure efficacy, compared to conventional surgeries.

The review overviews current research findings and highlights benefits such as decreased thermal damage, enhanced tissue preservation, and increased visual field during surgery. Furthermore, it addresses the limitations and potential concerns with piezosurgery, expense, and the practitioner learning curve. Moreover, it aims to address the limitations and potential concerns with piezosurgery, cost, and the practitioner learning curve. It is intended to offer a more nuanced view on incorporating piezoelectric surgery in periodontal therapy and forecast future directions by evaluating the current evidence and individual clinical experience.

Keywords

piezosurgery, ultrasonic devices, bone cutting, periodontal therapy, soft tissue management, bone harvesting, minimally invasive, surgical precision, osseous surgery, healing.

INTRODUCTION

In the last few decades, developments have occurred in dental surgery, primarily through piezoelectric ultrasonic vibration in dentistry and periodontics [1–3]. Previously, only manual or

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motorized instruments were used for skeletal surgeries. When working with small amounts of bone in low-density areas, manual instruments offer excellent control; however, they are not appropriate for dense cortical bone and are used for working on large segments of bone [4]. Denser bone responds better to motor-driven instruments [5]; however, there are certain drawbacks as well, including the potential for heat-induced tissue damage [6], loss of control over the instrument [7], inability to feel the surface of the bone [8], inability to gauge the thickness of the bone to be removed, risk of injuring unintended areas, and the likelihood of injuring vital structures such as the maxillary sinus or inferior alveolar nerve [9].

Heat is a factor that impedes the healing process [10]; thus, these instruments employ either a bur or a saw blade to transfer energy into the cutting action. As a result, water spraying is required to reduce heat in the cutting area. Additionally, the slower speeds of motorized cutting tools require more pressure on the tool [11], which increases macro vibrations and decreases tactile sensitivity. This is particularly true when the surgeon attempts to make incisions above the mandibular canal or create lateral windows for sinus grafting to move from cortical bone into softer tissue. The force required for dense bone must be released to avoid injuring the underlying tissue [12].

Ultrasonic vibration cutting has been in practice for approximately three to four decades. It has been adopted as a standard clinical practice in different surgical specialties in the last two decades. An osteotomy minimizes damage to adjacent soft tissues and other crucial structures like arteries and nerves. Electric current is passed through specific crystals and ceramics via ultrasonic equipment, causing micro-vibrations and oscillations. At 25-29 kHz, it is possible to make micro-movements within the range of 60-210 μm[1,13], which allows the removal of mineralized tissue without damaging neurovascular and other soft tissues, which demands higher frequencies [12,14,15].

One of the tremendous benefits of ultrasonic cutting is that one can change the frequency depending on the mineralization of the bones and,[16] hence, cut according to the type of bone [17]. Standard piezoelectric instruments consist of a handpiece and a foot switch connected to a primary power source; the irrigation fluids are provided by a peristaltic motor with adjustable flow rates of 0 to 60 ml/min. This setup guarantees that cutting is precise and debris is washed away while keeping the working area free from blood by cavitation of the irrigation solution, which also improves visibility, especially in regions with rugged topographical terrain. It is recommended that piezoelectric inserts should be oscillated at high frequencies and with low force [18].

Current piezoelectric devices available in the market come in different sizes, shapes, and inserts. The newer models are favored since they contain built-in programming for various procedures and have better visibility and minimal blood loss from the cavitation effect [19]. This effect occurs when liquid meets ultrasonic frequencies, which cause the bubbles to implode, thus enabling the fluid to be dispersed and turned into an aerosol (Figure 1).

Problem Statement of this Review Paper

Periodontal surgical procedures have improved over time, but there are still several disadvantages that traditional surgical techniques pose, such as inadequate control over the hard tissues, delayed rate of healing, and severe soft tissue injury. One such surgical method that has been shown to offer better control and less harm to adjacent tissues is piezosurgery, which employs ultrasonic vibrations. Further information regarding its prognosis, hazards, and efficacy in periodontal therapy is currently lacking. To better understand the potential of piezosurgery to improve periodontal therapy outcomes, this review article aims to critically analyze the literature on the subject, highlighting its advantages, disadvantages, and overall effectiveness compared to traditional surgical techniques.

Objectives of The Study

Researchers have upgraded therapeutic devices that use ultrasonic micro-vibrations to accurately cut bone in harmony with surrounding tissue, overcoming the limitations of standard instruments. The purpose of the study is to describe the advancement of piezosurgery, as well as the armamentarium, indications, contraindications, clinical application in periodontology and implantology, and limitations [20].

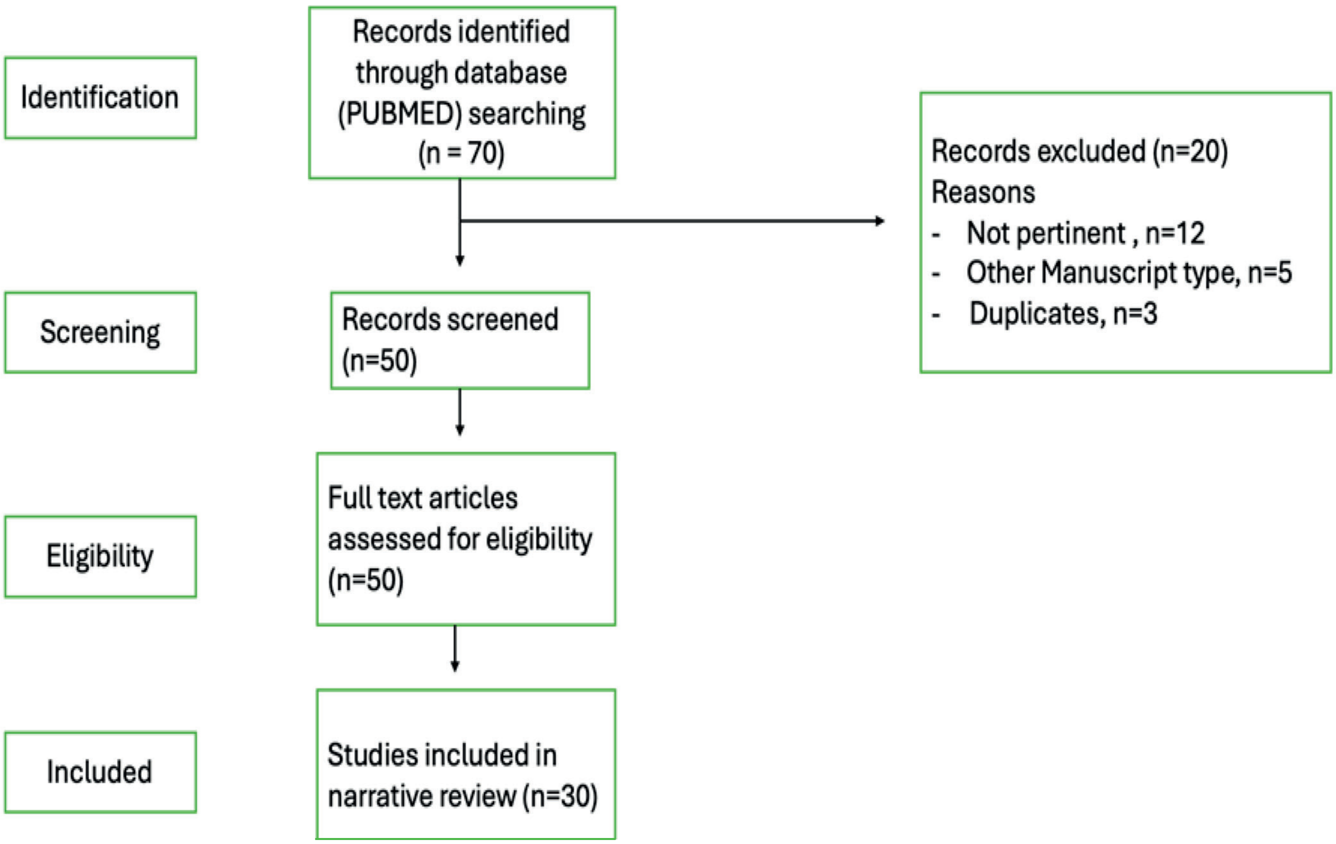

Figure 1: **Piezosurgery device functioning.**

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MATERIALS AND METHODS

Background And Physical Properties

Since 1955, periodontologists have used ultrasonic technology, which produces sound pressure waves with frequencies higher than human hearing (30–20 kHz), to treat periodontal disease and mechanically remove dental hard tissue [14,18,21]. When used in a clinical setting, ultrasonic waves are superior to conventional scaling because they may effectively remove calculus, retrieve broken instruments, and remove root canal fillings. Ultrasound, which uses electrical energy to produce ultrasonic waves through magnetostriction or piezoelectricity, is used in thermal, mechanical, and chemical processes. Piezo effect, discovered by Jean and Marie Curie in 1880, is the phenomenon in which mechanical stress on crystals produces electric current and vice versa [22].

A polarized piezoceramic expands and contracts in response to an alternating voltage, and oscillations occur at specific frequencies and amplitudes. This process results in beam variation at the tissue boundaries because of absorption, reflection, and diffraction [23]. It has been reported that for many years, ultrasonography has been used in periodontics to degranulate periodontal defects, remove calculus [24], and debride root surfaces [25]. Ultrasonic frequency-operating devices have revolutionized maxillofacial bone surgery in the last few years. In 1997, Tomaso Vercellotti pioneered using ultrasonic devices in periradicular osteotomy and developed Piezosurgery® in 1999 as a product of Mectron Medical Technology, which differentiated it from ultrasonic bone surgery [26]. This device employs a piezoelectric ultrasonic transducer and generator to drive various cutting inserts [27].

Piezosurgery procedures have gone beyond dentistry and have been adopted in craniofacial, cranial,[28] spinal neurosurgery,[29] and hand-foot surgery because of their excellent cutting capabilities [30]. Piezoelectric bone surgery offers three key benefits: high precision, rapid tissue healing, and minimal tissue injury [6,31]. Clinical studies show that the specificity of the procedure and the techniques employed in piezoelectric bone surgery are beneficial concerning the distinctions between the hard and soft tissue anatomy, thereby enhancing the therapy and the recovery period (Figure 2) [32].

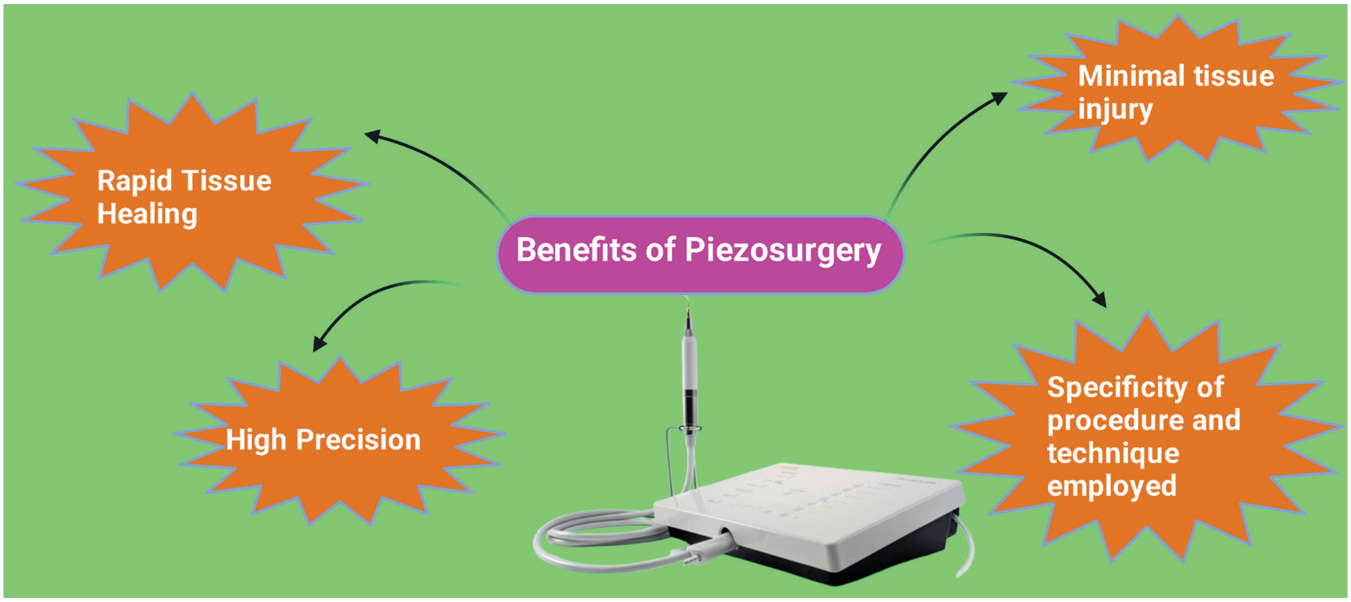

Figure 2: Benefits of Piezosurgery.
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Surgery is known to disrupt the normal physiology of the body by cutting off the blood flow to the tissues;[33] hence, surgical trauma should be kept to a minimum as much as possible. Surgical invasiveness determines whether a wound heals by repair or regeneration, which is a critical feature in tissue healing quality [34]. Reducing surgical stress stimulates the body's natural healing mechanisms and encourages tissue regeneration [35]. Conversely, more invasive techniques result in fibrosis and repair instead of tissue regeneration. Therefore, selecting the least stressful surgical instruments and methods is best for any surgical procedure [36].

MECHANISM OF PIEZOELECTRIC GENERATION

Piezoelectric generation in ultrasonic devices works through a generator that generates an electric current fed through piezo-ceramic rings [37]. This current deform the rings, which vibrate the amplifier or transducer to produce ultrasonic waves [38]. These waves travel to the insert, or handpiece tip, where the bone is cut or fractured using a longitudinal motion. Electrical pulses are transformed into mechanical vibrations and vice versa using ultrasonic technology [39]. The transducer's active element is a polarized material with opposite-facing electrodes. This material contains both anions and cations. When an electric field is applied, the polarized material changes in dimensions, causing the molecules to align with the field, generating induced dipoles inside the material's crystal or molecular structure [40]. This measurement of the polymer's dielectric anisotropy is called electrostriction [41].

Furthermore, when mechanical stress is applied, materials such as quartz (SiO2) or barium titanate (BaTiO3), which have permanent polarization, produce an electric field called the piezoelectric effect [42]. Almost all modern acoustic transducers incorporate piezoelectric ceramics as their active elements, which can be oriented in several ways to generate specific waveforms [30].

During the initial phase in the 1950s, low voltage and 300°C-operating magnetostrictive quartz crystals were employed as materials. Today's most common ceramics used in transducer production are lead zirconate titanate compositions, which replaced barium titanate as the first widely used piezo-ceramic material in the 1960s [43]. In specific applications, novel materials, including piezo-polymers and composites, have also been employed [44].

Clinical Characteristics of Piezosurgery

Considerable clinical advantages of piezosurgery include micro-precision,[27] selective cutting,[45] visibility, and favorable healing [46]. The cutting action is caused by mechanical micro-vibrations, multifrequency ultrasonic vibrations with a linear movement of 20 to 80 µm [47]. The efficiency of inserts influences this range. Heat generation from energy dissipation during ultrasonic cutting can be minimized by changing the frequency [48].

Micro-precision: Piezosurgery is a technique of cutting mineralized tissues using micro-vibrations at approximately 30,000 cycles per minute [4]. The mechanical energy needed is low, and in conjunction with water spray, it enhances the removal of bone fragments [49]. Piezosurgery requires gentle handling, which offers the most excellent control during surgery—especially in delicate parts of the body—in contrast to traditional handpieces that produce micro-vibrations.

Selective Cutting: The ultrasonic micro-vibrations only remove the mineralized tissue while sparing the soft tissue [6]. This property makes it possible to preserve vital tissues like nerves and membranes even when making an incision on the bone [50].

Maximum Visibility: One benefit of piezosurgery is the cavitation effect, which prevents blood from seeping into the surgical site during cutting [32]. This is accomplished by halting the bleeding of hard and soft tissues with a small amount of hydropneumatic pressure. Regulating liquid flow and interrupting cutting is necessary to maximize microcirculation, particularly during lengthy surgeries [51].

Excellent Healing: Compared to rotary instruments, piezosurgery has been reported to have fewer postoperative complications in patients, such as bleeding and swelling [52]. Additionally, piezosurgery allows the physician the most efficient surgical control while requiring less force to create an incision. This control is particularly critical when working on tissues that have a complicated arrangement to avoid complications during the surgery [53–55].

Clinical Applications of Piezoelectric Surgery

Piezoelectric surgery has a robust evidential background, and a vast amount of research has looked into bone healing and the biological response of the hard and soft tissues after piezoelectric osteotomy [56]. Nevertheless, it is evident that piezosurgery has numerous advantages, but the outcomes are contingent on the patient's characteristics and the surgeon's experience [36].

Efficiency and Limitations: Piezosurgery is also criticized as a time-consuming procedure [31]. Unlike conventional drilling, where the cutting speed can be manually changed, this approach depends on the selected power settings. Combining piezosurgery with conventional high-speed rotary instruments for comprehensive bone surgery is recommended. However, piezosurgery is recommended for all bone surgeries due to its intraoperative safety.

Bone Harvesting: The most preferred technique for determining lost bone volume is autologous bone to correct and reconstruct bony defects [57]. In the case of block graft harvesting, conventional tools are appropriate but not for bone chips. Piezosurgery solves this problem by having cutting tips specially designed for the surgery that is to be performed. These tips are intended for usual dental operations with variable power parameters that make piezoelectric technology a standard in dental operations [17].

Clinical Applications: In dentistry, piezosurgery has replaced conventional tools such as bone saws, drills, chisels, and burs. The following are the techniques and protocols for oral, periodontal, and implant procedures that Professor T. Vercellotti has established in the past ten years: Maxillary sinus augmentation, bone augmentation, inferior alveolar nerve repositioning, periodontal surgery, crown lengthening, tooth removal, alveolar ridge augmentation, and orthodontic microsurgical surgeries are among the many uses of piezosurgery in dentistry [58].

Periodontology Applications

Table 1: Illustrating Application of Periodontology.

Number of Application	Application of Periodontology and References
1	Supra and subgingival scaling and root planning [53,59].
2	Surgical removal of the periodontal pockets [53,59].
3	Crown lengthening [53,59].
4	Periodontal regeneration by bone grafting [53,59].

Number of Application	Application of Periodontology and References
5	Osteoplasty and osteotomy for the correction of bone defect [53,59].

Implantology Applications

Table 2: Illustrating Application of Implantology.

Number of Application	Application of Implantology and References
1	Implant site preparation [17,30].
2	Surgery involving the placement of an implant at the time of tooth removal [17,30].
3	Bone graft harvesting [17, 30].
4	Alveolar ridge expansion [17,30].
5	Distraction osteogenesis [17,30].
6	Sinus lift procedures [17,30].
7	Lateralization of the inferior alveolar nerve [60]
8	Implant removal [17,30].

Advantages of Piezosurgery Over Traditional Instruments

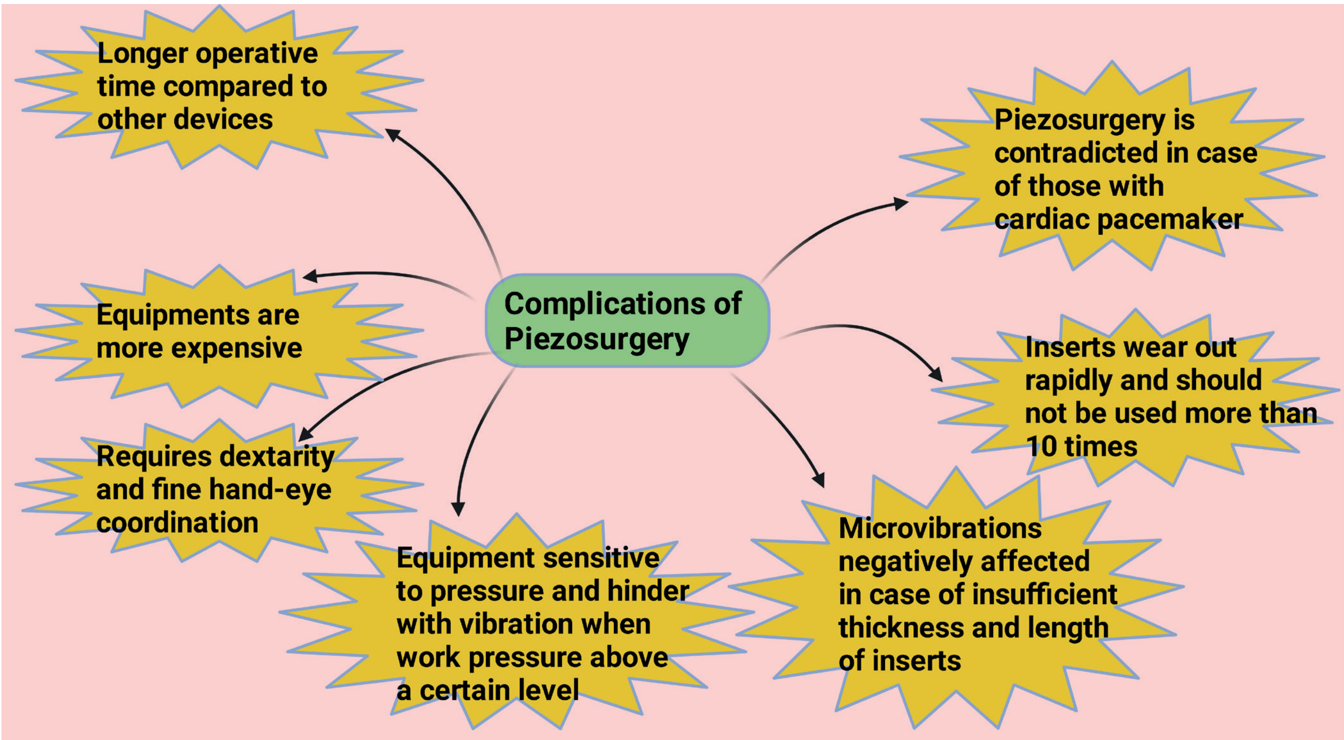
Table 3: Depicting Advantages of Piezosurgery Over Traditional Instruments.

No of Advantage	Advantage Towards	Findings and References
1	Enhanced Safety and Precision.	The frequency of the piezosurgery device is ultrasonic, which makes surgeries safer and improves operator control [18,21,53,61,62].
2	Power and Efficiency.	Piezosurgery units are three times more effective than conventional ultrasonic units for cutting highly mineralized tissue [18,21,53,61,62].
3	Minimal Bleeding.	The device minimizes bone/tissue bleeding, which is very important for visualization of the operating area [18,21,53,61,62].
4	Faster Healing.	It also enhances bone formation and healing rate [18,21,53,61,62].
5	Reduced Postoperative Pain.	The cutting action is much less aggressive; therefore, the tissue damage is reduced, allowing for better healing and little or no pain [18,21,53,61,62].
6	Lower Noise Levels.	It is less noisy than other motor-driven equipment, hence minimizing patient fear and psychological stress
7	Reduced Effort.	It uses less force for cutting than drills or oscillating saws and is much easier to control [18,21,53,61,62].
8	Cavitation Effect.	This prevents the irrigating solution from contacting the adjacent soft tissues, and the oscillating tips maintain a clear surgical site. This prevents the irrigating solution from contacting the adjacent soft tissues, and the oscillating tips maintain a clear surgical site [18,21,53,61,62].
9	Easy Graft Harvesting.	Enables the harvesting and molding of intra or extra-oral autogenous grafts to match the recipient site precisely [18,21,53,61,62].
10	Accessibility.	Angled inserts enable usage in those areas that are difficult to visualize and access [18,21,53,61,62].
11	Emphysema Risk.	The risk of developing emphysema is eliminated [18,21,53,61,62].
12	Sterility.	Asepsis is preserved by maintaining the sterility of water [18,21,53,61,62].
13	Temperature Control.	A cooling solution at 4° C is applied to the tissue to avoid overheating during the procedure [18,21,53,61,62].

Disadvantages of Piezosurgery

Table 4: Depicting Disadvantages of Piezosurgery Over Traditional Instruments.

No of Disadvantages	Disadvantages Towards	Findings and References
1	Longer Operative Time.	Compared to other devices, piezosurgery could take longer to complete [44,61].
2	Higher Equipment Cost.	The device is relatively more expensive than manual or motor-driven devices [44,61].
3	Learning Curve.	It requires dexterity and fine hand-eye coordination, which is a different learning curve [44,61].
4	Pressure Sensitivity.	Working pressure above a particular level can hinder vibrations, transforming energy into heat. Optimal use is characterized by higher speed and lower pressure [44,61].
5	Limitations in Deep Osteotomies.	Insufficient length and thickness of the inserts can result in higher hand pressure and, therefore, negatively affect micro-vibrations [44,61].



No of Disadvantages	Disadvantages Towards	Findings and References
6	Rapid Wear of Inserts.	They quickly wear out and should not be used more than ten times during bone surgery to prevent fracture or heat injury [44,61].
7	Pacemaker Precaution.	Contraindicated in patients with cardiac pacemakers [44,61].

Figure 3: Shortcomings of Piezosurgery.

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CONTRAINDICATIONS

Piezosurgery is contra-indicated in patients with cardiopathy, uncontrolled diabetes mellitus, metal or ceramic crowns, pacemakers, and radiotherapy. Also, age is a relative contraindication to any surgery [63].

Precautions for Using Piezosurgery Devices

Using piezosurgery devices necessitates specialized surgical skills to ensure precise procedures. A notable disadvantage is the significantly longer operating time required for bone preparation. Denser bone cutting can lead to quicker tip wear, and working with corticomedullary bone increases the risk of ultrasonic tip fractures. Therefore, thorough inspection and replacement of tips before use are crucial [64].

While piezosurgery significantly lowers the risk of damaging soft tissues like the sinus floor membrane, nerves, and blood vessels, safety precautions remain essential. The ultrasonic waves generate mechanical energy that can convert to heat, potentially affecting nearby tissues. To prevent overheating and leverage the cavitation effect, appropriate irrigation is vital. The intensity of the cooling liquid can be adjusted based on the specific requirements of different preparations [60].

Limitation of the Study

The review may include only studies with positive results, which could distort the results. Differences in research designs, surgical methods, and assessment standards among the included studies may make it more difficult to compare and synthesize the findings. The limited scope of treatments or results may be the focus of the evaluation, which could lead to the omission of critical aspects of piezosurgery in periodontics. Studies with positive outcomes may be overrepresented because they are more likely to be published than studies with negative or equivocal findings. Variations in the expertise and proficiency of the piezosurgery practitioners can result in different outcomes that are not considered in the study. Future reviews could enhance the validity and relevance of the results pertaining to piezosurgery in periodontics by addressing these shortcomings.

Future Research Recommendation

Conduct longitudinal studies to evaluate the long-term impact of piezosurgery on tissue regeneration and periodontal repair compared to conventional surgical techniques. Randomized controlled trials can also be conducted to assess the relative merits of piezosurgery vs. alternative surgical approaches for a range of periodontal treatments, including bone grafting and flap surgeries. Investigate improvements in vibration frequency, cutting efficiency, and tips explicitly made for periodontal applications in piezoelectric devices. Examine the possibilities of piezosurgery to create customized treatment regimens and the role of imaging technology in surgical planning. These research areas could significantly enhance the understanding and application of piezosurgery in periodontics, leading to improved patient outcomes and surgical techniques.

CONCLUSION

Piezosurgery is a novel skeletal surgery technique with numerous clinical applications in dentistry. It is considered superior to other procedures since it is less invasive, extremely accurate, and has a fast-healing period. It has been postulated that its biological impact on bone is better than that of traditional motorized instruments concerning implant osseous healing, remodeling, and osseointegration. Moreover, piezosurgery has the potential to redefine minimally invasive surgery in osteotomy and osteoplasty procedures by replacing conventional methods.

Although a relatively recent technology, the piezo-surgical device operates based on tunable frequency and power. Its ultrasonic micro-vibration technology, which targets the mineralized tissues and spares the other soft tissues, nerves, and vessels, allows for exact and secure bone cutting. When used appropriately, this technology can considerably aid in performing precise bone procedures, making it an invaluable medical tool

CONSENT FOR PUBLICATION

The author reviewed and approved the final version and has agreed to be accountable for all aspects of the work, including any accuracy or integrity issues.

DISCLOSURE

The author declares that they do not have any financial involvement or affiliations with any organization, association, or entity directly or indirectly related to the subject matter or materials presented in this review paper. This includes honoraria, expert testimony, employment, ownership of stocks or options, patents, or grants received or pending royalties.

DATA AVAILABILITY

Information for this review paper is taken from freely available sources.

AUTHORSHIP CONTRIBUTION

All authors contributed significantly to the work, whether in the conception, design, utilization, collection, analysis, and interpretation of data or all these areas. They also participated in the paper's drafting, revision, or critical review, gave their final approval for the version that would be published, decided on the journal to which the article would be submitted, and made the responsible decision to be held accountable for all aspects of the work.

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