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ORIGINAL ARTICLE

Evaluation of ultrasonic and conventional surgical techniques for genioplasty combined with two different osteosynthesis plates: a cadaveric study

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Abstract
Objectives The aim of this study was to compare genioplasties performed using traditional saw or piezosurgery combined with different osteosynthesis plates.
Materials and methods Thirty-two genioplasties were first performed on fresh human cadavers using a saw or piezosurgery, followed by chin osteosynthesis with bending or pre-shaped plates. The time required for osteotomy and plate fixation was measured, and the suprahyoid pedicle was inspected.
Results The mean time required was 204 s (SD 43) with the saw and 52 s (SD 67) with piezosurgery. Osteosynthesis fixation time was 100 s (SD 31) for pre-shaped plates and 124 s (SD 24) for individual plates. Statistical differences were found between both osteotomy techniques ($p < 0.001$) and osteosynthesis plates ($p = 0.025$). Injuries of the suprahyoid muscle pedicle were found in 10/16 saw cases and 3/16 piezosurgery cases ($p = 0.012$).
Conclusions Although piezosurgery is more time consuming compared with saw osteotomy, it is still adequate in time and allows a reduction of the suprahyoid pedicle injuries. Therefore, piezosurgery seems to be a viable alternative technique for genioplasty. From a clinical point of view, the time difference for osteosynthesis fixation has no significance.
Clinical relevance The time taken for ultrasonic surgery is suitable for clinical use and leads additional to less damage to the suprahyoid pedicle.

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Keywords Genioplasty · Ultrasonic osteotomy · Saw osteotomy · Piezosurgery · Suprahyoid pedicle injury

Introduction

The chin is the most prominent osseous part of the face and, therefore, one of the most important structures influencing facial esthetic harmony. The size, shape, position, or proportion of the anatomical landmarks in the lower third of the face can be influenced by chin malposition, leading to soft tissue deformities that can disturb the overall balance of facial expressions [1]. The unfavorable chin positions and projections can be caused by microgenia, macrogenia, retrogenia, pseudoretrogenia, or pseudmacrogenia alone or in combination, which can lead to significant facial disfigurement and a noticeable compromise in facial esthetics.

Genioplasty is conventionally a part of malocclusion therapy, making combination orthodontic-surgical-orthognathic treatments necessary. Isolated chin corrections can be useful in patients who reject orthognathic surgery but would like to achieve esthetic improvement of the facial profile and chin projection after orthodontic treatment. Moreover, genioplasty can also be performed as an addition to surgical procedures such as rhinoplasty or facelift so as to complement the overall esthetic outcome of the primary surgery. Finally, this procedure is also included in reconstructive or craniofacial surgery in Treacher–Collins syndrome or obstructive sleep apnea patients and is an effective way to advance the genioglossus muscle attachment and improve posterior airway space.

Various surgical skeletal techniques have been described for the improvement of chin esthetics and facial form. These primarily include chin augmentation with tissue grafts or prosthetic implants, chin displacement through various types of osseous osteotomy, and reciprocal movements of the mandibular segments [2–4]. It can be performed as a single operation or in combination with other orthognathic surgical procedures. The most popular approach for the correction of chin deformity is a horizontal bone osteotomy below the roots of the anterior mandibular incisor teeth and parallel to the inferior border of the mandible, allowing three-dimensional repositioning of the osteotomized chin segment and a significant improvement in the aesthetic outcome of the face [5]. This is considered a very safe method with good surgical outcome. The genioplasty can be performed using alloplastic materials for chin augmentation, reduction, or augmentation in the vertical and horizontal directions and correction of the lower facial third and chin asymmetry. In this context, some studies have suggested that alloplastic implants for chin augmentation are preferred due to easier performance and lower complication rates, while others have advocated osseous genioplasty due to better patient satisfaction, more predictable contours and soft tissue response, and less detrimental postoperative effects [6]. With regard to osseous genioplasty, Ward et al. classified chin osteotomies by technique, segment movement, and final results [7]. They differentiated the osteotomies into sliding, jumping, interpositional, wedge, oblique, stepladder/two-tiered, or centering genioplasty. Usually, the sliding or chin-shield technique is used for sliding advancement or setback genioplasty. It must be noted that the osteotomy technique used may influence the overall result. There may be differences in the ratio of soft and hard tissue response to genioplasty, labiomental fold depth alteration, lower lip position change, and bone contact area between segments following different techniques [8–10].

Possible complications of chin surgery include compromised facial outcome by unexpected lower labial sulcus depth, witch's chin deformity, and lip incompetence due to failure of the mentalis muscle at the time of wound closure [11, 12]. Additionally, the mental nerve may be affected resulting in neuroparaxia and neurotmesis, loss of dental vitality, periodontal pockets, and disruption of wound healing [13–16].

Ultrasonic surgery is well established in the field of oral and maxillofacial surgery and has become a viable alternative to conventional instruments for orthognathic operations [17–21]. The main advantages of this technique include minimal risk of soft tissue damage, vibrations without fracture when in contact with the osteotome tip, excellent visibility within the surgical field due to minimal bleeding and cavitation effect, precision in geometric cutting due to limited vibration amplitude and specific design of the osteotome, and low acoustic and vibrational impact [22]. This results in reduction of intraoperative blood loss, more cutting precision, longer surgical duration, less incidence of postoperative swelling and hematoma, lower incidence of nerve damage, and faster nerve recovery [19–21, 23, 24]. A comparison of piezosurgery and the traditional saw in bimaxillary orthognathic surgery showed better results for the ultrasonic device, particularly in terms of intraoperative blood loss, postoperative swelling, and nerve impairment [22].

At present, the use of the piezoelectric device for genioplasty has not been examined. The aim of this cadaveric study was to compare the surgical time when using the traditional saw and piezosurgery in combination with individually bent or prefabricated, pre-shaped chin plates as well as to identify suprahyoid pedicle injuries.

Materials and methods

After institutional approval, 32 chin-shield genioplasties were performed on fresh cadaver heads (14 females and 18 males; mean age 70 years, range 53–85 years) using the traditional saw or piezosurgery, followed by chin osteosynthesis with the help of individual bent plates or prefabricated pre-shaped plates. This resulted in 16 heads per group (saw vs. ultrasonic surgery, individual bent vs. prefabricated/pre-shaped plate) and the same oral and maxillofacial surgeon performed all surgical procedures.

A vestibular incision was made in the anterior region of the mandible through the mucosa extending between the depth of the labial vestibule and the border of the lower lip. The incision was extended towards the mesial aspect of the canine teeth bilaterally. Sub-periosteal soft tissue reflection was then performed, and the mentalis muscle was stripped from the anterior part of the mandible along the sub-periosteal plane. Finally, the mental nerve at the foramina was identified, and the surrounding periosteum was released to allow displacement of the bone segment (Fig. 1).

The curved osteotomy for chin-shield genioplasty was performed using either a traditional saw (group 1) (GC615R,

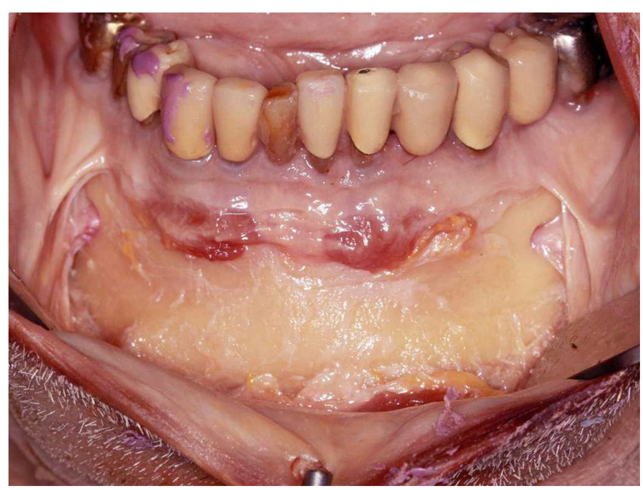

Fig. 1 Dissected anterior region of the mandible after sub-periosteal soft tissue reflection, stripping of the mentalis muscle, and release of the periosteum before osteotomy

Reciprocating, Microspeed Aesculap AG, Tuttlingen, Germany) (Fig. 2a, b) or an ultrasonic device at the cortical modus with full irrigation at the highest level of vibration (group 2) (MT1–20, Piezosurgery Medical, Mectron s.p.a., Carasco, Italy) (Fig. 3a, b). After complete mobilization of the chin and advancement by 5 mm, ostheosynthesis was performed to achieve bone contact using individual bent chin plates (group 1a/2a) or prefabricated pre-shaped chin plates (group 1b/2b) (M-4072C and M-4078C, Medartis AG, Basel Switzerland) (Fig. 4a, b).

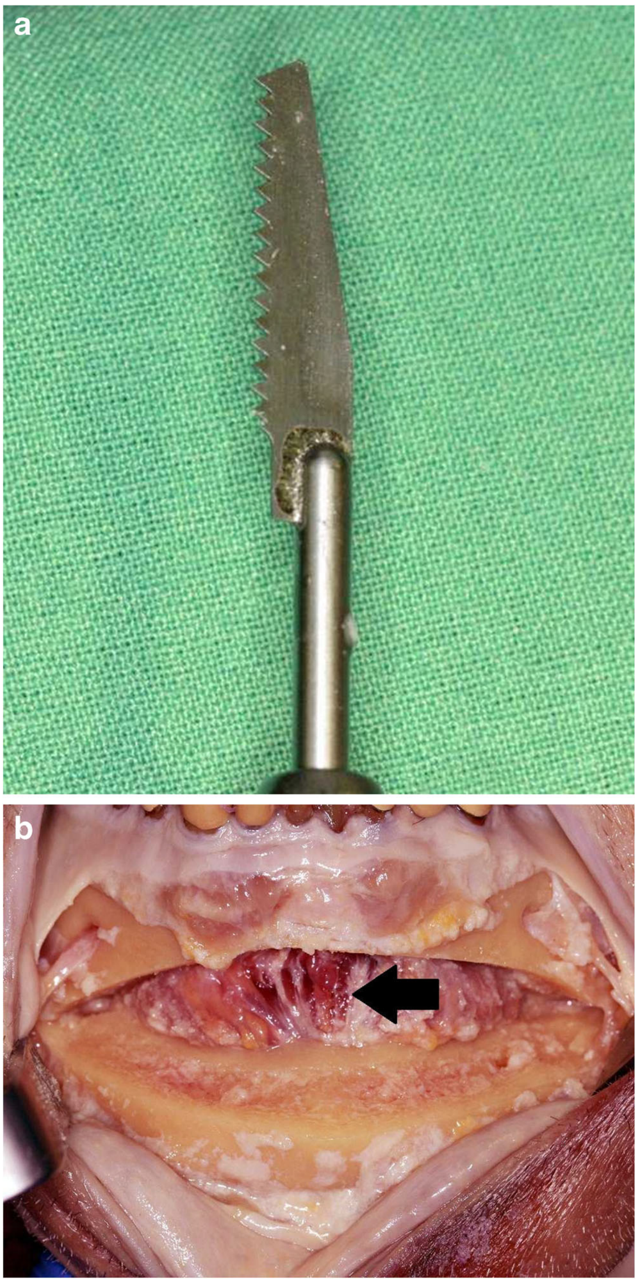

Fig. 2 **a** Microsaw for conventional reciprocating osteotomy. **b** Mobilized chin segment after traditional osteotomy and injury of the suprahyoid pedicle (*arrow*)

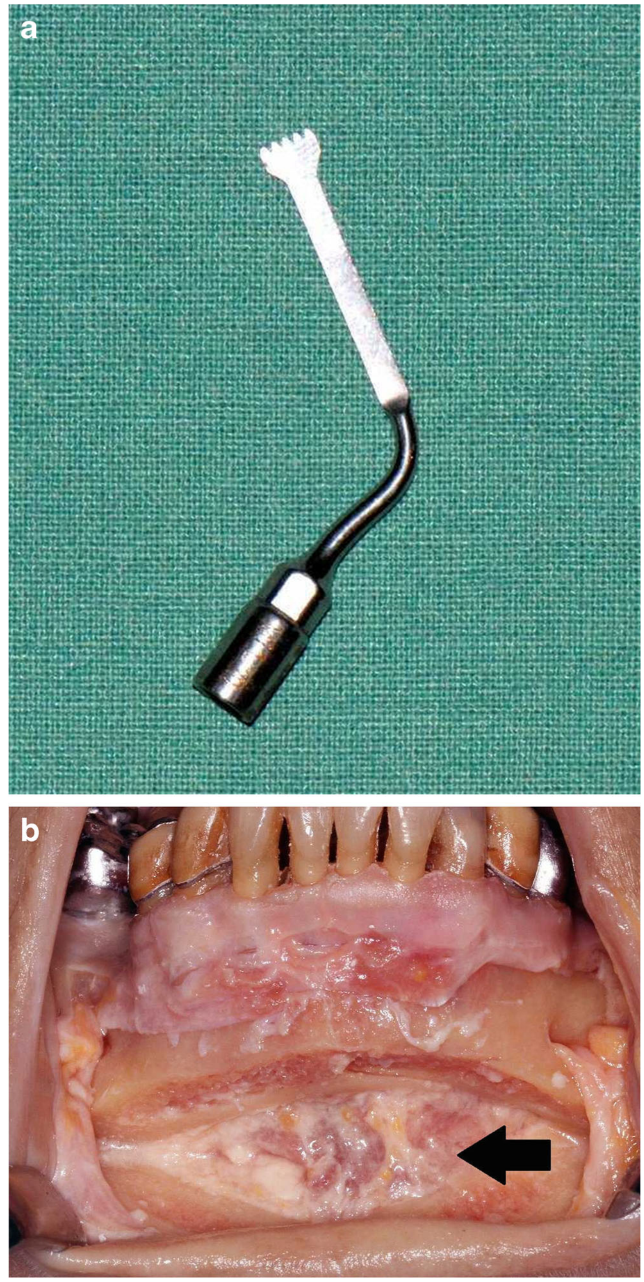

Fig. 3 **a** Surgical tip for osteotomy with piezosurgery. **b** Mobilized chin segment after ultrasonic osteotomy, and no injury of the suprahyoid pedicle (*arrow*)

The surgical time required for osteotomy and fixation of chin plates was measured, and the suprahyoid muscle pedicle was inspected.

Statistical analysis

All statistical analyses were performed using the Statistical Package for Social Sciences SPSS v23 (IBM, Chicago, IL, USA) on Apple OS X v10.10.2 (Apple Inc., Cupertino, CA, USA). The Shapiro–Wilks normality test and the Levene's

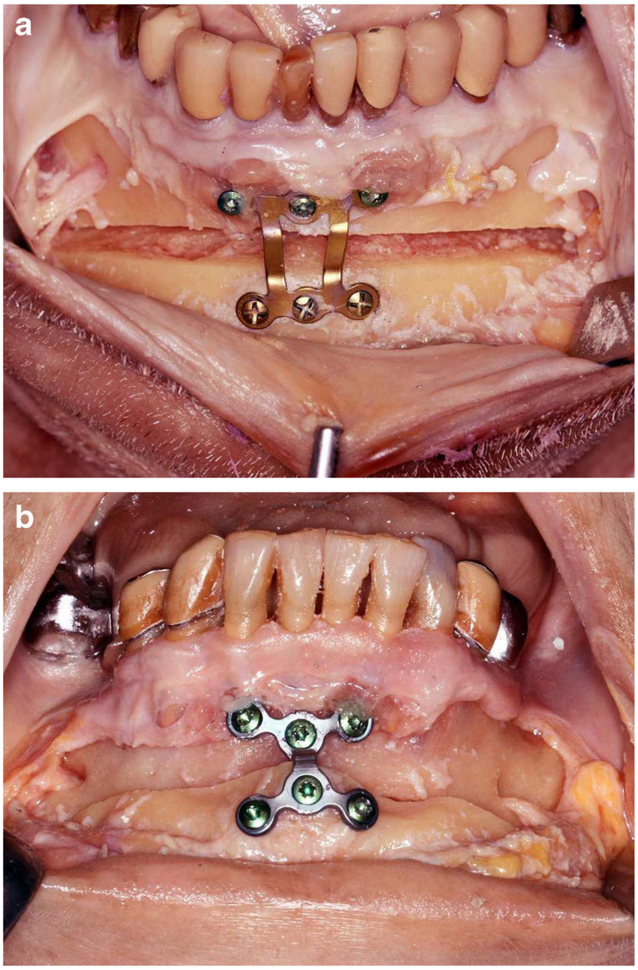

Fig. 4 Condition after fixation following 5 mm chin advancement using individual bending chin plate (**a**) or prefabricated pre-shaped chin plate (**b**)

variance homogeneity test were performed, and the data were found to be normally distributed with the homogeneity of variance between the groups. The Student's *t* test method was used for statistical analysis. The number injuries of the suprahyoid muscle pedicle was compared between osteotomy techniques using the chi-square test. The level of significance was set at $p \leq 0.05$. All data are expressed as mean values and standard deviation (SD).

Results

All time measurements for the different surgical procedures (conventional or ultrasonic), ostheosynthesis methods (individual bent or a prefabricated pre-shaped), and suprahyoid pedicle inspection are presented in Table 1. The corresponding comparisons between the time measurements are shown in the Boxplot charts (Fig. 5a, b).

The mean inter-foraminal distance was 6.01 mm (SD 0.74) in the saw group and 5.84 mm (SD 0.70) in the ultrasonic group. The mean osteotomy time was 204 s (SD 44) with the traditional saw and 525 s (SD 67) with the ultrasonic device. The mean osteosynthesis fixation time was 100 s (SD 32) for prefabricated pre-shaped plates and 124 s (SD 24) for individual bent plates. Statistically significant differences were observed between the osteotomy techniques ($p < 0.001$) as well the osteosynthesis plates ($p = 0.025$). Statistically significant injuries of the suprahyoid muscle pedicle were observed 10 out of 16 times after saw surgery and 3 out of 16 times after ultrasonic surgery ($p = 0.012$).

Discussion

The behavior of the local soft tissue during genioplasty depends on various factors, including the amount and type of bone displacement in horizontal and vertical directions, incision technique, implementation of other surgical procedures, detachment of the musculo-periosteal pedicle, and fixation technique [5, 8, 12, 25, 26].

Various studies demonstrated that wire fixation usually affords good stability [27, 28] but can result in less accurate advancement [14] and a tendency towards greater relapse compared with fixation with plates. However, these differences were not statistically significant [5]. In contrast, other authors found no differences in the relapse rates between genioplasties with various amounts of advancement [29, 30] and between wire and rigid fixation [31]. Currently, the effect to the soft-to-hard tissue ratio by the type of fixation such as wire, plates, or screws has not been clarified [32].

Particular attention is given to the prevention of scarring and reconstruction of the mentalis muscle. Scar contracture may induce resorption of the repositioned bony segments as well as decreased soft tissue thickness [16, 33]. Furthermore, chin ptosis and labial incompetence may occur when complete muscle stripping is performed [6, 34]. Therefore, the incision should be performed midway between the depth of the labial vestibule and the vermillion border, and the mentalis muscle should be mobilized minimally or satisfactorily reconstructed after transection.

With regard to detachment of the suprahyoid muscle pedicle, different studies have demonstrated that the soft tissues follow the hard tissues closely during genioplasty if the pedicle is kept intact [25, 33, 35, 36]. In a direct comparison between patients who underwent sliding genioplasty with or without detachment of suprahyoid muscles, greater bone resorption was found in the first group (30.9% bone resorption) than in the second group (11% bone resorption). Additionally, the ratio between the soft Pogonion (sPg) and hard Pogonion (Pg) was 0.53:1 for the group with the detached suprahyoid pedicle and 0.92:1 in the group with the preserved pedicle [37].

Ultrasonic surgery, an operative technique used for osteotomy, was developed mainly because of the need for

Table 1 Overview of the operated cadaveric heads ranked by surgical technique and type of osteosynthesis plate

Cadaver	Surgical technique	Osteo-synthesis	Gender	Age	Interforaminal distance (mm)	Osteotomy time (s)	Oseosynthesis time (s)	Injury of suprahyoid pedicle
1	Saw	Prefabricated/pre-shaped	Male	69	6.3	213	86	Yes
2	Saw	Prefabricated/pre-shaped	Male	72	6.2	182	114	Yes
3	Saw	Prefabricated/pre-shaped	Male	85	5.3	143	143	No
4	Saw	Prefabricated/pre-shaped	Male	75	6.1	194	164	No
5	Saw	Prefabricated/pre-shaped	Male	79	5.4	179	109	Yes
6	Saw	Prefabricated/pre-shaped	Female	65	6,2	234	132	No
7	Saw	Prefabricated/pre-shaped	Female	65	6.0	228	93	Yes
8	Saw	Prefabricated/pre-shaped	Female	83	4.8	168	103	No
9	Saw	Individual bent	Male	65	6.2	204	128	Yes
10	Saw	Individual bent	Male	54	7.2	294	125	Yes
11	Saw	Individual bent	Male	68	6.4	216	133	Yes
12	Saw	Individual bent	Male	62	7.1	249	79	No
13	Saw	Individual bent	Female	85	5.0	118	113	Yes
14	Saw	Individual bent	Female	75	5.5	206	91	Yes
15	Saw	Individual bent	Female	53	7.1	256	98	No
16	Saw	Individual bent	Female	80	5.4	182	109	Yes
17	Ultrasonic	Prefabricated/pre-shaped	Male	80	5,3	461	102	No
18	Ultrasonic	Prefabricated/pre-shaped	Male	73	6.2	516	78	No
19	Ultrasonic	Prefabricated/pre-shaped	Male	64	7.2	676	122	No
20	Ultrasonic	Prefabricated/pre-shaped	Female	71	5.6	513	48	No
21	Ultrasonic	Prefabricated/pre-shaped	Female	62	6.2	562	61	Yes
22	Ultrasonic	Prefabricated/pre-shaped	Female	80	5.3	496	75	No
23	Ultrasonic	Prefabricated/pre-shaped	Female	68	5.9	533	59	Yes
24	Ultrasonic	Prefabricated/pre-shaped	Female	60	6.4	589	109	No
25	Ultrasonic	Individual bent	Male	84	4.3	426	172	No
26	Ultrasonic	Individual bent	Male	55	6.6	623	137	No
27	Ultrasonic	Individual bent	Male	67	6.3	539	156	No
28	Ultrasonic	Individual bent	Male	66	6.4	572	142	No
29	Ultrasonic	Individual bent	Male	74	6.0	471	141	No
30	Ultrasonic	Individual bent	Male	67	6.1	504	108	Yes
31	Ultrasonic	Individual bent	Female	76	5.1	476	127	No
32	Ultrasonic	Individual bent	Female	84	4.6	444	117	No

higher levels of precision and safety during bone surgery compared with the standard bur and saw instruments. Frequencies ranging from 24 to 29 kHz and from 60 to 200 mm/s allow bone cutting without injuring the soft tissue, even in cases of minor accidental contact. The micrometric vibration ensures precise cutting action while simultaneously maintaining a blood-free site because of the cavitation effect [20]. In the context of orthognathic surgery, a particular advantage of this technique is the reduced blood loss and risk of inferior alveolar nerve injury with no extra surgical time [22]. However, additional chiseling or sawing may be occasionally required.

The piezoelectric device is known as the ideal instrument for pediatric craniofacial surgery because it increases the precision of bone cutting, ensures lower incidence of adjacent soft tissue damage, and reduction in surgical trauma [38]. Due to poor accessibility in the lingual area of the mouth, the ideal instrument should decrease the need for soft tissue protection.

This study examined the influence of two different surgical methods for osteotomy of the chin in fresh cadavers. Usually, human cadavers will be preserved by formalin fixation. Hereby, those cadavers are not being subjected to a rapid decaying process and do not provide for a tissue quality comparable with clinical conditions. The main disadvantages of the formalin embalming technique are stiffness and unnatural coloring of the tissues. However, this investigation focuses the behavior of hard tissue during osteotomy and soft

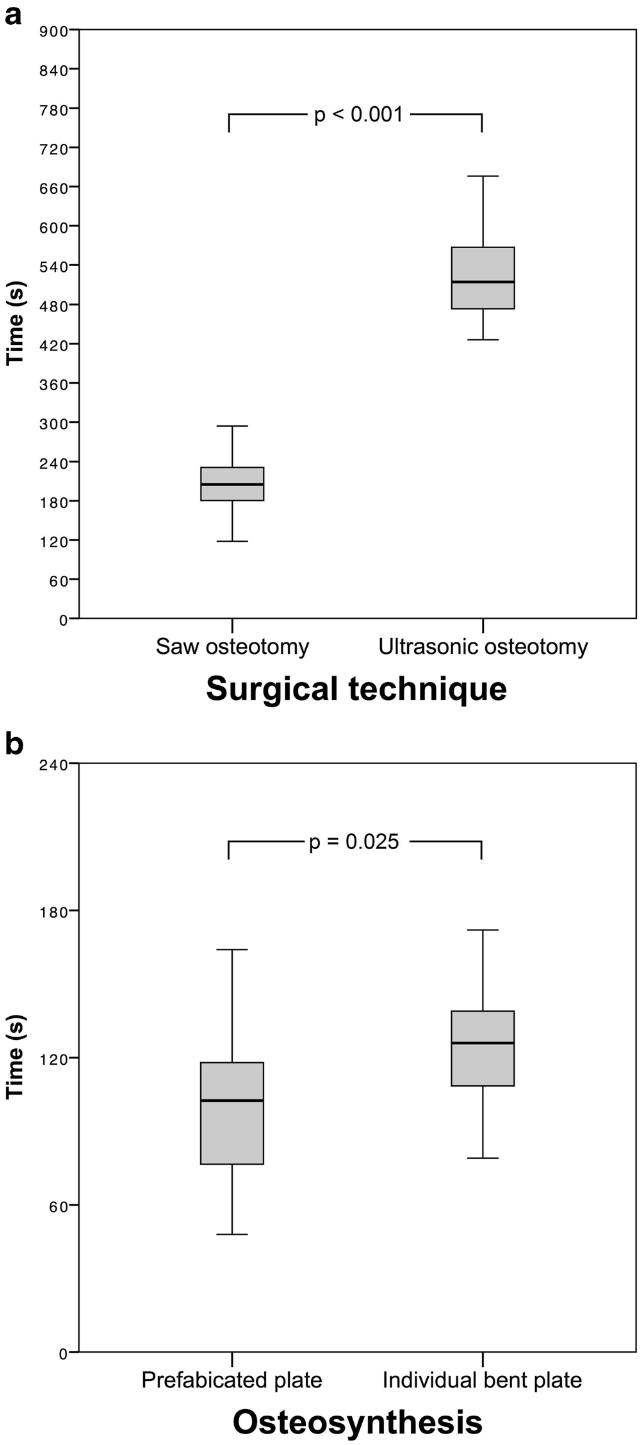

Fig. 5 Boxplots showing mean surgical time for different techniques of osteotomy (**a**) and osteosynthesis fixation (**b**)

tissue regarding possible injuries of the suprahyoid pedicle. Especially, changes in color after pedicle injury due the exposition of the mouth floor muscles are interesting. Therefore, a model comparable with the clinical situation is necessary. The thiel embalming technique could be an alternative to conventional formalin fixation because color, structure, and consistency of the different tissues are comparable to vital conditions [39]. However, also slightly differences in color were reported compared with the in vivo situation [40]. Therefore, in this study, only fresh cadaver heads are studied.

Our results demonstrated that using a conventional saw led to faster separation of the chin. Piezosurgery is more than two times slower than the conventional osteotomy technique. However, the mean necessary time for ultrasonic surgery is approximately 9 min, which is suitable for clinical use. Furthermore, a significantly higher number of injuries of the suprahyoid muscle pedicles were found in the saw osteotomy group, making the use of the ultrasonic device safer for the surrounding soft tissues. Considering the increased preservation of pedicles, this technique should be considered as an alternative to the conventional saw. However, implant surgeries have shown that the piezoelectric system can lead to bone damaging temperatures. Rashad et al. investigated the temperature development when piezosurgery was used to cut bone [41]. They compared two different ultrasonic devices with a conventional drilling system in cancellous and cortical bone and found that both systems produced more heat than conventional implant site preparation methods. Moreover, the critical level of 47 °C was exceeded, even with irrigation, in five cases. Stelzle and colleagues also reported similar results [42]. They observed a highest mean temperature of 48.6 °C for piezosurgery, and the corresponding histomorphometric analysis showed the greatest thermal effects at approximately 200 μm. Therefore, clinical trials examining this technique further are required in the future.

Furthermore, in this study, the influence of different osteosynthesis plates on bending and fixation time during genioplasty was determined due its relevance to patient morbidity and operation-related costs. Our results exhibited with regard to the required time for bone segment fixation prefabricated osteosynthesis plates only slight advantage in contrast to individually bent plates. In clinical practice, the measured time difference for osteosynthesis fixation leads to no advantages and has therefore no significance.

Conclusions

Within the limitations of this cadaveric study, we found that an ultrasonic device is more time-consuming than the conventional saw technique. However, the time taken for ultrasonic surgery is suitable for clinical use. Furthermore, piezosurgery results in less damage to the suprahyoid pedicle and, therefore, seems like a suitable alternative to genioplasty. However, clinical trials examining the soft tissue changes, blood loss, and bone healing are required in the future. From a clinical point of view, the statically significant difference in time between the osteosynthesis fixation is not relevant.

Compliance with ethical standards

Conflict of interest All author declare that they have no conflict of interest.

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Human and animal rights and informed consent This article does not contain any studies with living human participants or animals. Institutional approval was given.

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