Piezosurgery, advantages of ultrasound surgery in zygomatic implantology: a case report

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Abstract

Zygomatic implantology represents a consolidated solution for the rehabilitation of patients suffering from severe maxillary atrophy, offering a valid alternative to traditional bone grafting techniques. This technique, first introduced by Professor Branemark in 1998, is based on the anchorage of dental implants in the zygomatic bone, an anatomical structure characterized by high density and resistance to resorption. Unlike the maxilla, the zygomatic bone does not suffer the negative consequences of age, oral cavity pathologies, or tooth loss, ensuring high primary stability for the implants. In recent years, zygomatic implantology has evolved significantly, transitioning from transsinus techniques, which traversed the maxillary sinus, to juxta-sinus techniques, which minimize maxillary sinus involvement and reduce the risk of complications. In this context, piezosurgery, an innovative technique that uses ultrasonic micro-vibrations for bone cutting, is a promising option for zygomatic implantology, potentially improving clinical outcomes and patient comfort. This abstract analyzes the benefits of piezosurgery in zygomatic implantology, highlighting the advantages of precision, minimal invasiveness, and osseointegration. The case presented concerns a 76-year-old female patient with severe upper maxillary atrophy. A Zygoma Hybrid was successfully performed by inserting two zygomatic and two axial implants using the "Minimally Invasive Technique."

Keywords: Piezoelectric osteotomy; zygomatic implantology; ultrasonic surgical protocols; extrasinus implant site preparation.

Introduction

Piezoelectric bone surgery, developed by Dr. Tomaso Vercellotti in 1988, represents an innovative method in oral and maxillofacial surgery for dentistry (1). Numerous authors have recognized the scientific validity of this method, resorting to experimental studies on animal models that have shown how bone repair and remodeling are facilitated by using piezoelectric surgery (2, 3). These scientific bases have allowed piezoelectric surgery to be applied to other medical disciplines that deal with bone surgery, such as otolaryngology, neurosurgery, ophthalmology, traumatology, and orthopedics (1).

Overview of Piezoelectric Surgery

Unlike conventional cutting techniques with rotating instruments with diamond and tungsten carbide burs, piezoelectric surgery involves instrumentation with dedicated ultrasound inserts (1, 3). This method, as supported in the literature, is clinically valid and effective as it allows osteotomy to be performed, like traditional rotary instrumentation, but with the advantage of the absence of lamellar fragmentation and overheating pigmentation at the microscopic level in the treated areas (1, 2).

Piezosurgery is based on the generation of the inverse piezoelectric effect, a phenomenon described by Lippmann following the studies of the Curie brothers on the direct piezoelectric effect. According to the inverse piezoelectric effect, crystalline bodies, defined as piezoelectric transducers, deform elastically by compressing and expanding as a function of the frequency variation of the electric field (3, 4). The passage of electric current through the piezoelectric crystals generates ultrasonic frequency oscillations that manifest as mechanical micro-vibrations that are transferred through an amplifier to a tip, defined as an insert, which, applied with light pressure to the bone tissue, causes a selective mechanical cut for the mineralized tissue (4). During the piezoelectric insert, part of the mechanical energy is not used for the cutting action but is immediately transformed into thermal energy and transferred to the bone tissue (5). However, the thermal energy produced is partially dissipated by the refrigeration system of the piezoelectric unit that passes through the handpiece and allows the outflow of physiological solution with a flow of 0-60 ml/min that avoids overheating damage (4). The physiological solution in contact with the insert, vibrating at an ultrasonic frequency, generates the cavitation effect. This phenomenon, by reducing bleeding and promoting hemostasis, is responsible for maintaining maximum intraoperative visibility, cleansing the osteotomy groove, tissue oxygenation, a good postoperative course, and, in the field of implantology, the outflow of bone fragments from the surgical site (4, 5).

Using piezoelectric transducers that generate mechanical micro-vibrations at an ultrasonic frequency, with a linear oscillation amplitude ranging from 20 to 100 microns, gives an excellent cutting capacity through a minimally invasive surgical procedure (5, 6). The main operational characteristic of ultrasonic instrumentation is to allow selective cutting of bone tissue without damaging the soft tissues that could accidentally come into contact with the insert during osteotomy (6). This minimally invasive surgical procedure, therefore, allows intraoperatively to perform micrometric and precise osteotomies in all directions with minimal loss of bone tissue in areas previously considered anatomically inaccessible (7). The execution of accurate and conservative osteotomies, without resorting to manual instruments such as scalpels and surgical hammers, allows the intraoperative process and the patient's post-operative course to be made more comfortable due to reduced edema and the absence of hematomas (7). The sound produced during the cutting action can also be used as acoustic feedback to regulate the force applied (8).

It is important to emphasize that these considerations do not depend solely on the properties provided by the inverse piezoelectric phenomenon but add to the manageable structure of the ultrasonic handpiece, whose inserts allow facilitated access to the operating field (7, 8).

Applications of Piezoelectric Surgery in Dentistry

Ultrasound surgery is used in dentistry as it allows micrometric cuts without the risk of damaging soft tissues and noble structures. Several studies emphasize how the orthodontic branch uses piezoelectric surgery for orthodontic traction of the lower third molar, for the closure of edentulous spaces, and to speed up orthodontic movement through corticotomies (9-11).

In the field of oral surgery, the indications for resorting to the use of ultrasound include extraction surgery (with reference to both simple and eighth tooth extractions with particular proximity to the inferior alveolar nerve and germectomies), implant surgery, endodontic surgery and the removal of cystic lesions (12-17).

Many indications for piezoelectric device use are also found in maxillofacial, orthognathic, and reconstructive surgery (1, 16-17).

Piezoelectric Surgery in Implant Surgery

Using ultrasound in the field of implantology allows oral surgery procedures such as maxillary sinus lifts, implant site preparation, and alveolar crest expansion to be performed (1).

The positioning of an endosseous implant is inevitably followed by an inflammatory reaction, correlated to the extent of the insult and the type of material inserted, which activates the cascade of events responsible for the osseointegration of the implant itself. Excessive intraoperative trauma, related to thermal, mechanical, and vascular factors, is considered the leading cause of implant failure as it is responsible for the formation of necrotic tissue at the bone-implant interface that prevents implant osseointegration if excessively extensive (18). The extent of necrotic tissue formed depends on the overheating of the surgical site and, therefore, more specifically, depends on the intraoperative temperature reached and its persistence over time. The literature defines "threshold temperature" as reaching 47°C; beyond this reference temperature value, potentially irreversible biological damage can occur (5, 18-19).

Traditional implant site preparation involves using steel burs mounted on an implantology micromotor or, in specific cases with poor bone quality, using osteotomes (20). Although preparation is carried out in the most atraumatic way possible with the conventional technique using helical burs to increase diameter cooled by external irrigation, the initial phlogistic reaction will inevitably be followed by the appearance of a necrotic area around the surgically created bone defect (20-26). The factors that influence the excessive development of heat during implant preparation with the conventional method depend on the operator (pressure and movement on the bur, preparation technique and time, bur rotation speed), the rotating instruments used (design, diameter, and cutting effectiveness, irrigation) and the implant site itself (cortical thickness and preparation depth) (20).

The introduction of ultrasound surgery in implant preparation has allowed the exploitation of micrometric cutting and the favorable tissue response in the postoperative course (20-26). Micrometric cutting favors the correct preparation of the implant site by making intraoperative preparation axis corrections, thus allowing the implant to be positioned with the correct case angle (24). Furthermore, the cavitation effect and ultrasonic vibrations produce a practical cleansing effect at the level of the trabeculae of the spongiosa, removing the debris produced during cutting and speeding up the healing process; under microscopic examination, the cutting surface appears perfectly clean, unlike surfaces treated with the conventional technique (25). It is, therefore, possible to conclude that in implant preparation, micrometric cutting associated with correct irrigation allows valid osteotomies to be performed using the appropriate inserts whose temperatures remain below the threshold value of 47°C (5, 18).

In 2005, Vercellotti compared, through a study on an animal model, bone healing following osteotomy and osteoplasty performed with burs mounted on an implant motor and piezoelectric inserts at 14, 28, and 56 days after implant placement in histological, immunohistochemical, and biomolecular terms. The autopsy samples, consisting of implant and bone for implanting, at the histological and immunohistochemical examination showed, in the sites prepared with piezoelectric inserts, a more significant number of osteoblastic cells and a smaller number of inflammatory cells (polymorphonucleates, mononucleates) compared to the sites prepared with burs (1, 18). This study has thus made it possible to demonstrate that the preparation of the implant site with traditional burs induces a more significant inflammatory response, unlike the sites prepared with piezoelectric inserts that induce early and greater neo-osteogenesis through increased expression of bone morphogenetic proteins and a higher quantity of osteoblasts. The reduced inflammatory response, following the minor trauma, determined by the piezoelectric ultrasonic inserts, induces an earlier activation of the repair and healing mechanisms through greater preservation of the micromorphology of the bone (trabeculae, vessels, anatomical spaces, Hawers and Wolkmann canals) (20-24).

Preti's biomolecular analyses also confirmed these results by analyzing the factors 7 and 14 days after implant insertion: BMP-4, TGF-β2, TNFα, IL-1β, and IL-10. During this period, concerning the sites prepared with piezoelectric inserts, BMP-4, TGF-β2, and IL-10 were increased, while IL-1β and TNFα were reduced. Therefore, This study has made it possible to affirm that the piezoelectric device has stimulated neo-osteogenesis in the peri-implant with a greater quantity of osteoblasts and reduced pro-inflammatory cytokines (26).

Furthermore, as Silva Neto emphasizes, implants inserted using the ultrasound method are more stable in the resonance frequency analysis (27).

Piezoelectric Surgery in Zygomatic Implantology

Implant-prosthetic rehabilitation of edentulous patients is a widely used method that utilizes standardized procedures with excellent predictability. The main limitation of standard implant rehabilitation is the presence of anatomical characteristics unfavorable to implant insertion due to extensive resorption or degenerative processes of the alveolar bones (28). Attempts have been made to address this with regenerative surgical techniques such as bone grafting procedures, the use of short, tilted, or zygomatic implants, maxillary sinus lifts, and inferior alveolar nerve transposition for the insertion and integration of implant devices (29).

Zygomatic implants are used in oral surgery in cases of edentulism with severe atrophy of the maxilla as a valid alternative to bone augmentation procedures and conventional implants (30). Brånemark was the first to introduce the concept of the zygomatic implant, allowing Aparicio to propose the rehabilitation of severely compromised maxillae with this method (30, 31). Although few studies in the literature have long-term data, many authors support the use of zygomatic implants. In these studies, the survival rate ranges from 94.32% to 100% (32-35).

Indications for this form of implant-prosthetic rehabilitation include all cases where the bone volume at the premaxilla level is sufficient to insert standard implants, and the posterior crest is resorbed to the point of not providing support except with the insertion of zygomatic implants themselves (36-38).

Rehabilitation with zygomatic implants involves the insertion of long implants (approximately 30 to 55 mm) that emerge into the oral cavity at the lateral-posterior level, in the premolar area, to obtain anchorage both at the crystal level and at the zygomatic bone level (39-41).

Surgical techniques for the insertion of zygomatic implants are divided into intra- or extra-sinus, depending on whether the inserted implant passes through the maxillary sinus or not (40).

Despite the evolution of surgical techniques and the introduction of the computerized approach, zygomatic implantology procedures have high executive complexity associated with risks and complications (38, 42-46). Risks and complications include damage to anatomical structures near the surgical site, such as the infraorbital nerve, the orbit, and the infratemporal fossa, implant failure, post-operative problems such as sinusitis, paresthesia of the infraorbital or zygomatic-facial nerves, and the formation of oroantral fistulas (42, 43). Additional complications may be secondary to instrumentation unsuitable for the procedure (40).

In zygomatic surgery, the evolution of surgical technique brings continuous improvements to control implant placement and the bone-implant interface and minimize soft tissue detachment, reducing post-operative edema (40, 43-46).

This case report aims, in cases where the anatomy of the specific case allows it, to use an extra-sinus preparation approach using ultrasonic instrumentation. The use of ultrasonic instrumentation in implant preparation in zygomatic implantology procedures is emphasized to highlight the advantages this method provides compared to traditional rotary instrumentation, reducing the invasiveness of the surgical procedure."

Material and Methods

Case Description

A 76-year-old female patient presented to the authors' attention, wearing a complete upper removable denture and a lower partial denture, with masticatory difficulties. The patient's medical history revealed she was being treated with Ramipril 10 mg tablets for hypertension.

The patient was evaluated both clinically and radiographically. The intraoral examination and radiographic assessment of the orthopantomogram (Figures 1-2) indicated the need for implant-prosthetic rehabilitation treatment.

Following the analysis of the second-level radiographic examination, the CBCT, it was decided in agreement with the patient to satisfy her specific request to perform a fixed implant-supported prosthetic rehabilitation for both arches. To achieve optimal implant-prosthetic rehabilitation, given the severe atrophy of the upper jaw, it was decided to opt for a Zygoma Hybrid intervention by inserting two zygomatic implants and two axial implants in areas 1.2 and 2.2 for the upper arch and an All-on-4 for the lower arch.

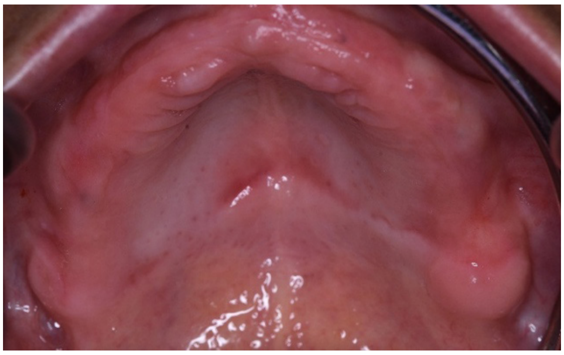

Figure 1. Intraoral Objective Examination

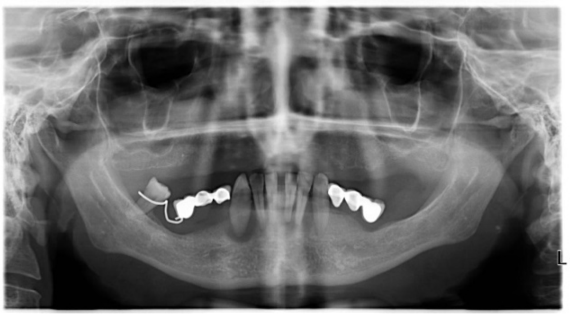

Figure 2. Pre-operative Orthopantomography

The two procedures were performed separately after obtaining specific informed consent for the case. The upper arch procedure was performed under general anesthesia, following an anesthesiology consultation and preoperative examinations.

From a dental standpoint, the procedure began with regional anesthesia of the infraorbital, greater palatine, and nasopalatine nerves using 3% Mepivacaine and infiltration anesthesia with 2% Mepivacaine with 1:100,000 epinephrine.

The surgical phase involved creating a full-thickness mucoperiosteal flap in the para-marginal coastal region, extending palatally from the midline to the area ideally occupied by the second molar, with a posterior vertical releasing incision.

The flap was then carefully elevated both buccally and palatally to expose the anterolateral surface of the maxillary bone, visualizing the nasal fossae, the infraorbital foramen from which the namesake nerve emerges, and finally, the zygomatic bone, exposing the zygomatic body. During this surgical phase, the emergence of the infraorbital nerve was identified, and using a dermatological pen, a horizontal line was drawn above the infraorbital foramen. This line, directed towards the zygomatic body, defines the safety zone where the surgeon can operate, avoiding complications to the orbit.

The next phase involves preparing the implant site using a piezoelectric motor. Osteotomy is initiated on the anterolateral surface of the maxillary bone, tracing the implant path along the plane connecting the buccal region of the residual bone crest to the zygomatic body. During this operational phase, work begins on the anterolateral surface of the maxillary bone at the level of the maxillary sinus without invading it. Using appropriate inserts, the residual alveolar crest is then prepared, creating a buccal bone plate to the coronal third of the implant, and with specific inserts, depending on the length of the implant bed preparation, the procedure is completed at the level of the zygomatic bone (Figures 3-4). The process continues by following the created groove, preparing the cortical bone of the zygomatic body while maintaining the angulation established in the previous preparatory phases.

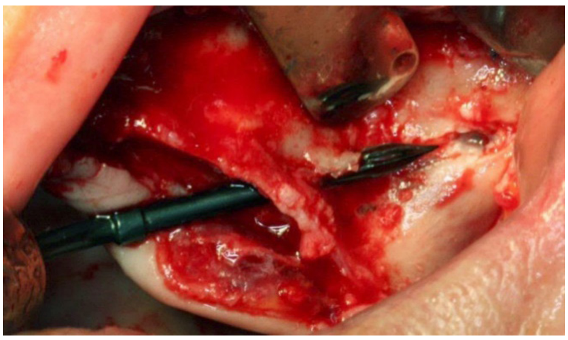

Figure 3. Implant Site Preparation Using Ultrasonic Instrumentation

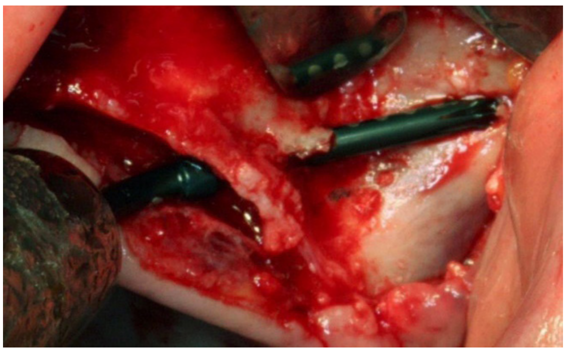

Figure 4. Implant Site Preparation Using Ultrasonic Instrumentation

The implant length is confirmed by measuring the preparation depth with a specific millimeter probe.
The next phase involves manually inserting the implant with a minimum torque of 35 Ncm, ensuring that the crystal emergence is favorable for prosthetic abutment access.
In each hemiarch, a 3.5 mm diameter and 42.5 mm length zygomatic implant and a 4 mm diameter and 11.5 mm length axial implant were inserted (Figure 5).

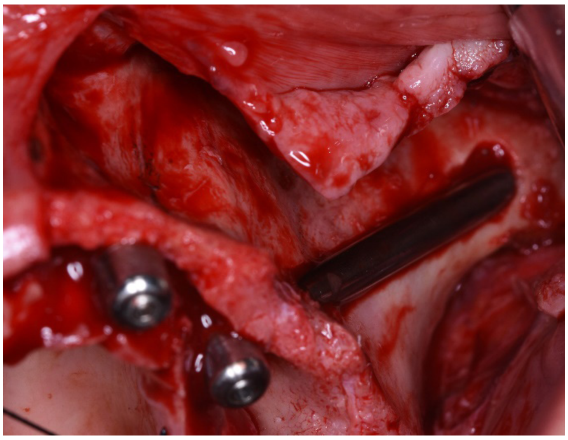

Figure 5. Zygomatic Implant Placement in Area 2.5 and Axial Implant Placement in Area 2.2

The procedure was completed by suturing the flap with interrupted stitches using 3/0 Vicryl resorbable thread.
After completing the right hemiarch, the procedure on the left hemiarch was performed using the same surgical techniques.
Following hemostasis control, the patient was discharged with a prescription for antibiotic and analgesic therapy and post-operative instructions regarding home hygiene and dietary guidelines.
The pharmacological treatment consisted of:

- Amoxicillin and Clavulanic Acid 1 g (tablets), twice daily for 6 days, starting three days before the procedure;
- Metronidazole (AUROBINDO) 250 mg (tablets), twice daily for 10 days, starting three days before the procedure;
- Pantoprazole 40 mg (tablets), once daily for 6 days, beginning the day before the procedure;
- Dexamethasone sodium phosphate 0.2% (oral drops) from the day after the procedure according to the following protocol: a reducing dose.
- Sodium Naproxen 550 mg (tablets), as needed, one tablet every 12 hours for a maximum of 3 days;
- 0.5% chlorhexidine digluconate gel for plaque control twice daily after home oral hygiene, starting 24 hours after the procedure for 15 days.

The prosthesis was delivered 48 hours after the procedure (Figures 6 - 7).

Figure 6. Post-operative Prosthesis Delivery

Figure 7. Implant-Prosthetic Rehabilitation

The patient reported no complications upon returning for a post-operative check-up after one week.
A follow-up examination two years post-surgery revealed no clinical or radiographic problems secondary to the procedure (Figures 8-9).

Figure 8. 2-Year Follow-up of Soft Tissues

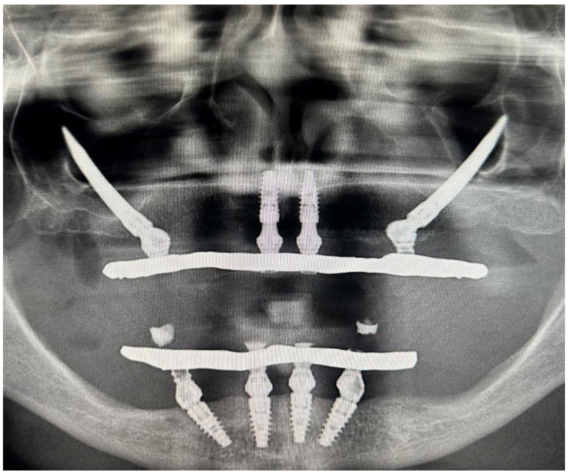

Figure 9. 2-Year Post-operative Orthopantomography

Discussion

Zygomatic implants provide a valid rehabilitation of the atrophic maxilla by utilizing immediate loading functional protocols (40). Unlike standard implants, inserting zygomatic implants requires creating a surgical site preparation on an oblique working plane between the maxillary bone crest and the zygomatic body, often located on different transverse planes (41). The distance between these two anatomical portions varies depending on the degree of atrophy, which may be more or less pronounced, with multiple risks of intraoperative complications related to the topographic anatomy of the site (47). Osteotomy on the lateral surface of the zygomatic bone represents the most challenging surgical phase, followed by the actual preparation of the implant site once the axis to follow has been identified (46-47).

The “Minimally Invasive Technique” proposed by Prof. Tedesco for inserting zygomatic implants involves, where clinically possible, inserting zygomatic implants using the extrasinus technique (39, 47). This method consists of preparing the implant site externally to the maxillary sinus using dedicated piezoelectric inserts and maintaining as much residual bone crest around the implant as possible, facilitating intraoperative preparation and allowing the surgeon to manage “bur anxiety” by using a significantly less invasive and more predictable method (41, 47). It is essential to emphasize further that the classic intrasinus approach, involving the maxillary sinus, inevitably increases morbidity, operative times, and complications to the anatomical site itself; therefore, it is preferable to adopt an extrasinus preparation method (39).

This minimally invasive technique involves performing an always manageable osteotomy and, depending on the anatomy of the specific clinical case, an extra-sinus approach to avoid complications to the maxillary sinus itself (32, 43). The particular protocol divides implant preparation into three phases: 1) maxillary bone preparation, 2) crestal bone preparation, and 3) zygomatic bone preparation. Each phase is always manageable by the operator as it is controllable and rectifiable, especially in cases where it is realized that the preparation axis needs to be improved. Once the implant bed has been created on the maxillary bone, the phase of connecting the preparation from the residual bone crest at the palatal level to the cortical bone of the zygomatic body is significantly simplified. This advantage is secondary to ultrasonic instrumentation with which the instrument is positioned on the bone plane to gently slide towards the zygomatic bone, maintaining the preparation on the malar bone without tilting the instrument downwards, risking entry into the sinus. The implant length is confirmed by measuring the preparation depth using a millimeter probe (41, 49).

To complete the preparation before inserting the implant, it is necessary to flare, to adjust the preparation diameter according to the chosen implant diameter. A further advantage provided by this technique is therefore to represent a universal surgical protocol capable of adapting to any type of implant (41, 49).

The traditional surgical protocol, described in the literature, involves creating the implant site using long drilling burs. Traditional burs, however, are very aggressive and difficult to control, given their length, which is responsible for the continuous rotary movement of the bur itself (43, 46).

The new surgical protocol introduces the use of ultrasonic devices in implant site preparation, both for the preparation of the potentially atrophic alveolar crest and the zygomatic bone, thus reducing the complications of the traditional technique (43). Piezoelectric inserts, since they have a vibrating and non-rotary movement at the high end of the insert, are less destructive and allow minimally invasive zygomatic surgery to be performed. Micro-vibration generation also makes it possible to appreciate bone consistency, reduce the risk of error, and offer the operator time to reason, change direction, or bone support plane (36, 41, 45).

The use of ultrasound in the field of zygomatic implantology allows for extremely precise osteotomy. Ultrasound osteotomy enables the surgeon to maintain good instrument control and intraoperative visibility of the surgical field both during sinus access and during the procedure since, during the operational phase on the zygomatic bone, the initial point of penetration using the first ultrasonic insert remains unchanged throughout the surgical procedure, reducing intraoperative errors by the operator (43-53). On the contrary, traditional burs, having a rotary movement on the entire body of the bur, do not allow the maintenance of fundamental bone structures to guarantee the primary and secondary implant stability of the zygomatic implant, even if osseointegration is achieved (43-53).

Another significant advantage of using the ultrasonic method in zygomatic surgery is the selectivity of the instruments for mineralized tissues, which avoids complications to structures such as the Schneiderian membrane, nerves, and vascular bundles (53). The use of ultrasonic instruments also requires them to be used with high speed and low pressure to ensure good cutting performance with minimal risk of osteonecrosis secondary to overheating (excessive pressure, in fact, blocks vibrations and cutting action) (43, 49-53).

The literature also supports the alternative to drills in

implant surgery using ultrasonic instruments, given the encouraging results and advantages related to the cavitation effect (51, 52). In piezoelectric surgery, in fact, the internal irrigation of the ultrasonic inserts dedicated to zygomatic implantology results in perfect cleaning of the osteotomy site with consequent good visibility of the field and complete cleaning of the site (18, 51). The constant jet of physiological solution also favors bacterial decontamination with consequent sterilization of the operating field, tissue oxygenation, control of overheating at the site, and reduction of edema, facilitating the post-operative course (18, 20, 32).
Preparing the zygoma with very long rotary burs could also damage the surrounding soft tissues, such as the skin of the lip. Although this does not occur directly using piezoelectric inserts, attention must be paid. The insert suitable for the individual case must be chosen based on the patient's amplitude since, producing heat, the ultrasonic insert could also cause burns to the skin of the lower lip (41,42,56,57).

Conclusions

Piezoelectric surgery proves to be a valid surgical technique for implant site preparation in zygomatic implantology, with significantly reduced complications compared to the conventional technique. The extreme surgical precision of micrometric bone cutting, greater safety, and reduced trauma allow surgeons who adopt this technique to perform bone surgery and zygomatic implantology procedures in a less traumatic way for the patient, significantly reducing pain and after-effects compared to traditional surgery performed with drills or bone saws.

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