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Piezoelectric versus conventional techniques for orthognathic surgery: Systematic review and meta-analysis



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ABSTRACT

Purpose: The purpose of this study was to perform a systematic review and meta-analysis of complications after orthognathic surgery comparing piezo-surgery with conventional osteotomy.

Methods: We conducted this study according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. We performed a systematic search of PubMed, Scopus, Science Direct, Lilacs, Cochrane Central Register of Controlled Trials, Google Scholar, and OpenThesis to identify randomized and nonrandomized controlled trials (RCTs and nRCTs, respectively) comparing patient outcomes (operative time, intraoperative blood loss, postoperative swelling, pain, neurosensibility) after orthognathic surgery by piezoelectric or conventional osteotomy. We pooled individual results of continuous and dichotomous outcome data using the mean difference (MD) and risk difference (RD) with the 95% confidence interval, respectively.

Results: Three RCTs and five nRCTs were selected. No difference in operative time was observed between piezo-surgery and conventional osteotomies. We found a decrease of intraoperative blood loss with piezo-surgery (MD -128 mL; $P < 0.001$) and a pooled difference in severe blood loss of 35% ($P = 0.008$) favouring piezo-surgery. Based on pooled individual results of studies evaluating neurosensibility by clinical neurosensory testing, our meta-analysis showed a pooled difference in severe nerve disturbance of 25% ($P < 0.0001$) favouring piezo-surgery. Test for subgroup differences ($I^2 = 26.6\%$) indicated that follow-up time may have an effect on neurosensory disturbance. We found differences between piezo-surgery and conventional osteotomy at 3 months (RD 28%; $P < 0.001$) and 6 months (RD 15%; $P = 0.001$) after surgery. Meta-analyses for pain and swelling were not performed because of a lack of sufficient studies.

Conclusion: Currently available evidence suggests that piezo-surgery has favorable effects on complications associated with orthognathic surgery, including reductions in intraoperative blood loss and severe nerve disturbance.

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1. Introduction

Piezo-surgery was first used in oral and maxillofacial surgery by Vercellotti and colleagues (Vercellotti et al., 2001), who sought to

simplify maxillary sinus surgery by avoiding perforation of the schneiderian membrane. Recently, ultrasonic bone cutting has been used in orthognathic procedures (Gruber et al., 2005; Beziat et al., 2007; Robiony et al., 2007; Landes et al., 2008a, 2008b; Chung et al., 2012; Bertossi et al., 2013; Gilles et al., 2013; Spinelli et al., 2014), extraction of impacted third molars (Jiang et al., 2015), corticotomy-facilitated orthodontics (Farid et al., 2014), implant site preparation (Brugnami et al., 2014; Canullo et al., 2014;

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Lamazza et al., 2015), management of temporomandibular disorders (Jose et al., 2014), cyst enucleation (Kocyigit et al., 2012; Pappalardo and Guarnieri, 2014), and head and neck oncological and reconstructive surgeries (Crosetti et al., 2009). Piezo-electric surgery uses low-frequency ultrasonic vibration for osteotomy, which minimizes the risk of damage to soft tissues (nerves, vessels, and mucosa) (Vercellotti, 2004; Landes et al., 2008a, 2008b). Micrometric vibration ensures precise cutting action and permits perioperative control, with a consequent increase in safety, in a difficult-to-access anatomic area (Vercellotti, 2004).

A meta-analysis of randomized controlled trials (RCTs) (Jiang et al., 2015) showed that patients receiving piezo-surgery for impacted third molars experienced longer operative times but less postoperative swelling, pain, and trismus than patients who received conventional rotary techniques. Although piezo-surgery is a promising alternative technique for removal of impacted third molars, there is no evidence that ultrasonic bone cutting decreases operative time, intraoperative blood loss, postoperative swelling, pain, or paresthesia in orthognathic surgery. Therefore, the aim of this study was to perform a systematic review and meta-analysis of complications after orthognathic surgery by piezo-surgery versus conventional osteotomy.

2. Materials and methods

We conducted this study according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2010).

2.1. Eligibility criteria

We used PICOT elements to define eligibility criteria, as follows: (1) *population*: patients submitted to orthognathic surgery; (2) *intervention*: piezo-electric osteotomy; (3) *comparison*: conventional osteotomy; (4) *predefined outcomes*: operative time, intraoperative blood loss, postoperative swelling, pain, and postoperative neurological analysis; and (4) *study type*: RCTs and non-randomized controlled trials (nRCTs). We excluded animal studies and studies from which we were unable to extract data regarding at least one of the outcomes of interest.

2.2. Search strategy

We performed a systematic search to identify relevant studies from PubMed, Scopus, Science Direct, Lilacs, and Cochrane Central Register of Controlled Trials (CENTRAL). A grey-literature search was performed through Google Scholar and OpenThesis. We performed the following consecutive searches in May 2016: ultrasonic surgical procedures, ultrasonic surgery, ultrasonic therapy, ultrasonic cutting, ultrasonic bone cutting, piezo-surgery, piezo-electric surgery, piezo-electric bone surgery, piezo-electric osteotomy, high-energy shock waves, ultrasonic surgery procedure OR high-energy shock waves, orthognathic surgery, orthognathic surgical procedures, jaw surgery, osteotomy, orthognathic surgery OR osteotomy, and ultrasonic surgery procedure OR high-energy shock waves AND orthognathic surgery OR osteotomy. We also conducted a hand search of cross-references from original articles and reviews to identify additional studies that could not be located in the electronic database.

Two reviewers (S.J.A.V. and T.S.S.) independently screened the search results. Considering the titles and abstracts, they identified potentially relevant studies. No restrictions on language or publication year were imposed. Relevant studies were read in full and, if they met the eligibility criteria, were included in the systematic

review. Disagreements between the two reviewers were resolved by consensus or by a third reviewer (P.R.S.M.-F.).

2.3. Data extraction

Two reviewers (S.J.A.V. and T.S.S.) independently extracted data using a predefined protocol. Disagreements were resolved by consensus or by a third reviewer (P.R.S.M.-F.). Extracted data regarded the study design, study population, indications and methods for orthognathic surgery, characteristics of ultrasonic osteotomy, intraoperative and postoperative parameters, and outcome measures.

2.4. Risk of bias

Risk of bias was assessed by considering the Cochrane guidelines for clinical trials. We assessed seven domains: sequence generation (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective outcome reporting (reporting bias), and other potential sources of bias. We rated risk of bias as low, unclear, or high, according to established criteria (Higgins et al., 2011).

2.5. Statistical analysis

We used the mean difference (MD) and the risk difference (RD) with the 95% confidence interval (95% CI) to pool individual results of continuous and dichotomous outcome data, respectively. MD was calculated by using the generic inverse variance method, abstracting means and standard deviations (SDs) for each study group and outcome of interest. RD was calculated by comparing rates of severe intraoperative blood loss (>500 mL) and severe nerve injury between piezo-surgery and conventional osteotomy. RD is directly related to the number needed to treat (NNT), a useful measure of clinical effectiveness.

We used forest plots to present graphically the pooled estimates and 95% CIs. In the plot, each study was represented by a square, the size of which was proportional to the study's weight in the meta-analysis. Two-sided p-values less than 0.05 were considered statistically significant. We investigated heterogeneity by the Cochran Q test, using a cut-off of 10% for significance (Cochran, 1954) and the I^2 index [$100\% \times (Q-df)/Q$] for quantification (Higgins and Thompson, 2002). Although funnel plots may be useful tools in investigating small study effects in meta-analyses, they have limited power to detect such effects when there are few studies (Simmonds, 2015). Therefore, because we had only a small number of included studies, we did not perform funnel plot analysis. All statistical analyses were performed by using Review Manager Version 5.0 (Cochrane Collaboration).

3. Results

3.1. Selection

In our initial search, we found 999 references to be analyzed by title/abstract. Thirty-five studies were considered to be potentially relevant and were analyzed in full. After a complete reading, we excluded 26 studies because their study design ($n = 24$) or study population ($n = 2$) did not match the inclusion criteria. One additional study was excluded because of the potential for overlapping samples. Finally, eight studies (Beziat et al., 2007; Landes et al., 2008b; Bertossi et al., 2013; Rana et al., 2013; Monnazzi et al., 2014; Shirota et al., 2014; Spinelli et al., 2014; Brockmeyer et al.,

2015) met the eligibility criteria and were included in our systematic review. We did not identify ongoing studies. No additional studies were found through our manual search. Fig. 1 shows the PRISMA flow diagram of studies in this review.

3.2. Study characteristics

Of the studies selected for this review, three were RCTs (Bertossi et al., 2013; Rana et al., 2013; Brockmeyer et al., 2015) and five were nRCTs (Beziat et al., 2007; Landes et al., 2008b; Monnazzi et al., 2014; Shiota et al., 2014; Spinelli et al., 2014). Study sample sizes varied from 12 (Spinelli et al., 2014) to 280 (Beziat et al., 2007) with follow-up periods ranging from 2 months (Beziat et al., 2007) to 1 year (Bertossi et al., 2013; Brockmeyer et al., 2015). All studies included adult patients, most of them in the third decade of life (Table 1). Three studies involved patients with class III dentofacial deformity (Bertossi et al., 2013; Shiota et al., 2014; Spinelli et al., 2014), two involved class II and III dentofacial deformities (Beziat et al., 2007; Brockmeyer et al., 2015), and one study involved patients with class I, II, or III deformity and additional open bite or cleft lip and palate (Landes et al., 2008b). In two studies, dentoskeletal deformities were not described (Rana et al., 2013; Monnazzi et al., 2014).

3.3. Surgical interventions

Studies reported using different orthognathic surgical interventions, including surgically assisted maxillary expansion (SAME) (Rana et al., 2013), bilateral sagittal split osteotomy (BSSO) (Beziat et al., 2007; Monnazzi et al., 2014; Shiota et al., 2014; Brockmeyer et al., 2015), and bimaxillary osteotomy (Bertossi et al., 2013; Spinelli et al., 2014). In one study, patients underwent isolated Le Fort I osteotomy, BSSO, symphyseal osteotomy, mandibular body osteotomy, or bimaxillary osteotomy (Landes et al., 2008b) (Table 1). Piezo-surgical bone osteotomy was performed by using Piezo-surgery® (Mectron, Carasco, Italy) (Beziat et al., 2007; Landes et al., 2008b; Bertossi et al., 2013; Rana et al., 2013; Shiota et al., 2014; Brockmeyer et al., 2015) or Piezo-sonic® (VK Driller, São Paulo, Brazil) (Monnazzi et al., 2014) instruments. In one study, details on piezo-electric equipment and

manufacturer were not described (Spinelli et al., 2014). Controls were submitted to conventional osteotomies.

3.4. Risk of bias

Studies were poorly reported, and risk of bias was high or unclear for most domains (selection bias, performance bias, detection bias, and reporting bias). Risk of attrition bias (loss to follow-up) was judged as low for all studies. Results of the assessment of risk of bias of the included studies are detailed in Table 1 and Fig. 2.

3.5. Overall analysis

3.5.1. Operative time

Six studies evaluated operative time as an outcome of interest. Two studies defined operative time as the time of the whole surgical procedure, from first cut to final suture (Landes et al., 2008b; Spinelli et al., 2014). Two studies measured operative time from the beginning to the end of bone osteotomy (Beziat et al., 2007; Bertossi et al., 2013). Two studies did not describe the surgical time (Rana et al., 2013; Shiota et al., 2014). We performed the meta-analysis of operative time considering the results of bimaxillary osteotomies in the two studies (Landes et al., 2008b; Spinelli et al., 2014) that provided details of the outcome measurement, including the mean and SD of the procedure duration (in min). No difference in operative time was observed between piezo-surgery and conventional osteotomies (MD 23.45 min; 95% CI: -44.49 to 91.39; $p = 0.50$). High between-study heterogeneity was observed ($I^2 = 90\%$), and a random-effects model was used to pool the data (Fig. 3).

3.5.2. Intraoperative blood loss

Five studies evaluated blood loss during orthognathic surgery. In three studies (Landes et al., 2008b; Bertossi et al., 2013; Spinelli et al., 2014), measurements of intraoperative blood loss were based on the difference between the amounts of irrigating saline solution used and total aspirated fluids. One study (Rana et al., 2013), in which patients were submitted to surgically assisted maxillary expansion, blood loss was calculated based on the change in hemoglobin levels. In another study (Shiota et al., 2014), measurements of blood loss were not described.

We performed the meta-analysis of intraoperative blood loss using a two-stage analysis, in which we extracted continuous and binary outcome measures from bimaxillary osteotomies of two (Landes et al., 2008b; Spinelli et al., 2014) and three (Landes et al., 2008b; Bertossi et al., 2013; Spinelli et al., 2014) studies, respectively. Meta-analysis of the continuous outcome showed that intraoperative blood loss was lower when piezo-surgery was used (MD -128 mL; 95% CI: -187.67 to -68.70; $P < 0.001$). No between-study heterogeneity was found ($I^2 = 0\%$), and a fixed-effects model was used to pool the data (Fig. 4). In the meta-analysis of binary outcomes, we extracted the number of patients with severe bleeding (>500 mL) during orthognathic surgery. Our meta-analysis yielded a statistically significant pooled difference in severe blood loss of 35% (95% CI: 9–61%; $P = 0.008$), favoring piezo-surgery over conventional osteotomy. The RD corresponds to a NNT of 3 (95% CI: 2–11). A high level of heterogeneity among studies ($I^2 = 85\%$) was observed (Fig. 5).

3.5.3. Postoperative swelling

One study (Spinelli et al., 2014) described a quantitative method to measure postoperative swelling by using photos of each patient's frontal, lateral, and third/fourth side at 1 day, 1 week, and 1, 3, and 6 months after surgery. Incidence of postoperative swelling was

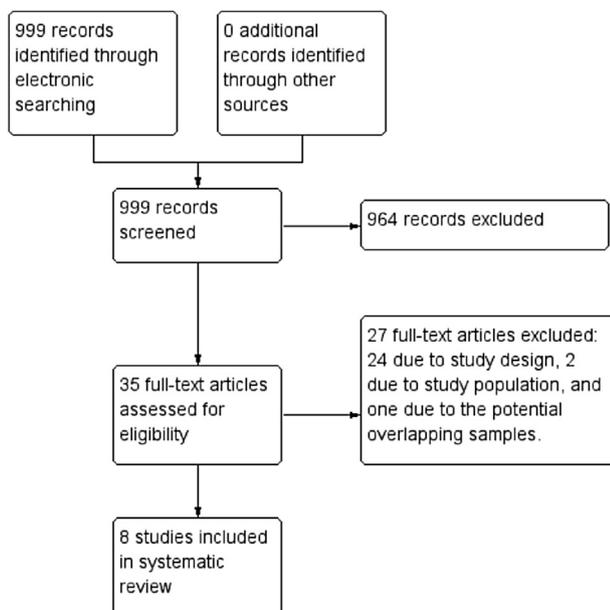


Fig. 1. Study selection.

Table 1
Characteristics of studies included in the systematic review.

Author, year	Study type	N	Age (y)	Gender	Types of surgeries*	Surgeons involved	Follow-up time	Outcomes of interest	Risk of bias Selection (randomization)	Selection (allocation)	Performance	Detection	Attrition	Reporting
Bertossi et al., 2013	RCT	110	>18	ND	BMO	ND	1 y	OT, IBL, NI	?	?	?	?	(+)	(-)
Beziat et al., 2007	nRCT	280	29.3 (P) 26.8 (C)	42M/98F (P) 56M/84F (C)	BSSO	2 surgical teams	2 m	OT, NI	(-)	(-)	(-)	?	(+)	(-)
Spinelli et al., 2014	nRCT (split mouth)	12	26.08	5M/7F	BMO	1 surgical team	6 m	OT, IBL, S, NI	(-)	(-)	?	?	(+)	(+)
Landes et al., 2008a	nRCT	136	21.0 (P) 27.0 (C)	26M/24F (P) 50M/36F (C)	BMO	ND	3 m	OT, IBL, NI	(-)	(-)	?	?	(+)	(+)
Brockmeyer et al., 2015	RCT (split mouth)	37	26.0	9M/28F	BSSO	2 surgical teams	1 y	NI	?	?	(+)	(+)	(+)	(-)
Monnazzi et al., 2014	nRCT (split mouth)	20	28.4	ND	BSSO	1 surgical team	6 m	NI	(-)	(-)	(+)	(+)	(+)	(-)
Rana et al., 2013	RCT (split mouth)	30	29.8 (P) 27.4 (C)	12M/18F	SAME	1 surgical team	6 m	OT, IBL, S, pain, NI	(+)	(-)	?	(+)	(+)	(-)
Shirota et al., 2014	nRCT	59	28.0	24M/35F	BSSO	1 surgical team	3 m	OT, IBL, NI	(-)	(-)	?	?	(+)	(-)

ND, not described; P, piezo-surgery; C, control.

Study type: RCT, randomized clinical trial; nRCT, non-randomized clinical trial.

Types of surgery: BMO, bimaxillary osteotomy; SAME, surgically assisted maxillary expansion; BSSO, bilateral sagittal split osteotomy.

Outcomes: OT, operative time; IBL, intraoperative blood loss; S, swelling; NI, nerve injury.

Risk of bias assessment: (+) low, (-) high, (?) unclear.

* Surgical procedures performed in patients analyzed in this systematic review.

higher after traditional saw procedures than after piezo-surgery (P = 0.05).

3.5.4. Pain

One study (Rana et al., 2013) evaluated postoperative pain by using a visual analogue scale at 2 and 3 days after surgery. No differences were observed between ultrasonic surgery and conventional osteotomy.

3.5.5. Postoperative neurological analysis

All studies evaluated postoperative neurosensitivity as an outcome of interest. Five studies (Beziat et al., 2007; Landes et al., 2008b; Bertossi et al., 2013; Rana et al., 2013; Spinelli et al., 2014) made measurements through clinical neurosensory testing (pin prick sensation, light touch sensation, 2-point discrimination tests, and subjective analysis). Two studies (Monnazzi et al., 2014; Shirota et al., 2014) evaluated neurosensitivity using Semmes–Weinstein testing (graduate nylon filaments). One study (Brockmeyer et al., 2015) used quantitative sensory testing (thermal, mechanical and pain detection).

We pooled individual results of studies evaluating neurosensitivity based on clinical neurosensory testing. Data were extracted from studies (Beziat et al., 2007; Landes et al., 2008b; Bertossi et al., 2013; Spinelli et al., 2014) that provided details on the number of patients with severe nerve injury during the follow-up time. Our meta-analysis yielded a statistically significant pooled difference in severe nerve disturbance of 25% (95% CI: 10–39; P < 0.0001), favoring piezo-surgery over conventional osteotomy. The RD corresponds to a NNT of 4 (95% CI: 3–10). The test for subgroup differences (I² = 26.6%) indicates that follow-up time may have had an effect on neurosensory disturbance. We found differences between piezo-surgery and conventional osteotomy at 3 months (RD 28%; 95% CI: 14–42; P < 0.001) and 6 months (RD 15%; 95% CI: 6–24; P = 0.001) after surgery. A high level of heterogeneity among studies (I² = 87%) was observed (Fig. 6).

Studies using Semmes–Weinstein testing showed contrasting results. Monnazzi et al. reported no differences in sensitivity of the labiomental area between groups at 7 days, 1 month, 2 months, and 6 months after surgery (Monnazzi et al., 2014). Shirota et al. found higher values on the Semmes–Weinstein test when using the piezo device 3 months after surgery (P = 0.008) (Shirota et al., 2014). Brockmeyer et al. using quantitative sensory testing, observed less postoperative impairment in the warm detection threshold (P = 0.046), less dynamic mechanical allodynia (P = 0.002), and a lower vibration detection threshold (P = 0.030) with piezo-surgery than with the conventional approach (Brockmeyer et al., 2015).

4. Discussion

In this study, we performed a systematic review and meta-analysis to compare piezo-surgery and conventional osteotomy in orthognathic surgery. We found no differences in operative time for bimaxillary osteotomies, but patients subjected to ultrasonic bone cutting had less intraoperative blood loss and less postoperative neurosensory disturbances than patients who received the conventional technique for osteotomy.

Piezo-surgery is a new surgical technique that uses micrometric (24–29 kHz and 60–200 μm amplitude) ultrasonic vibration for osteotomy. This technique avoids damaging the soft tissues and maintains a blood-free surgical site through the cavitation effect (Labanca et al., 2008; Landes et al., 2008b). In contrast to our study, reports in the literature have suggested that piezo-surgery requires a shorter operating time than conventional osteotomy because the soft tissues have less need of protection, and a clearer surgical field is produced (Bertossi et al., 2013). Other reports showed a longer

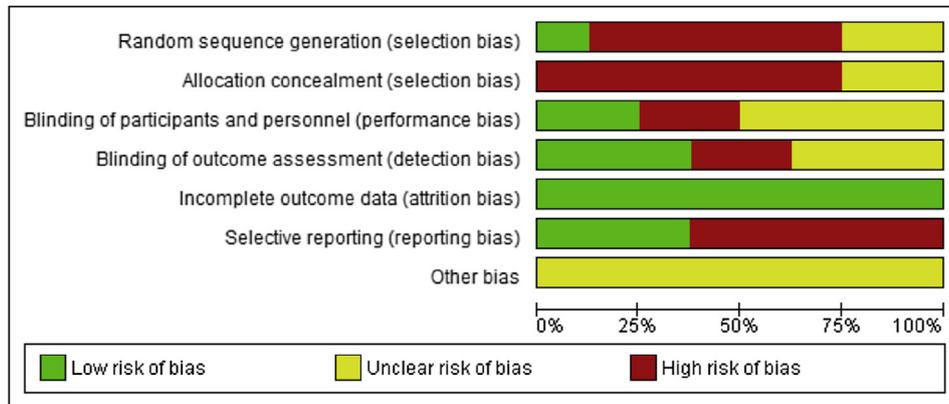


Fig. 2. Risk of bias assessment.

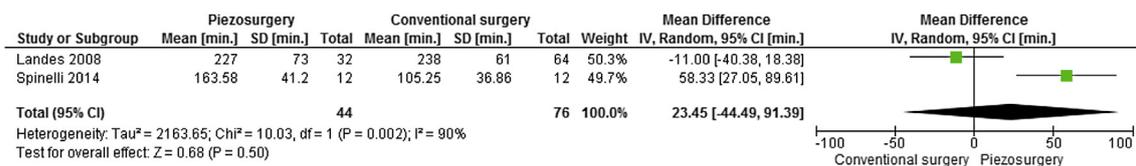


Fig. 3. Meta-analysis of studies investigating operation time with piezo-surgery or conventional osteotomy for orthognathic surgery.

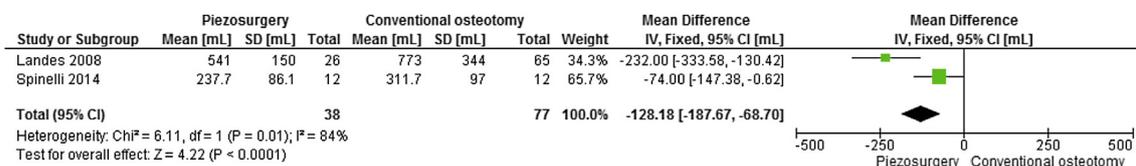


Fig. 4. Meta-analysis of intraoperative blood loss for continuous data comparing piezo-surgery and conventional osteotomy.

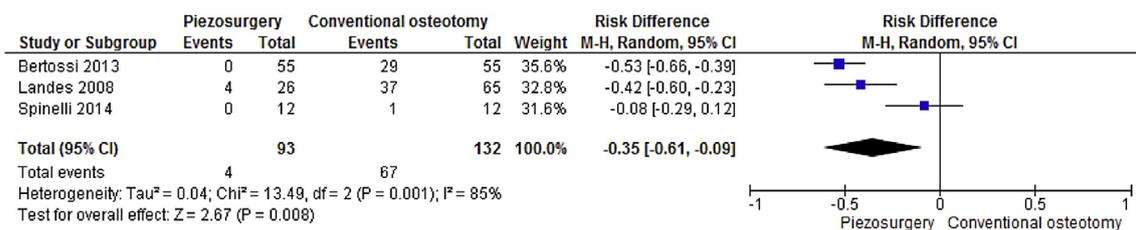


Fig. 5. Meta-analysis of studies investigating the number of patients with severe bleeding (>500 mL) during piezo-surgery or conventional osteotomy for orthognathic surgery.

operating time when using ultrasonic bone cutting due to the need of cooling, especially in cases of dense cortical bone cutting (Spinelli et al., 2014). Piezo-osteotomy requires unique surgical skills that are acquired with a learning curve (Landes et al., 2008b). Therefore, it is possible that the initial cases performed by using this new surgical technique have longer operation times, which would decrease as the surgeon gains experience.

Previous studies reported mean operating times for conventional bimaxillary osteotomies of 3 (Ueki et al., 2005; Garg et al., 2010; Posnick et al., 2016) to 4 (Panula et al., 2001; Dhariwal et al., 2004; Kretschmer et al., 2008) hours. Although ultrasonic bone cutting is not a method for fast surgeries, it is suitable for sensitive and non-traumatic operation procedures (Rana et al., 2013). Our meta-analysis of bimaxillary osteotomies showed no difference in operating time between piezo-surgery and conventional osteotomy (MD 23.45 min; P = 0.50). This evidence should be improved through additional high-quality studies, including

studies analyzing the surgical team's experience with the ultrasonic device, surgery-related complications, and results of other surgical interventions.

According to Posnick et al., an efficient operating time and safe perioperative airway management are two essential factors related to the limited need for blood transfusion and successful cardiopulmonary recovery (Posnick et al., 2016). One recent paper (Thastum et al., 2016) reported that the relative blood loss increases 18% for each hour of operating time exceeding 3 h. A systematic review (Piñero-Aguilar et al., 2011) reported a mean intraoperative blood loss in orthognathic surgery by conventional osteotomy of approximately 400 mL, which is less than the limits set for blood transfusion (Hb < 7 g/dL). Our meta-analysis showed that the intraoperative blood loss in bimaxillary procedures was lower for piezo-surgery than for conventional osteotomy (MD -128 mL; P < 0.001). Bimaxillary surgeries result in large blood loss due directly to the operating time and magnitude of the intervention

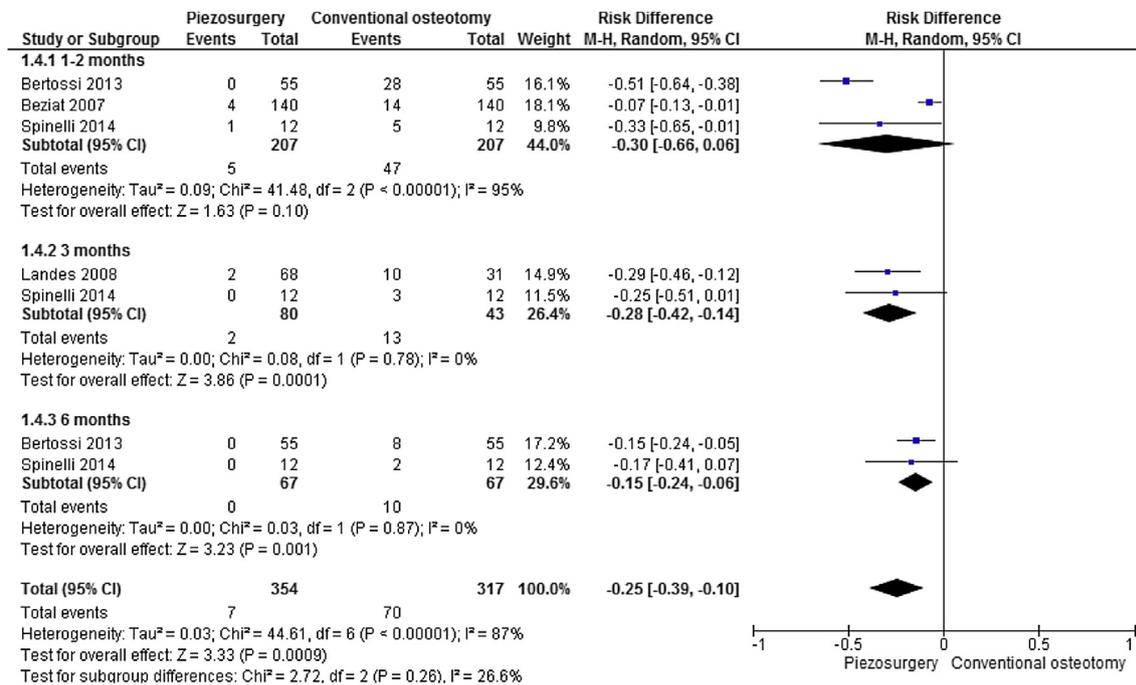


Fig. 6. Meta-analysis of studies investigating the number of patients with severe nerve injury after piezo-surgery or conventional osteotomy for orthognathic surgery.

(Yu et al., 2000). Although the need for blood transfusion in patients subjected to orthognathic surgery is extremely low (Choi et al., 2013; Posnick et al., 2016), our meta-analysis showed a significant difference between osteotomy types for severe blood loss. Accordingly, three patients submitted to orthognathic surgery must be operated by ultrasonic bone cutting to prevent one additional case of severe blood loss during surgery. Unfortunately, we were unable to calculate the risk of blood transfusion related to the types of bone cutting and the reciprocal NNT. Piezo-osteotomy seems to provide a more controlled bleeding than conventional osteotomy. This effect may be caused by the ultrasonic device's provision of a relatively blood-free surgical field during the cutting procedure, due to the distribution of cooling fluid and type of vibration (Bertossi et al., 2013).

Postoperative pain, swelling, and neurosensory disturbances are common occurrences after orthognathic surgery. For most patients, the pain and swelling associated with orthognathic surgery are acceptable and controllable (Chen et al., 2012) and these issues resolve within 2–3 weeks after surgery (Phillips et al., 2008). Postoperative pain is frequently controlled by opioids and seems to be affected by age, preoperative pain, anxiety, and type of surgery (Ip et al., 2009). Bimaxillary surgery tends to be more painful than single procedures, such as Le Fort I osteotomy, because of the involvement of the second and third branches of the trigeminal nerve. Only two studies in our systematic review provided information on pain (Rana et al., 2013) and swelling (Spinelli et al., 2014) related to piezo-surgery and conventional osteotomy. Individual results showed a decreased incidence of postoperative swelling after ultrasonic bone cutting, but differences in pain scores were not observed. Even if piezo-osteotomy enables more precise and non-traumatic cutting of bone, future studies are needed to clarify the real impact of the ultrasonic device on pain and swelling after orthognathic surgery.

The infraorbital, lingual, and inferior alveolar nerves are in close proximity to osteotomy cuts in orthognathic surgery. This proximity leads to an increased risk of nerve damage during bone dissection (Kim and Park, 2007). In orthognathic surgery, the most common complication is neurosensory deficit in the region

innervated by the inferior alveolar nerve (IAN) (Kim and Park, 2007; Jędrzejewski et al., 2015), especially after BSSO (Politis et al., 2014). Damage to the IAN negatively affects the quality of facial sensibility, as well as the patient's ability to translate patterns of altered nerve activity into functionally meaningful motor behaviors (Phillips and Essick, 2011). A recent systematic review (Agbaje et al., 2015) showed a wide variation in the reported incidence of IAN injury after orthognathic surgery. This variation was explained by the lack of standardized assessment procedures and reporting.

No standard method exists for estimating IAN-related neurosensory disturbances. Clinical neurosensory testing is one of the most common methods for evaluating nerve injury after osteotomy. This testing quantifies the patient's capacity to detect stimuli applied to the skin or mucosa. Although these stimuli are objective, the response depends on the subject's subjective report (Phillips et al., 2008). Our meta-analysis showed a significant difference between osteotomy types for severe nerve disturbance diagnosed by clinical neurosensory testing. Accordingly, five patients subjected to orthognathic surgery must be operated on with ultrasonic bone cutting to prevent one additional case of severe nerve disturbance during follow-up, especially at 3 and 6 months after surgery. Results from individual studies using other methods of estimating sensory disturbances were contrasting and, unfortunately, were not pooled. Studies suggest that piezo-surgery decreases somatosensory impairment and accelerates recovery of somatosensory functions. Use of ultrasonic bone cutting preserves microvessels surrounding the perineurium of the IAN because the piezo-electric device vibrations avoid stretching or warming the nerve (Spinelli et al., 2014; Brockmeyer et al., 2015). In addition, complete liberation of the nerve from the lateral cortex by the insert vibrations and water jet seems important for preventing nerve injury (Beziat et al., 2007).

Our meta-analysis has some limitations. First, the included studies had relatively small sample sizes, which may have led to an extremely beneficial treatment effect. However, an analysis of publication bias was not performed. The aim of the sample size calculations was to ensure that the statistical power was acceptable

while maintaining a small probability of type I error. Only one study (Rana et al., 2013) in our meta-analysis reported the power calculation or sample size estimates for planning the trial. Second, because of incompatible definitions across studies and attrition bias, we were unable to pool individual results of all studies for the outcomes of interest. Finally, the quality of evidence was low, and a pragmatic recommendation about the use of ultrasonic bone cutting over conventional osteotomy is not possible.

5. Conclusion

The currently available evidence suggests that piezo-surgery has favorable effects on complications associated with orthognathic surgery, including significant reductions in intraoperative blood loss and severe nerve disturbance. However, further high-quality studies 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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