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Research Article

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The Application of Piezosurgery in Orthognathic Surgery. A Literature Review

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Abstract

Introduction: Piezosurgery is a soft tissue sparing bone-cutting device developed by Italian surgeon Dr. Tomaso Vercellotti in 1988. It has been successfully used in Le Fort I osteotomy, BSSO, bimaxillary osteotomy and surgically assisted rapid maxillary expansion (SARME).

Aim of the Study: The aim of this literature review is to highlight the advantages of using piezosurgery compared to conventional osteotomy in orthognathic surgery.

Material and methods: A comprehensive literature search was conducted in PubMed and Google Scholar using "orthognathic surgery" and "piezosurgery" as keywords to identify clinical studies, randomized clinical trials (RCTs), reviews, systematic reviews, and meta-analyses.

Results: Of the 12 selected studies selected for this review, five were randomized controlled trials (RCTs), six were non-randomized controlled trials (nRCT) and one was a systematic review. Piezosurgery offers reduced intraoperative blood loss and blood-free surgical field which enhances visibility. The osteotomy lines were more precise with piezosurgery and neat cut edges were observed compared to the ragged and uneven edges with bur osteotomy. It reduces the risk of damaging nerves or vessels; however, the surgical time is prolonged with piezosurgery.

Conclusions: Piezosurgery is a safe and effective device which offers many advantages in orthognathic surgery. However, further studies with a larger sample should be conducted to compare piezo-surgery with conventional osteotomy regarding operating time, as well as intra- and post-operative complications in orthognathic surgery.

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1. Introduction

Piezosurgery is a soft tissue sparing bone-cutting device developed by Italian surgeon Dr. Tomaso Vercellotti in 1988. It has garnered significant attention from oral and maxillofacial surgeons in recent years. Piezosurgery was invented for safely performing sinus lift operations but its use has become widespread across various areas of oral surgery, including orthognathic surgery. It is an innovative osteotomy technique using piezoelectric ultrasonic vibrations. Piezosurgery uses low-frequency ultrasonic vibrations which makes it useful in osteotomies in close proximity to nerves, vessels, Schneiderian membrane etc. It works on the principle of "pressure electrification", which offers a less invasive surgery and greater precision compared to conventional bone-cutting techniques such as diamond or carbide rotary instruments. Piezosurgery has been successfully used in Le Fort I osteotomy, BSSO, bimaxillary osteotomy and surgically assisted rapid maxillary expansion (SARME).

2. Material and Methods

A comprehensive literature search was conducted in PubMed and Google Scholar using the following search strategy: "(Piezosurgery or piezo) and (orthognathic surgery) or (orthognathic surgeries) or (orthognathic) or (jaw surgery)". This search yielded a total of 148 articles. Additionally, a hand search of well-known journals within the last ten years was performed.

To identify relevant studies for inclusion in this literature review, the following inclusion criteria were applied:

- Articles published between 2013 and 2023.
- Studies based on clinical research in humans.
- Articles written in English.
- Clinical studies, randomized clinical trials, reviews, systematic reviews, and meta-analyses were all considered.

Exclusion criteria were:

- Articles published before 2013.
- Articles in languages other than English.
- Studies conducted on animals.

After applying these criteria, 19 articles were selected for further reading. Cross-referencing and removal of duplicates were conducted, resulting in 12 articles that met the inclusion criteria. Relevant data from each selected study were extracted and synthesized for this review.

3. Results

3.1 Study characteristics

Of the studies selected for this review, five were randomized controlled trials (RCTs) [1-5], six were non-randomized controlled trials (nRCTs) [6-10], and one was a systematic review and meta-analysis [11]. Study sample sizes varied from 10 [5] to 350 [8]. All studies included adult patients over 18 years old, except for one study that included patients over 16 years old [5]. Various osteotomies were included in these studies, such as bimaxillary osteotomy (BMO) [1,6,10,8,1], surgically assisted rapid maxillary expansion (Rana et al., 2013) [2], bilateral sagittal split osteotomy [7,3,9], and genioplasty [4]. Surgeries were performed by one or more surgical teams. All surgeries utilized Piezosurgery or piezoelectric cutting devices, while controls in RCTs were performed using conventional burs.

3.2 Surgical time

Three studies evaluated operative time, but only two measured it from the beginning to the end of bone osteotomy [1,5]. Spinelli et al. timed the entire surgical procedure. Bertossi et al. reported a mean bone osteotomy time of 7 minutes, while Raj et al. reported a mean bone osteotomy time of 13.28 minutes. Spinelli et al. noted a longer mean operating time of 152 minutes compared to 101 minutes for traditional saw procedures. However, no significant difference in operative time was observed between piezo-surgery and conventional osteotomies in the systematic review by Pagotta et al.

3.3 Intraoperative blood loss

Five studies evaluated blood loss during orthognathic surgery. Two studies reported mean blood losses of 300 mL [1] and 237 mL [6]. In the abovementioned studies, the intraoperative blood loss was based on the difference between the amounts of irrigating saline solution used and the total aspirated fluids. Shirota et al. reported that the amount of bleeding decreased significantly with increasing age while using piezosurgery. Rana et al. concluded that the probability of hematoma is lower in the group that received piezotherapy. In this study, blood loss was calculated based on the change in hemoglobin levels, with no statistical significance found. In Raj et al.'s study, the bleeding during surgery was evaluated using a visual guide by Ali Algadiem et al. and categorized as mild (<500 mL), moderate (500–1000 mL), and severe (>1000 mL). They reported that blood loss was significantly lower on the piezosurgery side (split mouth).

3.4 Postoperative neurological analysis

A thorough postoperative neurological analysis were performed in all studies. They evaluated patients at day 1, week 1- and one-month following surgery. In a 13 years retrospective study of complications in patients undergoing orthognathic surgery by Piezosurgery [10] it was concluded that 31.03% of patients didn't have complications and forty postoperative complications were identified. The most frequented complications were TMJ and TMD disorders, paresthesia and hypoesthesia. In eight studies the neurological analysis was performed through clinical neurosensory testing (i.e pinprick sensation, light-touch sensation, 2-point discrimination tests, subjective analysis) [1,2,6,10,4,9,5,8]. In two studies the Semmes-Weinstein monofilament esthesiometer were used for evaluating neurosensitivity [7] and quantitative sensory testing (QST) was used in Brockmeter et al.

4. Discussions

Orthognathic surgery is a complex procedure involving the surgical repositioning of the jaw and/or dentoalveolar segments to correct severe skeletal discrepancies after growth has ceased. The aims of orthognathic surgery are numerous: correcting malocclusions, promoting temporomandibular joint health, maintaining or increasing upper airway space, improving dental relationships, correcting reverse bites, enhancing muscle function, achieving facial aesthetic harmony, and ensuring patient satisfaction [10].

In orthognathic surgery, precision and safety are crucial to achieving optimal outcomes. Given the proximity of important anatomical structures such as nerves and blood vessels to osteotomies, traditional saws, burs, and chisels can be potentially dangerous. (Raj et al., 2022) [5]. These instruments may damage soft tissues and produce excessive heat, impairing bone regeneration and potentially resulting in bone necrosis. To address these challenges, piezosurgery—an ultrasonic device—was developed.

When electric tension is applied to certain materials, such as quartz and Rochelle salts, they expand and contract, producing ultrasonic vibrations. Piezosurgery uses micrometric ultrasonic vibrations at 60–200 μm/s and 24–29 kHz to selectively remove bone while minimizing damage to soft tissues like blood vessels and nerves. It also provides a blood-free surgical site through the cavitation effect [12-14].

In this literature review, we focused on surgical time, intraoperative blood loss, postoperative neurological outcomes, and postoperative swelling to evaluate the efficacy of piezosurgery. Relevant information was extracted from articles selected for this review.

Surgical time was generally prolonged when piezosurgery was used, with conventional burs proving more efficient than piezosurgery tips. Although some literature suggests that piezosurgery can reduce operating time compared to conventional osteotomy, this review found longer operating times associated with piezosurgery. Pagotta et al., in their meta-analysis, reported no statistically significant difference in operating time between piezosurgery and conventional osteotomy. However, a larger number of studies is needed for a more reliable statistical result in the future.

The increased operating time could be due to the need for cooling in dense cortical bone cutting [6]. The cooling system is generally less efficient when cutting deep layers of bone because increased pressure on the bone decreases cutting speed, so interrupted cutting is advisable. For deep osteotomies, a combination of piezosurgery and subsequent chisel use may be beneficial (Pavlikova et al.).

Intraoperative blood loss was significantly reduced when piezosurgery was used. Spinelli et al. reported a mean blood loss reduction of 25% compared to traditional saw procedures. In the study by Bertossi et al., a low bleeding rate (<300 cc) was observed in 100% of patients in the piezosurgery group. In conventional osteotomies, the mean intraoperative blood loss in orthognathic surgery is approximately 400 mL, which is below the threshold for transfusions (Hb < 7 g/dL) (Pineiro-Aguilar et al., 2011). With piezosurgery, blood loss is even smaller, making transfusions unnecessary. However, no study has calculated the risk of blood transfusion related to the types of bone cutting.

Temporomandibular joint (TMJ) disorders are among the most common complications following orthognathic surgery, with a prevalence of 13.64% in the literature [15-17]. Bertossi et al. also found TMJ disorders to be the most frequent complication, with a prevalence of 24.14%. Other studies report that neurosensory deficits in regions innervated by the inferior alveolar nerve, especially following bilateral sagittal split osteotomy (BSSO), are the most common complications of orthognathic surgery [18,19]. However, D'Agostino et al. concluded that while the severity of neurosensory disturbance in the inferior alveolar nerve (IAN) is reduced, the incidence of permanent nerve lesions remains unchanged. Interestingly, female patients were found to be at higher risk for developing neurosensory disturbances, while age did not appear to be a factor.

Although stimuli in clinical neurosensory testing are objective, responses rely on the patient's subjective reporting (Philips et al., 2008). The most commonly used tests in this review were pinprick sensation, light-touch sensation, two-point discrimination, and subjective analysis.

Piezosurgery is associated with a faster recovery of neurosensory disturbances, with similar findings across various studies. Spinelli et al. reported that the majority of patients recovered within a week, and the remaining patients recovered within the first postoperative month. Additionally, piezosurgery was associated with reduced postoperative swelling. However, Raj et al. found no significant difference in postoperative swelling between piezosurgery and conventional methods, potentially due to the use of dexamethasone postoperatively.

5. Conclusions

The application of piezosurgery in orthognathic surgery is highly advisable and the following conclusions have been drawn:

1 Piezosurgery offers reduced intraoperative blood loss and blood-free surgical field which enhances visibility.
2 Piezosurgery reduces the risk of damaging nerves, vessels or Scheiderian membrane. This results in faster recovery of neurosensory disturbances.
3 The surgical time is prolonged with piezosurgery.
4 The osteotomy lines were more precise with piezosurgery and neat cut edges were observed compared to the ragged and uneven edges with bur osteotomy.
5 Piezosurgery induces an earlier increase in bone morphogenetic proteins, controls the inflammatory process better, and stimulates remodeling of bone.
6 To conclude, piezosurgery is a safe and effective device which offers many advantages in orthognathic surgery. However, further studies with a larger sample should be conducted to compare piezo-surgery with conventional osteotomy regarding operating time, as well as intra- and post-operative complications in orthognathic surgery.

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