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RHINOLOGY

A comparison of piezosurgery with conventional techniques for internal osteotomy

İ. Koçak[1] · R. Doğan[2] · O. Gökler[1]

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Abstract To compare conventional osteotomy with the piezosurgery medical device, in terms of postoperative edema, ecchymosis, pain, operation time, and mucosal integrity, in rhinoplasty patients. In this prospective study, 49 rhinoplasty patients were randomly divided into two groups according to osteotomy technique used, either conventional osteotomy or piezosurgery. For all patients, the total duration of the operation was recorded, and photographs were taken and scored for ecchymosis and edema on postoperative days 2, 4, and 7. In addition, pain level was evaluated on postoperative day 2, and mucosal integrity was assessed on day 4. All scoring and evaluation was conducted by a physician who was blinded to the osteotomy procedure. In the piezosurgery group, edema scores on postoperative day 2 and ecchymosis scores on postoperative days 2, 4, and 7 were significantly lower than in the conventional osteotomy group ($p < 0.05$). On postoperative day 2, the pain level was lower in the piezosurgery group than in the conventional osteotomy group ($p < 0.05$). In an endoscopic examination on postoperative day 4, while 24% of the patients in the conventional osteotomy group had mucosal damage, no such damage was observed in the piezosurgery group. When total operation duration was compared, there was no significant difference between the groups ($p > 0.05$). Piezosurgery is a safe osteotomy method, with less edema (in the early postoperative period) and ecchymosis compared with conventional osteotomy, as well as less pain, a similar operation duration, and no mucosal damage.

Keywords Ecchymosis · Edema · Mucosal integrity · Osteotomy · Piezosurgery · Rhinoplasty

Introduction

Rhinoplasty surgery may often require osteotomy to achieve lasting and satisfying outcomes, and the nature of the osteotomy (medial, lateral, or transverse) depends on the type of nasal deformity to be addressed [1]. Following a hump removal, the dorsum tends to remain wide, leading to an open roof deformity. Lateral osteotomy enables closure of an open roof, narrowing of the bone nasal pyramid, and fixing of the nasal bones [2, 3]; however, it is usually the most difficult step of rhinoplasty and is associated with complications that include massive bleeding, prolonged post-operative edema, and ecchymosis, as well as asymmetrical irregularities of the nasal wall [4]. At this stage, it is important to provide sufficient nasal bone mobilization, avoid damage to soft tissues surrounding nasal bones, and refrain from over narrowing nasal bones just to avoid disrupting the nasal physiology. Mechanical energy has recently become a commonly used method in osteotomy, but it causes extreme trauma in the nasal mucosa, leading to prolonged post-operative ecchymosis and edema. The effects of edema and ecchymosis around the eyes can vary, from minor changes in color to decreased vision. Similarly, unintentionally broken nasal bones may result in undesirable post-operative cosmetic outcomes [3].

A variety of lateral osteotomy techniques, including percutaneous, transoral, and endonasal procedures, have been introduced to reduce post-operative edema and ecchymosis,

✉ O. Gökler
ogokler@kuh.ku.edu.tr

[1] Department of Otolaringology, Koc University Hospital, Davutpasa Cad. No: 4, Topkapi, 34010 Istanbul, Turkey

[2] Department of Otolaringology, Bezmialem University Hospital, Istanbul, Turkey

and achieve optimum esthetic outcomes [5–7]. These techniques are commonly used in daily practice, with the type depending on a surgeon's choice and experience, and numerous studies have compared their benefits and limitations [5, 8]. The optimal method has been seriously discussed, although the indications of lateral osteotomy are clear.

The principle of piezosurgery, which heralded a breakthrough in osteotomy, is based on the incision of bones through piezoelectric micrometric ultrasonic vibrations [9]. Piezosurgery is suitable for all bone surgeries, and assumes particular importance in cases where access is limited and the bones are adjacent to soft tissues. Its primary benefits are that the piezosurgery device is not harmful to soft tissues, leading to minimal bleeding and bruising, and that it forms a straight incisional line on nasal bones [10]. These advantages make piezosurgery a favorable option at the stage of lateral osteotomy for rhinoplasty.

Piezosurgery is used for maxillofacial surgeries and rhinoplasty for lateral osteotomy and hump excision [9, 11, 12]. Tirelli et al. reported that it resulted in significantly fewer complications than traditional external osteotomy [13], and İlhan et al. [14] recently showed that piezosurgery led to reduced post-operative edema and ecchymosis, although Taşkın et al. [15] reported no difference between the two methods in terms of post-operative edema and ecchymosis. Our study compared conventional internal osteotomy as the most common method for lateral osteotomy with piezosurgery in terms of duration of surgery, periorbital edema, ecchymosis, pain, and internal mucosal integrity.

Materials and methods

Study design

Following approval by the local ethics board, our study was initiated in 49 patients who underwent rhinoplasty at Koç University Hospital between January 2016 and July 2016. The patients were provided with full information, following which we obtained their oral and written consents. Exclusion criteria were a history of rhinoplasty, an extremely wide nasal roof, a need for double lateral osteotomy, a narrow nasal roof and coagulopathy, smoking, and systemic diseases.

The patients (32 women, 17 men) were randomly divided into two groups by a department nurse on the day of surgery. Group 1 ($n=25$) underwent conventional internal osteotomy, while Group 2 ($n=24$) underwent osteotomy with piezosurgery. A postoperative evaluation was blindly made by an otolaryngologist with no knowledge of the groups or of the procedures carried out.

Surgical technique

All procedures were conducted under general anesthesia by the same surgeon, and the surgeries were carried out via the open technique, concurrent with septoplasty. Cartilage and bone dorsum elevation was followed by removal of the nasal hump with rasping. All osteotomies were internally conducted as either low-to-low lateral osteotomy with transverse osteotomy or low-to-high lateral osteotomy.

In group 1, a subperiosteal tunnel was created through a planned osteotomy line on the bone, following a 3 mm vertical incision just above the inferior concha. Lateral osteotomies were performed using a 3 mm guided curved osteotome. Nine patients had transverse osteotomy with low-to-low lateral osteotomy, and 16 patients had low-to-high lateral osteotomy.

In group 2, after hump removal with rasp, the periosteum on the lateral edges of nasal bone was elevated for osteotomy. Elevation was anatomically restricted from the inner canthus level to the pyriform aperture ligaments, and the lateral border was the medial edge of the frontal process of the maxilla. The lateral edge of the frontal process of the maxilla and the medial fibers of the orbicularis oculi muscle were not included in elevation. Any bleeding resulting from perforating vessels was controlled. NSK VarioSurg 3 device (Nakaniski INC, Japan) tips, which are suitable for rhinoplasty, were activated by a foot switch, after which osteotomy was performed on the lateral nasal bone (Fig. 1). Thirteen patients underwent transverse osteotomy with low-to-low lateral osteotomy, and 11 patients underwent low-to-high lateral osteotomy.

Following osteotomy, each patient underwent tip-plasty, and at the finish of the surgical procedures, Doyle splints were bilaterally placed in the nasal cavity. A thermal splint was externally placed to keep the nasal pyramid intact. In addition, an anesthesiologist recorded the average arterial blood pressure of the patients during the operations.

The patients received post-operative antibiotics twice daily for 7 days, and oral acetaminophen twice daily for 5 days. Within the first 24 h, all patients tilted their heads 30 degrees upward, and then a cold compress was applied for 20 min every hour. Nasal tampons were removed on day 4, and the external splint was removed on day 7 post surgery.

Post-operative evaluation

Periorbital ecchymosis and edema A professional photographer (using a Canon EOS 600D) photographed the patients pre-operatively and then post-operatively on days 2 [post-operative ecchymosis peaks on day 2 (16)], 4, and 7. The extent of periorbital ecchymosis and edema was evaluated blindly, using the scoring system described in the literature (Figs. 2, 3) [16].

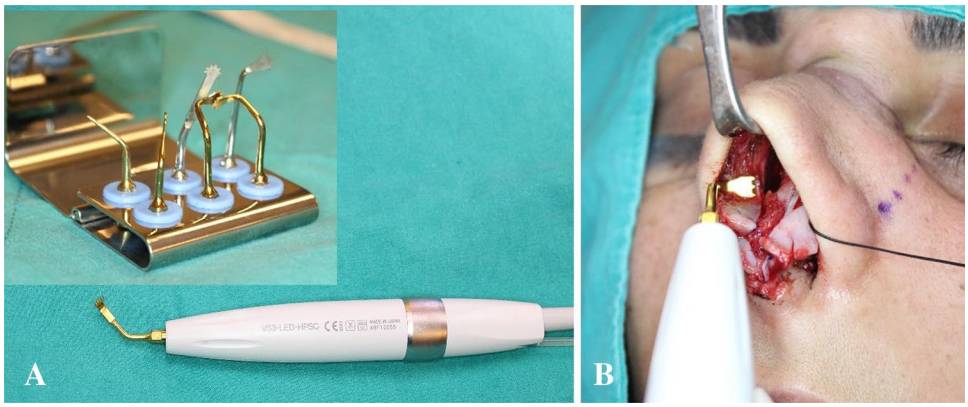


Fig. 1 **a** Handpiece and tips of piezo surgery device **b** intraoperative view

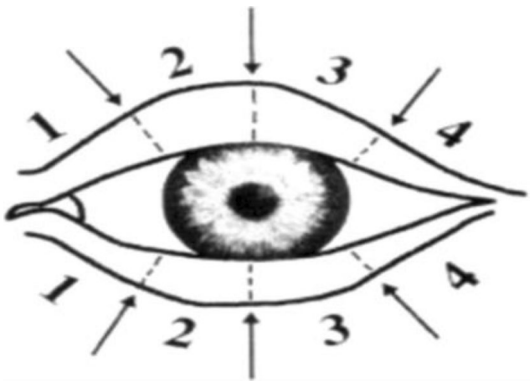


Fig. 2 Evaluation of periorbital ecchymosis. 0 (none), 1+ (medial), 2+ (extending to the pupil), 3+ (past the pupil), and 4+ (to the lateral cantus)

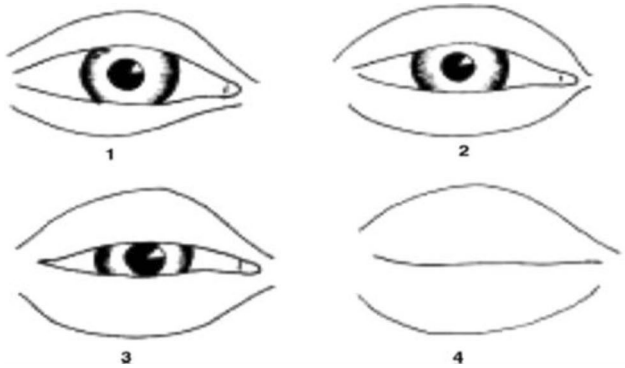


Fig. 3 Evaluation of eyelid edema. 0 (none), 1+ (minimal), 2+ (extending onto the iris), 3+ (covering the iris) and 4+ (massive edema with the eyelid swollen shut)

Duration of the osteotomy and surgery The osteotomy duration, including the periosteum elevation in the lateral nasal bone, and the total duration of the operation for each patient, was recorded using a chronometer within the operation room.

Pain The pain score of the patients was evaluated on day 2 using the visual analogue scale (0 = no pain, 10 = severe pain).

Mucosal integrity After the tampons were removed on post-operative day 4, an otolaryngologist with no knowledge of the purpose and the groups of the study blindly performed an endoscopic examination to examine whether there was any mucosal injury to the medial surface of the nasal bone.

Statistics

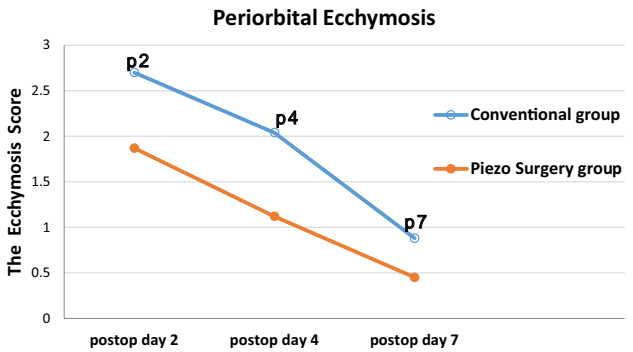
Statistical analysis was carried out using Statistical Package for the Social Sciences version 22.0 software for Windows (SPSS Inc, Chicago, Illinois, USA). All quantitative variables were estimated using the measures of central location (i.e., mean and median) and measures of dispersion (i.e., standard deviation). Data normality was checked using the Kolmogorov–Smirnov test. Repeated analysis of variance (ANOVA) was used for within-group evaluations (periorbital edema and ecchymosis), and $p < 0.05$ was considered statistically significant. Bonferroni and Tukey HSD post hoc tests were used to determine which groups differed (statistical significance was set at $p < 0.008$). Independent t test was used for between-group evaluation of quantity data (age, mean arterial blood pressure, eyelid edema, periorbital ecchymosis, osteotomy and operative time, pain scores), and $p < 0.05$ was considered statistically significant. Chi-square test was used to compare qualitative data (gender, osteotomy type, mucosal integrity), and $p < 0.05$ was considered statistically significant.

Results

The patients were aged from 18 to 42 years (mean 25.7 ± 5.4 and 28.5 ± 3.1 in groups 1 and 2, respectively), and there was no significant difference in age between the

two groups ($p > 0.05$). In group 1, transverse osteotomy with low-to-low lateral osteotomy was carried out in nine patients, and low-to-high lateral osteotomy was performed in 16 patients. In group 2, transverse osteotomy with low-to-low lateral osteotomy was conducted in 13 patients, and low-to-high lateral osteotomy was performed in 11 patients. There was no significant difference in osteotomy types ($p > 0.05$), and no significant difference in average arterial blood pressure ($p > 0.05$; 66 ± 7 and 72 ± 6 mmHg for groups 1 and 2, respectively).

Table 1 Postoperative periorbital ecchymosis scores of the groups ($p < 0.05$ was statistically significant)



	Postop day 2	Postop day 4	Postop day 7
Conventional group (mean ± std)	2.72 ± 0.73	2.04 ± 0.84	0.88 ± 0.6
Piezo surgery group (mean ± std)	1.87 ± 0.79	1.12 ± 0.74	0.46 ± 0.5
p value	$p2 < 0.001$	$p4 < 0.001$	$p7 = 0.011$

Periorbital ecchymosis and edema No significant difference between the groups was observed at the beginning of the study ($p > 0.05$). The periorbital ecchymosis scores were significantly lower in group 2 than in group 1 on postoperative days 2, 4, and 7 ($p < 0.001$ for days 2 and 4; $p = 0.011$ for day 7) (Table 1). In addition, on post-operative day 2, the eyelid edema score was significantly lower in group 2 than in group 1 ($p = 0.006$) (Figs. 4, 5); however, on post-operative days 4 and 7, no significant difference was observed ($p > 0.05$) (Table 2).

The ecchymosis score decreased significantly in both groups from day 2 to day 7 ($p < 0.001$ for both). Similarly, the eyelid edema score for group 1 decreased significantly from day 2 to day 7 ($p < 0.001$). However, in group 2, eyelid edema was increased on postoperative day 4 compared to day 2 ($p = 0.007$), although it significantly decreased after postoperative day 4 until postoperative day 7 ($p < 0.001$; Fig. 6).

Duration of the osteotomy and surgery Group 1 (1.7 ± 0.2 min) had a significantly shorter duration of osteotomy than Group 2 (6.9 ± 1.2 min) ($p < 0.001$). However, no significant difference between the groups was observed in the duration of the operations ($p > 0.05$; 178 ± 16 and 186 ± 17 min for groups 1 and 2, respectively) .

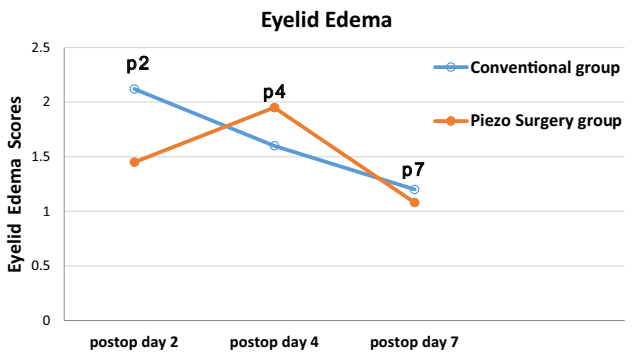
Pain The pain evaluation performed on postoperative day 2 showed that the pain scores of the group 2 patients were significantly lower than those of the group 1 patients ($p = 0.03$; 2.68 ± 0.7 and 2.12 ± 0.9, respectively).

Mucosal integrity Mucosal injury of the medial surface of the nasal bone was observed in 24% of the patients in group 1, while no patients in group 2 showed any sign of mucosal injury; it was significantly less common in the group that underwent osteotomy via piezosurgery ($p = 0.01$).

Fig. 4 A patient who underwent osteotomy with conventional osteotome **a** second- **b** fourth- and **c** seventh day after surgery photographs

Fig. 5 A patient who underwent osteotomy with piezo surgery **a** second- **b** fourth- and **c** seventh day after surgery photographs

Table 2 Postoperative eyelid edema scores of the groups ($p < 0.05$ was statistically significant)



	Postop day 2	Postop day 4	Postop day 7
Conventional group (mean ± std)	2.12 ± 0.92	1.6 ± 0.64	1.2 ± 0.4
Piezo surgery group (mean ± std)	1.45 ± 0.65	1.95 ± 0.62	1.08 ± 0.28
p value	$p2 = 0.006$	$p4 > 0.05$	$p7 > 0.05$

With the exception of two patients in group 1 who had epistaxis on postoperative day 1, no complications were observed in either group.

Discussion

The nose is the most crucial organ with regard to facial aesthetics, and numerous surgical procedures to make it look more beautiful have been defined and undertaken throughout history [17]. Edema and ecchymosis are the most common problems encountered following rhinoplasty, and previous studies have described various agents that may minimize these issues, for example, corticosteroids, arnica, and melilotus extract [17–19], as well as several surgical procedures [6]. Many studies have also compared internal and external lateral osteotomy, as well as open and closed rhinoplasty [17, 20, 21]; however, as yet there is no consensus regarding the explanation for these complications. An ideal technique for lateral osteotomy requires that the integrity of the nasal mucosal integrity remains intact. In addition, it must be safe, effective, and replicable, with minimal post-operative bleeding and ecchymosis [1].

Two different methods were previously used for lateral nasal osteotomy: intranasal continuous osteotomy and external osteotomy [6, 8, 21, 23]. Studies comparing these methods have suggested that internal osteotomy results in less mucosal trauma, as well as reduced post-operative ecchymosis and edema [24]. Mottura [25] and Murakami [5] obtained similar results in their respective studies. However, Giacomarra [3] and Rohrich [26] found the opposite, and reported that the external method results in less ecchymosis and edema compared to the internal continuous method. Therefore, previous studies did not reach a consensus.

We also performed lateral osteotomies through the internal continuous method, until we were introduced to piezosurgery in 2015. The piezosurgery device is equipped with a mechanism that converts electrical current into ultrasonic sound waves that are transmitted to a handpiece, while a chisel on its edge generates vibrations. These vibrations enable bone incision. Although piezosurgery was first used for dental and oral surgical procedures, it is now also used in maxillofacial [27] and craniofacial surgery [28].

Fig. 6 A patient who underwent osteotomy with piezo surgery **a** second day- **b** fourth day; increase of eyelid edema (after 24 h eyelid edema was almost disappeared) **c** fifth day; disappearance of eyelid edema **d** seventh day after surgery photographs

Previous studies have also described numerous other uses of piezosurgery in otorhinolaryngology. As piezosurgery does not damage the anatomical structures of the middle or inner ear, protects soft tissue, and is associated with precise cutting, it is safe for otologic surgeries, such as intact canal wall mastoidectomy, stapedotomy, and facial nerve decompression [29–31]. It has also been reported that, as the operating fields are blood-free with perfect intraoperative visibility with no sign of surgical damage to the soft tissue, it is safe for use in endonasal procedures, such as malignant nasal tumor surgery, dacryocystorhinostomy, and endoscopic pituitary surgery [32–34]. Indeed, piezosurgery can be used for all types of surgery that interfere with bones.

Robiony [11] first used piezosurgery for a rhinoplasty procedure, while Cochran [12] and Pribitkin [35] reported using a piezo electric device for lateral osteotomy and dorsal hump reduction, respectively. This device is selective for mineralized tissues, and produces micrometer-scale incisions without any damage to soft tissues. This means that there is a fairly low risk of damage to delicate structures, such as blood vessels, nerves, and mucosal membranes, near the device's tip during an osteotomy procedure. Therefore, it does not lead to any bleeding or lymphatic damage induced by vascular trauma, while ecchymosis and edema remain minimal [13]. In addition, histological studies have shown that osteotomies conducted via piezosurgery do not result in bone necrosis and keep osteocytes intact [36].

Previous studies suggested that osteotomies performed with piezosurgery are safe and effective, thus leading to reduced edema and ecchymosis in rhinoplasty [9–11]. However, such studies did not compare this procedure with other osteotomy techniques. Tirelli et al. [13] compared piezosurgery with external lateral osteotomy, and found that piezosurgery leads to less post-operative edema

and periorbital ecchymosis. In this study, closed technique external osteotomy was used as a surgical method. There was no consensus on the feasibility of osteotomy with a closed or open technique with a piezoelectric device [10, 37]. A specially designed piezo scalpel can be used to make endonasal lateral osteotomies [37]. If transverse osteotomy is necessary in the presence of a wide bony vault or low-to-low osteotomy indication, it is difficult to perform an endonasal osteotomy with a piezo electric device; specially designed tips are also required for transverse osteotomy. Other authors have stated that an external percutaneous osteotomy could be performed with a piezoelectric device [9, 13]; however, it is also necessary to open a larger incision than that made for a percutaneous 2 mm osteotome, which increases the probability of cutaneous scarring, particularly for those prone to keloid formation. There is also the risk of cutaneous thermal burns due to skin contact with metal tips, even with adequate water irrigation [10]. Although no thermal injuries resulting from metal shaft contact with nasal skin have previously been described, we know that thermal injury occurs in some cases. In addition, a large dissection is required for a better evaluation of nasal bone deformities [10]. Therefore, we believe that it is more feasible and practical to use piezosurgery with the open technique. In our study, open technique rhinoplasty and internal osteotomy were used. İlhan et al. [14] recently showed that piezosurgery results in less postoperative edema and ecchymosis than conventional osteotomy. However, Taskin et al. reported that piezosurgery did not reduce postoperative edema and ecchymosis [15]. In the present study, conventional osteotomy was performed after extensive subperiosteal elevation. The likelihood of inner nasal mucosal injury is elevated with conventional osteotomy, and there is a risk of developing nasal bone collapse in the absence of internal mucosal support. In addition, we believe that hemorrhages in the inner mucosa play a role in ecchymosis formation. We also observed fewer postoperative complications, such as ecchymosis, on days 2, 4, and 7 in the group who underwent piezosurgery than in the conventional osteotomy group. Unlike other studies [9, 13, 14], although our piezosurgery group had less eyelid edema on postoperative day 2, there was no difference between the groups on postoperative days 4 and 7. We observed that eyelid edema was increased in the piezosurgery group on postoperative day 4, and that this decreased rapidly until postoperative day 7. We considered that ecchymosis was reduced as a result of the coagulation of the bleeding angular and perforating vessels and preservation of the inner mucosa, and that eyelid edema was more likely, due to extended subperiosteal elevation.

Another problem that is likely to manifest following a lateral osteotomy is inner nasal mucosal injury, and accompanying intra-operative and early post-operative bleeding. Previous studies have shown that both the internal continuous [24] and the external technique may lead to nasal mucosal injury induced by osteotomies [38]. In our study, 34% of the patients in group 1 had mucosal injury while no patients in group 2 had any nasal mucosal injury, meaning that piezosurgery is selective only for the bone and does not damage the soft tissue.

It has long been known that blood pressure is directly associated with intraoperative bleeding. Previous studies suggested that hypotension provides a bloodless surgical site for rhinoplasty and nasal surgeries [39], and it has also been shown that intra-operative hypotension leads to reduced ecchymosis and edema following rhinoplasty [40]. In our study, there was no statistically significant difference between the groups in average intraoperative arterial blood pressure, while less edema (in the early period) and periorbital ecchymosis was observed in group 2 patients (osteotomy with piezosurgery). In our opinion, this was because the piezosurgery did not damage soft tissues, such as blood vessels.

Postoperative pain, one of the biggest issues for patients, is an acute complication common following rhinoplasty, and occurs as a result of osteotomy [41]. The pain scale peaks within the first postoperative 24 h. Less pain mitigates length of stay in hospital, and also means major improvements in a patient's postoperative comfort. A variety of techniques and agents have been used to eliminate postoperative pain following rhinoplasty [42, 43]. Piezosurgery is thought to cause less such pain because it prevents soft tissue damage. A previous study showed that the piezo electric device resulted in less postoperative pain than the microdril in otological surgery [29]. In addition, Tirelli et al., showed that a piezo electric device group required less pain reliever following rhinoplasty than a control group [13]. In our study, we observed lower pain scores in the patients undergoing osteotomy through piezosurgery. Since piezosurgery is bone-selective with no damage to soft tissues, such as nerves, we believe that it is likely to cause less pain.

Tirelli et al. showed that piezosurgery does not extend the duration of osteotomy [13]. In our study, although piezosurgery extended the osteotomy duration, total length of operation was not significantly longer than conventional osteotomy. In addition, we believe that piezosurgery will further shorten the length of osteotomy as a result of a learning curve, as long as it is more often used, enabling further experience to be gained.

Cost is a major problem of piezosurgery. The device itself is expensive, and the incisive tips generate further costs. On the other hand, the tips could be used for more than one patient as osteotomes. In addition, insufficient mobilization and the need for revision that may occur following a conventional osteotomy can be eliminated by

piezosurgery, due to osteotomy under direct visualization, thereby mitigating the revision costs. Another problem with piezosurgery is that the handpiece must be used with extreme care. If metal tips touching the skin are not irrigated with water as much as necessary, it can cause skin burns, particularly during transverse osteotomy, which can lead to undesirable results.

Our study was planned, randomized, prospective, and double-blind, and a sufficient number of parameters (periorbital ecchymosis, edema, pain, duration of osteotomy and operation, mucosal integrity) were evaluated. However, it was limited in terms of the number of patients (despite this being statistically sufficient), short follow-up periods, and evaluation of patients irrespective of nasal deformity types.

Conclusion

Our study showed that piezosurgery is safe, effective, and precise, and capable of reducing eyelid edema (in the early postoperative period), periorbital ecchymosis, and pain compared to the conventional osteotomy technique. In addition, mucosal integrity was better preserved in the piezosurgery group, and the durations of all the operations were similar. Further studies are required to evaluate the long-term outcomes of piezosurgery, and the patient comfort.

Compliance with ethical standards

Ethical approval This study was approved by the Local Ethics Committee (Bezmialem Foundation University, Decision No. 01/21) for clinical studies. The patients were informed about the surgical procedures and the possible complications and informed consent was obtained from all individual participants included in the study.

Conflict of interest The authors have no conflicts of interest and/or financial interest to disclose. No financial support was received for this work.

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