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Comparison between piezoelectric surgery and conventional saw in sagittal split osteotomies: a systematic review

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Abstract. A systematic review of the advantages and disadvantages of piezoelectric surgery in comparison with conventional saws for sagittal split osteotomy (SSO) was performed. Relevant studies published in the last 10 years were identified through a search of the PubMed/MEDLINE, Science Direct, and Embase databases and assessed against predetermined eligibility criteria. The initial search resulted in 1736 articles. After applying the inclusion and exclusion criteria, 12 articles remained. A total of 799 patients with an average age of 27.5 years underwent SSO performed using a saw or ultrasonic device. Results showed that it took longer to perform the osteotomies using an ultrasonic device than using a conventional saw. At ≥6 months of follow-up, neurosensory disturbance was seen in 4.7% of patients who underwent piezoelectric surgery versus 61.6% of patients who underwent surgery in which a conventional saw was used. It was found that the use of piezoelectric surgery in SSO leads to the best outcome regarding neurosensory disturbance when compared to conventional saws ($P = 0.04$) at ≥6 months of follow-up. Further studies are required for the evaluation of the other clinical parameters assessed.

Key words: piezoelectric surgery; orthognathic surgery; osteotomy; sagittal split ramus.

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The sagittal split osteotomy (SSO) is a technique commonly used for the correction of mandibular deformities and malocclusions, mainly because it offers a good contact area for the osteotomized segments[1,2]. However, there are complications associated with this technique, such as injury to the inferior alveolar nerve (IAN), haemorrhage, temporomandibular dysfunction, periodontal disease, bad split, and recurrence[3].

Factors related to neurosensory disturbance after SSO include age of the patient, amount of intraoperative mandibular movement, degree of IAN manipulation, and thickness of the marrow space between the IAN canal and the external

cortical bone[4–6]. Most of these risk factors can be minimized during the surgical procedure by experienced surgeons; however, neurosensory disturbance remains a common postoperative morbidity[7].

Piezoelectric bone surgery is a system of bone cutting based on ultrasonic microvibrations that preserves the soft tissue. It is indicated for surgical procedures such as bone graft harvesting, tooth extraction, maxillary sinus lifting, osteogenic distraction, and orthognathic surgery[8]. With regard to SSO, some studies on the use of ultrasonic devices have reported minor postoperative complications such as oedema, bleeding, and IAN lesions[9–11]. The major limitations of ultrasonic devices are related to the prolonged time needed to perform the bone cuts and the necessity of completing the bone cuts with other instruments[12–14].

The aim of this study was to perform a systematic literature review to compare the advantages and drawbacks of SSO completed via piezoelectric surgery with those of SSO completed using electric or pneumatic saws.

Methods

This systematic review was conducted in accordance with the PRISMA statement[15] and following models proposed in the literature[16–18]. The selection of the articles was performed by two authors (LFS and ENRCR) and by a third reviewer (JPB).

Eligibility criteria

The studies were selected for this review according to the following PICO framework: (1) population: patients undergoing orthognathic surgery; (2) intervention: SSO; (3) comparison: SSO using conventional saw vs. piezoelectric surgery; (4) outcome: the main outcomes assessed were bleeding, duration of surgery, bad splits, postoperative oedema, and neurosensory disturbance.

Information sources and search strategy

Articles in the English language reporting the results of relevant studies were sought in the PubMed/MEDLINE, ScienceDirect, and Embase databases.

The search was conducted using three pairs of key words: ''Orthognathic surgery'' AND ''Piezosurgery''; ''Orthognathic surgery'' AND ''Ultrasonic surgical procedures''; ''Orthognathic surgery'' AND ''Osteotomy; sagittal split ramus''.

Study selection

The following inclusion criteria were applied: articles from clinical trials, prospective and retrospective studies concerning orthognathic surgery where an SSO was performed, published in the English language during the last 10 years.

Studies on animals, case reports, case series, and reviews and systematic reviews of the literature were excluded. Articles that used a similar sample and were reported by the same authors in the same year were also excluded. In these cases, only the article with the more relevant data was included. Articles that did not present data relevant to the aim of this study were excluded.

Data collection process

The articles were selected by two authors (LFS and ENRCR) and a third reviewer (JPB). Inter-examiner (kappa) tests were applied to the evaluation of titles and abstracts, and to the full-text reading for article interpretation, resulting in concordance kappa test values of $\kappa = 0.83$, 0.92, and 1, respectively. Agreement was reached during a meeting, and any differences were discussed and resolved by consultation with the third reviewer (JPB). After analysis of the titles, abstracts, and full-text articles, 12 studies were selected based on the inclusion criteria.

Data items

The following data were identified in each article and recorded: first author, level of evidence, number of patients, number of SSOs performed, equipment used to perform the osteotomy, volume of blood loss, duration of surgery, level of postoperative oedema, and the presence of IAN lesions as a complication.

For the analysis of neurosensory disturbances, articles that presented at least one of the following evaluation methods were selected: light touch sensation, pin-prick sensation, static two-point discrimination (the Weber test), moving two-point discrimination (the Dellon test), and subjective evaluation. For the articles that presented all of these methods, a global sensitivity score was used, while for those that did not use all of the tests above, the test with the largest number of patients showing sensory disturbances was chosen.

Risk of bias in the individual studies

The studies were analyzed to determine the risk of bias in the results and conclusions. The Jadad scale was used to assess the quality of each study[19]. Each study received a score from 0 to 5; studies with a score of 3 or above were considered adequate.

Summary measures

A comparative analysis between piezoelectric surgery and electric or pneumatic saws used in SSO was performed to evaluate the volume of blood loss, duration of surgery, postoperative oedema, damage to the IAN, and number of bad splits.

Risk of bias across studies

Regarding this review, it is acknowledged that the comparison of outcomes of different studies with different surgeons, different patient selection, and different methods of patient evaluation is difficult. However, this is a challenge for any systematic review.

Additional analyses

Fisher's exact test was applied for the comparative evaluation of neurosensory disturbances observed between osteotomies performed with a saw or via piezoelectric surgery, at 3 months and 6 months post-surgery. A P-value of <0.05 was considered statistically significant. The statistical analysis was performed using SigmaPlot 12.3 (Systat Software Inc., San Jose, CA, USA).

Results

After searching the three databases, 1736 articles were identified. Of these, 24 were selected after evaluation of the title and abstract based on the inclusion and exclusion criteria. Seven of these were excluded because they did not use a saw or piezoelectric device, or did not make clear which instrument was used[20–26]. One article was excluded to avoid the risk of data duplication (two articles were published in the same year, with the same author and subject)[11]. Another two were excluded because they did not present data relevant to this study[27,28]. Two articles were excluded because they did not represent the conventional technique[29,30]. Therefore, 12 articles were selected for quantitative and qualitative analysis (Fig. 1)[9,10,12,31–39].

Experimental design

Of the 12 studies selected, 10 were prospective and two were retrospective; all were published between 2006 and 2015.

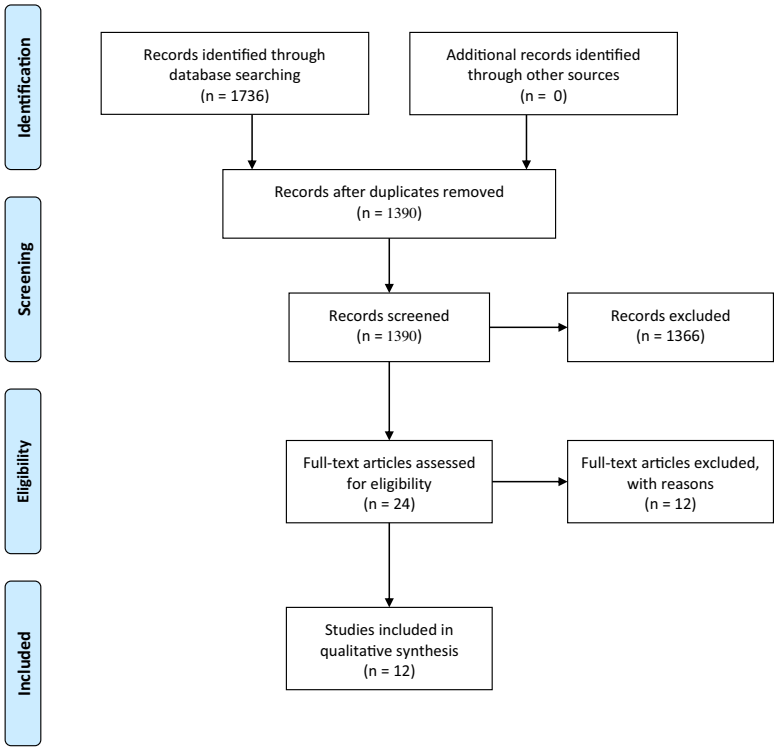

Fig. 1. Flowchart of the literature search strategy.

The number of patients in each study ranged from 12 to 280. A saw was used to perform the osteotomies in three studies[33,34,38] and an ultrasonic device in three studies[31,35,39]; in the remaining six studies, the two techniques were compared[9,10,12,32,36,37] (Table 1).

Patient selection

SSO was performed through the use of a saw or an ultrasonic device in 799 patients with an average age of 27.5 years. Thus, a total 1598 osteotomies were performed: 652 were performed with a piezoelectric device and 946 with a saw. The duration of follow-up in these studies varied from 2 to 55 months.

Type of movement and manufacturers of the instruments used

Only six articles reported the type of movement[9,10,31,33,37,39] (Table 2). Mandibular setback was predominant, with 96 cases compared to 64 cases of advancement. Among these, 28 mandibular setbacks were performed exclusively with an ultrasonic device and 37 exclusively with a saw. Twenty-three advancements were performed exclusively with an ultrasonic device and 23 exclusively with a saw. The remaining 31 setbacks and 18 advancements were performed with the two techniques.

In the studies in which the two types of surgical instruments were compared, the results obtained were compared between different patients[10,12], or the comparison was made in the same patient where one side of the SSO had been performed with a saw and the contralateral side with a piezoelectric device[9,36,37]. Two articles reported 34 cases of rotation of the occlusal plane (Table 2)[10,39]. The manufacturers of the saws and ultrasonic devices used are presented in Table 2.

Intraoperative bleeding

There was no uniformity in the studies regarding the methods of assessment for blood loss during SSO. Only three studies evaluated intraoperative bleeding[9,10,39]. Among these, one referred to the amount of blood loss during SSO exclusively performed with piezoelectric surgery[39]. Another study reported SSO together with a one-sided Le Fort I osteotomy using ultrasound in the same patient[9]. The remaining study performed the assessment of bleeding in patients who underwent a bilateral SSO associated with Le Fort I osteotomy[10].

Duration of surgery and level of oedema

All studies that assessed the duration of surgery showed that it took longer to perform the osteotomies with the ultrasonic device than with the saw. However, there was no uniformity regarding the measurement of operating time. Among the five studies that evaluated the duration of surgery[9,10,32,38,39], three assessed the time necessary to perform a bilateral SSO along with a Le Fort I osteotomy[10,38,39]. Two articles evaluated the operating time to perform a one-sided SSO[9,32].

Regarding oedema, only one study made this assessment[9]. It was observed that eight of the 12 patients presented with some level of oedema within a week of piezoelectric surgery. Of these, six patients recovered within a week, while the other two recovered within a month. One patient developed a haematoma,

Table 1. Details of the articles selected for this review.

Author	Publication year	Type of study	Year of the study	Patients (*n*)	Technique used
Geha et al.[31]	2006	Prospective	2004	20	Piezoelectric surgery
Beziat et al.[32]	2007	Prospective	–	280	Piezoelectric surgery and saw
Landes et al.[10]	2008	Prospective	2005–2006	87	Piezoelectric surgery and saw
D'Agostino et al.[33]	2010	Prospective	2003–2007	50	Saw
Monnazzi et al.[34]	2012	Prospective	2009–2010	30	Saw
Bertossi et al.[12]	2013	Prospective	–	55	Piezoelectric surgery and saw
Gilles et al.[35]	2013	Prospective	2009–2012	51	Piezoelectric surgery
Bruckmoser et al.[38]	2013	Retrospective	1999–2001	128	Saw
Monnazzi et al.[36]	2014	Prospective	2011–2012	20	Piezoelectric surgery and saw
Spinelli et al.[9]	2014	Prospective	2011–2012	12	Piezoelectric surgery and saw
Landes et al.[39]	2014	Retrospective	2009–2011	29	Piezoelectric surgery
Brockmeyer et al.[37]	2015	Prospective	2006–2008	37	Piezoelectric surgery and saw

Table 2. Distribution of the studies regarding the type of movement.

Author	Year	Technique used	Type of movement	Manufacturer
Geha et al.[31]	2006	Piezoelectric surgery	Setback, advancement	–
Beziat et al.[32]	2007	Piezoelectric surgery/saw	–	–
Landes et al.[10]	2008	Piezoelectric surgery/saw	Setback (16/37), advancement (6/23), rotation of occlusal plane (2/3)	Piezosurgery, Mectron, Carasco, Italy Saw blades GC615R and GC588R, motor unit Microspeed Elan-EC GA835, all B. Braun Aesculap, Tuttlingen, Germany
D'Agostino et al.[33]	2010	Saw	Setback, advancement	–
Monnazzi et al.[34]	2012	Saw	–	Stryker, Kalamazoo, MI, USA; Driller, Jaguaré, SP, Brazil
Bertossi et al.[12]	2013	Piezoelectric surgery/saw	–	Piezosurgery Medical II, Mectron, Carasco, Italy
Gilles et al.[35]	2013	Piezoelectric surgery	–	BoneScalpel, Misonix Inc., Farmingdale, NY, USA
Bruckmoser et al.[38]	2013	Saw	–	–
Monnazzi et al.[36]	2014	Piezoelectric surgery/saw	–	Piezosonic, Driller, Jaguaré, SP, Brazil; Stryker, Kalamazoo, MI, USA; Driller, Jaguaré, SP, Brazil
Spinelli et al.[9]	2014	Piezoelectric surgery/saw	Setback (11), advancement (1)	–
Landes et al.[39]	2014	Piezoelectric surgery	Setback (12), advancement (17); clockwise rotation (14), counter-clockwise rotation (15)	Piezosurgery, Mectron, Carasco, Italy
Brockmeyer et al.[37]	2015	Piezoelectric surgery/saw	Setback (20), advancement (17)	Piezosurgery, Mectron, Carasco, Italy

Table 3. Distribution of neurosensory disturbance according to the follow-up period and the equipment used.

Equipment	Follow-up period					
	≤3 months			≥6 months		
	Total number of SSO	Neurosensory disturbance	*P*-value	Total number of SSO	Neurosensory disturbance	*P*-value
Saw	846	341	1.00	435	268	0.04[a]
Piezoelectric surgery	652	185		171	8	

SSO, sagittal split osteotomy.
[a] $P < 0.05$ was considered statistically significant.

which healed within a month. Eight of the 12 patients showed some level of oedema within a week of the procedure using a saw. Four of them recovered within a month and the remaining four recovered within 6 months. Four of 12 patients developed a haematoma in the first post-operative days.

Neurosensory disturbance

Regarding neurosensory disturbance, four studies did not report the number or percentage of those who developed nerve damage after the SSO[9,36–38]. The remaining eight studies presented an evaluation with follow-up varying from 1 to 55 months[10,12,31–35,39]. Two studies reported the percentage of neurosensory disturbance by zone and it was not possible to determine the numbers of patients[9,38].

Table 3 shows the total number of SSO and the amount of neurosensory disturbance measured at ≤3 months and at ≥6 months after surgery. For the assessment at ≤3 months of follow-up, 652 SSO performed with an ultrasonic device and 846 with a saw were compared. It was observed that 185 (28.4%) of the sides submitted to an SSO with an ultrasonic device and 341 (40.3%) submitted to an SSO with a saw presented some type of neurosensory disturbance. For periods of 6 months or longer, 171 SSO performed with an ultrasonic device were compared to 435 performed with a saw. The rate of neurosensory disturbance was 4.7% (8/171) for the sides submitted to SSO with a piezoelectric device and 61.6% (268/435) for those submitted to SSO with a saw (Fig. 2).

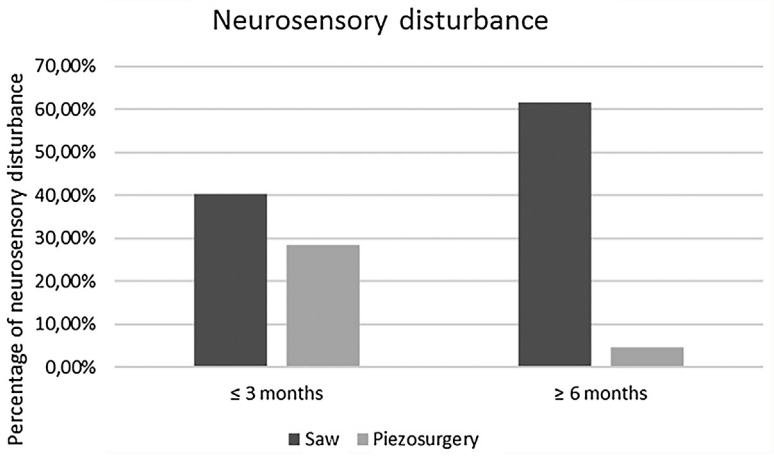

Fig. 2. Comparison of neurosensory disturbance between the two techniques.

Table 4. Jadad quality scale.

Authors	Question and scale							Total score
	Was the study described as randomized? (0 or +1)	The method of randomization was described and it was appropriate (0 or +1)	Was the study described as double-blind? (0 or +1)	The method of blinding was described and it was appropriate (0 or +1)	The method of randomization was described, but was inappropriate (0 or −1)	The method of blinding was described, but was inappropriate (0 or −1)	Was there a description of withdrawals and dropouts? (0 or +1)	
Geha et al.[31]	0	0	0	0	0	0	0	0
Beziat et al.[32]	0	0	0	0	0	0	0	0
Landes et al.[10]	0	0	0	0	0	0	0	0
D'Agostino et al.[33]	0	0	0	0	0	0	0	0
Monnazzi et al.[34]	0	0	0	0	0	0	0	0
Bertossi et al.[12]	0	0	0	0	0	0	0	0
Gilles et al.[35]	0	0	0	0	0	0	0	0
Bruckmoser et al.[38]	0	0	0	0	0	0	1	1
Monnazzi et al.[36]	1	1	1	1	0	0	1	5
Spinelli et al.[9]	0	0	0	0	0	0	0	0
Landes et al.[39]	0	0	0	0	0	0	0	0
Brockmeyer et al.[37]	1	1	1	1	0	0	1	5

Methodological quality and risk analysis of the studies

The Jadad quality scale scores of the studies ranged from 0 to 5. Ten studies were prospective and two were retrospective (Table 1). The Jadad quality evaluation of the studies is presented in Table 4.

Discussion

The assessment of study quality was performed using the scale developed by Jadad et al.[19]. Only two studies presented a methodological quality and risk analysis that was considered good; these two studies had a score of 5[36,37]. Of the 12 selected articles, two reported retrospective studies[38,39], which impairs randomization and blinding. The other studies were categorized as prospective[9,10,12,31–37]. However, the majority of these studies received a score of zero for randomization and were of low methodological quality with a poor analysis of the results. In this type of assessment, the present authors believe that randomization should be mandatory, even though the double-blind method cannot be applied. Patient blinding can be performed conveniently, but blinding of the professional performing the SSO with conventional saws or a piezoelectric device is impossible.

Osteotomy is an important surgical step in the correction of dentofacial deformity. In the era of minimally invasive surgery, it should present some features that promote tissue regeneration. The procedure should be designed precisely and performed under abundant irrigation with saline solution to ensure that there is no overheating of the bone or resulting delays that could decrease cell viability between the osteotomized stumps. Thus, research has focused on ultrasonic instruments, particularly piezoelectric surgery, when looking for the best biological responses in comparison to conventional saws[40,41].

Most of the studies included in this review reported that the duration of osteotomies performed by piezoelectric surgery was longer than that of osteotomies performed with a saw. This review sought to examine the relationship between the duration of surgery and the magnitude of postoperative swelling[9,10,32,38,39]. However, the studies reported in the literature lacked standardization in the measurement of surgical duration, hindering the evaluation as proposed in this research, which investigated only mandibular osteotomies. Most studies analyzed the operative time of bimaxillary surgery[10,38,39], which naturally increases the surgical duration, and this caused much difficultly for the analysis proposed in this review. In addition, only one study compared the degree of postoperative swelling between osteotomies[9], in which 12 patients showed a higher amount of swelling over the long term after osteotomy with conventional saws. Therefore, more studies are required before valid conclusions can be drawn regarding these points.

As for the parameters discussed above, the amount of blood loss was measured for bimaxillary procedures in most of the studies[9,10], while only one study assessed blood loss in a sagittal mandibular osteotomy performed with piezoelectric surgery[39]. A greater blood loss was identified in procedures performed with conventional saws[9,10]. Landes et al. stated that as the cut made using the piezoelectric device is more accurate and well-defined in comparison to that made by conventional saws, the surrounding anatomical structures are less likely to be injured, including the vascular tissue, which directly relates to the volume of intraoperative blood loss[10].

With regard to the standardization of the evaluation of neurosensory disturbance, this review assessed the methods most often described in the literature. Eight studies investigated the occurrence of long-term nerve damage[10,12,31–35,39]. The group treated with a conventional saw showed a higher percentage of neurosensory disturbances at $\geq$6 months post-surgery. This can be explained by the lower numbers of patients who were followed up over a longer postoperative period. However, the main goal of this review was to compare neurosensory disturbances between piezoelectric surgery and conventional saw surgery. Table 3 shows that better results were achieved for the group treated with piezoelectric surgery when the postoperative period was 6 months or longer ($P = 0.04$). Although there was no statistically significant difference between the two techniques for the period up to 3 months post-surgery ($P = 1.00$), piezoelectric surgery showed a lesser amount of neurosensory disturbance. An interesting observation was that piezoelectric surgery, in the period up to 3 months after surgery, showed a lesser amount of neurosensory disturbance ($n = 185$) with a larger number of SSO ($n = 652$) than seen in the group in which a conventional saw was used within the follow-up period of 6 months or longer (268 cases of neurosensory disturbance in 435 SSO).

It is concluded that the use of piezoelectric surgery in SSO promotes better clinical outcomes with regard to neurosensory disturbance when compared to the use of conventional saws. However, there is lack of sufficient data in the literature to support any conclusions about postoperative swelling, blood loss, or the duration of surgery in SSO exclusively. Therefore, more studies are required to evaluate these aspects.

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Competing interests

None.

Ethical approval

Not required.

Patient consent

Not required.

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