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Comparison of piezosurgery, percutaneous osteotomy, and endonasal continuous osteotomy techniques with a caprine skull model

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Abstract *Background:* Osteotomy is a crucial step in rhinoplasty, which can have a significant impact on the outcome. In addition to previous percutaneous (external perforating) and endonasal (internal) approaches, piezosurgery has been used in rhinoplasty practice since 2007. This experimental model was planned to compare the three osteotomy techniques.
Materials and methods: This study was performed on a caprine skull osteotomy model. Three groups were created from 12 animals, namely, endonasal continuous, external perforating, and piezosurgery groups. All the groups were evaluated for bone gaps, comminuted fractures, and nasal mucosa damage.
Results: There were no comminuted fractures and mucosal defects in any of the samples in the piezo osteotomy group. The average amount of bone gap at the osteotomy site and the nasal mucosa damage was lower in the piezo group than in the other groups. The time required for the osteotomy was shorter in the endonasal group, similar to that in the external and piezo groups.
Conclusion: New techniques are constantly being developed to achieve better results in rhinoplasty. As a natural consequence to technological developments, new devices are being introduced to rhinoplasty practice. Piezo is one such device. We have found that piezo osteotomy

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has resulted in lower amounts of nasal mucosal damage and comminuted fractures. We believe that piezo can safely be used in rhinoplasty practice until newer and more reliable technologies are being developed.

Introduction

Osteotomy is a crucial step in rhinoplasty, which can have a significant impact on the outcome. Conventionally, lateral osteotomies have been used to narrow the open roof deformity after the reduction of the dorsal hump. This approach aims to provide symmetry of the dorsal aesthetic lines. Lateral osteotomy is usually planned on the axis of the frontal process of the maxilla and nasal bones. Medial osteotomy is occasionally required as a secondary procedure to aid in the completion of greenstick fracture. Complications resulting from nonprecise osteotomies are common with the conventional techniques, which involve trauma to the adjacent tissue involving mucosa, nerves, and vessels.[1]

Lateral osteotomy can conventionally be performed through the transcutaneous (external perforating) or endonasal (internal) approach. Transcutaneous osteotomy has been shown to significantly reduce the risk of mucosal injury and nonprecise fractures.[2] Despite this, the endonasal approach is still the most common among surgeons.[3] It has been reported in previous studies that the scarring is usually not visible following the external osteotomy with a 2 mm osteotome. In spite of this, the risk of hypertrophic scarring might still be a concern among surgeons and patients to avoid external approach.[4]

Piezosurgery has initially been used by Horton for alveolar bone surgery back in 1975.[5,6] The first use of piezo in rhinoplasty is by Robiony in 2007, in which hump resections were performed with piezo, and less edema and ecchymosis were reported when compared with the conventional techniques.[7]

This experimental model was planned to compare piezo, endonasal osteotomy, and percutaneous osteotomy techniques.

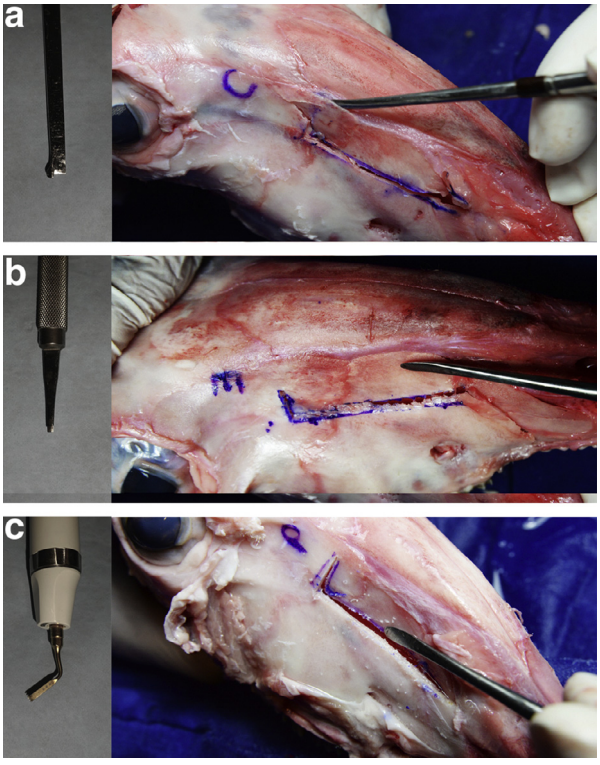

Figure 1 Sample photographs after the completion of the osteotomies and mobilization of the bone fragments. (a) Image from the endonasal osteotomy group reveals a straight osteotomy line with a comminuted fracture. (b) An image from the percutaneous osteotomy group reveals a serrated fracture line. (c) Image from the piezo osteotomy group reveals a straight osteotomy line without any comminuted fractures.

Materials and methods

This study was performed on a caprine skull osteotomy model. Domestic caprine heads were obtained from a local butcher. The first author, who is a trained plastic surgeon, performed all the surgical procedures. The skin and soft tissue overlying the facial bones and the skull were removed, and the periosteum was removed from the planned osteotomy site. An osteotomy line was marked 1 cm below the nasomaxillary suture line. Three groups were created from 12 animals. In each animal, a 5 cm lateral osteotomy and a 1.5 cm medial osteotomy were planned on both sides. These 24 osteotomy sites were randomly distributed into three groups, with each group containing eight osteotomies.

Group 1: Conventional endonasal continuous osteotomy group: Classical continuous osteotomies were performed with a guarded osteotome (width: 4 mm) (Figure 1a).

Group 2: Percutaneous external osteotomy group: Lateral and medial osteotomies were performed with an external osteotome with 2 mm width (Figure 1b).

Group 3: Piezosurgery (Mectron) osteotomy group: Lateral and medial osteotomies were performed with a piezoelectric scalpel, which was 0.35 mm thick and 2 mm wide (0T7S-3 scalpel, Piezo Medical Device, Italy) (Figure 1c). Piezoelectric device was set to cortical function mode with level 4 irrigation setting.

In all groups, osteotomies were concluded with the mobilization of the bone fragments toward the midline with two-finger manipulation.

In the end of the study, three-dimensional computed tomography (CT) scans were taken to evaluate the bone gap and comminuted fracture lines (fractures resulting in

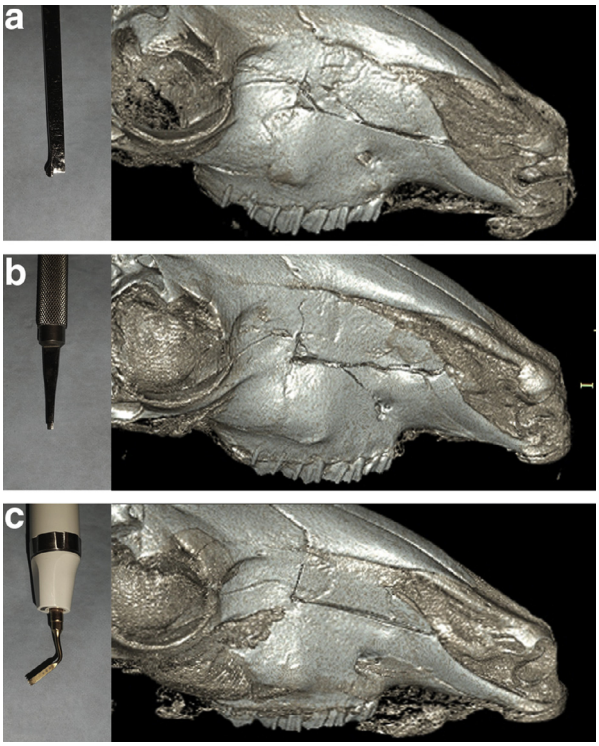

Figure 2 Sample images from three-dimensional computerized tomography scans of the osteotomy region illustrate the bone gaps and comminuted fracture lines. (a) CT image from the endonasal osteotomy group demonstrates increased bone gap and comminuted fracture lines. (b) CT image from the percutaneous osteotomy group demonstrates serrated and comminuted fracture lines. (c) CT image from the piezo osteotomy group demonstrates a straight osteotomy line without any comminuted fractures.

small bone fragments and spicules) at the osteotomy line (Figure 2). Following the CT scan, the bone segments 2 cm superior and 1 cm inferior to the osteotomy line were removed to evaluate the mucosal damage (Figures 3 and 4). The Kruskal–Wallis test with Dunn's multiple comparisons was performed to assess the statistical significance. GraphPad Prism (version 7.00 for Windows, GraphPad Software, La Jolla, CA, USA) software was used for statistical analysis.

Results

The average amount of bone gap at the osteotomy site was significantly lower in the piezo osteotomy group than in the other groups (Endonasal Osteotomy vs. Piezo Osteotomy $p = 0.0369$; Percutaneous Osteotomy vs. Piezo Osteotomy $p = 0.0402$). The difference between endonasal osteotomy and the percutaneous osteotomy was insignificant (Figure 5).

There were no comminuted fractures and mucosal defects in any of the samples in the piezo osteotomy group (Table 1). The average number of comminuted fractures branching from the main osteotomy line was significantly lower in the piezo osteotomy group than in the classical osteotomy group ($p = 0.0263$). Although statistically insignificant, piezo osteotomy resulted in a lower number of comminuted fractures than external osteotomy ($p = 0.0657$) (Figure 6). The average size of mucosal defects bordering the osteotomy site was significantly lower in the piezo osteotomy group than in the other groups (Figure 7) (endonasal osteotomy vs. piezo osteotomy $p = 0.0277$; percutaneous osteotomy vs. piezo osteotomy $p = 0.0038$). The difference between endonasal osteotomy and the percutaneous osteotomy was insignificant.

The average time required to complete the osteotomies was 217, 301, and 307 s in the endonasal, percutaneous, and piezo groups, respectively. The average osteotomy line quality was evaluated as serrated in the percutaneous osteotomy samples and smooth in the piezo samples. In the endonasal group, both serrated and smooth samples were present (Table 1).

Discussion

Lateral osteotomy increases morbidity following rhinoplasty including hemorrhage, edema, and ecchymosis.[8-10] Various techniques and modifications have been defined to decrease the complications and to increase cosmetic satisfaction.[11] Most commonly used techniques for lateral osteotomy include endonasal continuous and percutaneous techniques.[8,9,12] In a previous cadaver study, Rohrich et al. have shown that the percutaneous method resulted in less mucosal trauma when compared to the endonasal technique.[11,13] Despite these results, it has been shown that the external perforating technique can result in an increased number of comminuted fractures which could potentially cause aesthetically less pleasing results.[14,15] The same study also revealed that irregular osteotomies and soft tissue trauma are more prevalent with the external perforating technique.[14,15] Because of these findings, we believe that the external perforating technique can lead to better results only in the hand of an experienced surgeon. On the other hand, an inexperienced surgeon might find it difficult to guide the external osteotome, which could lead to repeated passes and undesired results.[8,10,14]

Piezosurgery medical device (PMD) is a relatively new technology, which cuts the bone with micrometric ultrasonic piezoelectric waves (through different frequencies and energies). PMD cuts only the mineralized tissues and does not affect the soft tissue. This results in minimal trauma to the vessels, nerves, mucosa, and soft tissues during the osteotomies. Since the introduction of PMD for rhinoplasty by Robiony,[7] it has been used in various clinics. Despite this, very few articles are present on the effectiveness of PMD in rhinoplasty. Tirelli et al. have compared external perforating osteotomy with PMD on 22 patients.[16] These results revealed less edema, mucosal damage, and ecchymosis with piezo osteotomies. In another clinical study with 90 patients, the endonasal continuous osteotomy was compared with the piezo, and a similar amount of edema and ecchymosis was found.[17] In this study, extensive periosteal dissection was performed in both groups, which might have been responsible for similar results. The authors conclude in this study that soft tissue trauma during osteotomies is caused by insufficient dissection and is independent of the tools used for the osteotomy. In the current study,

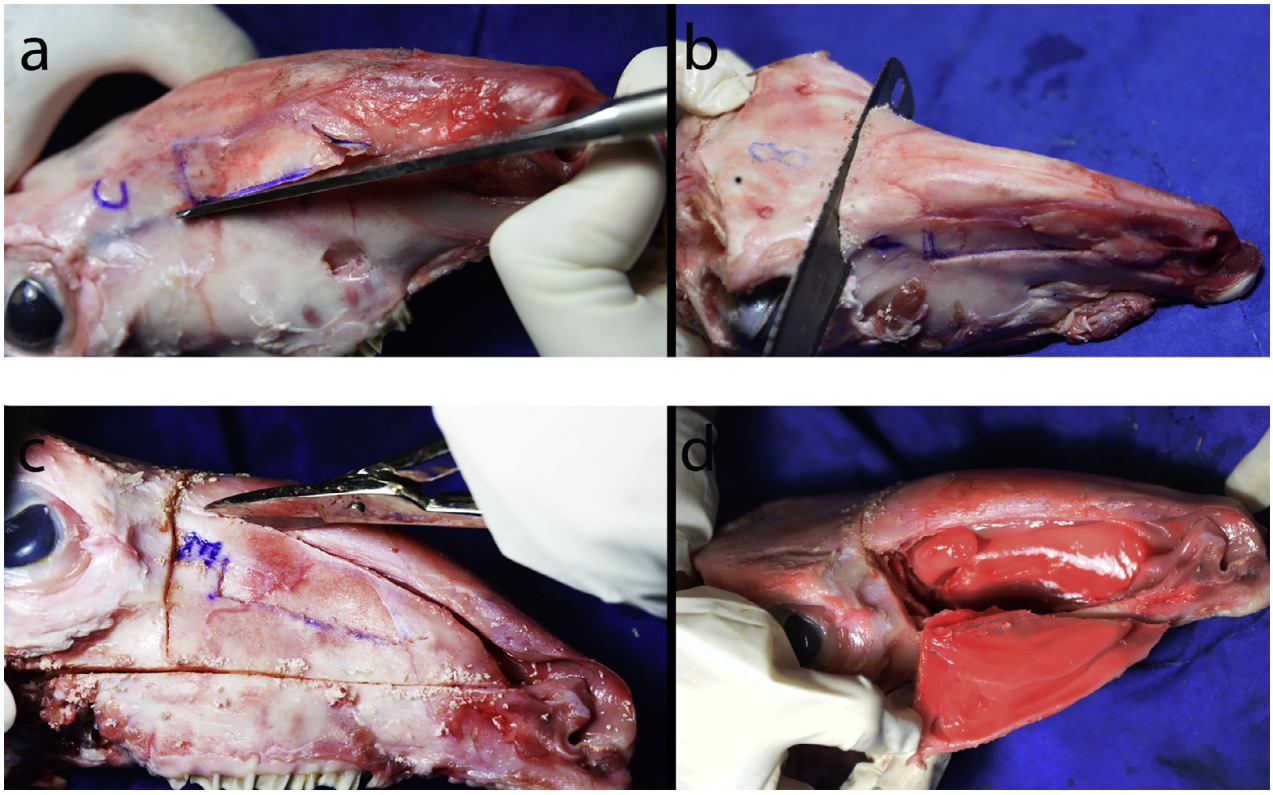

Figure 3 Photographs illustrate the procedure for removal of the bone segment including the osteotomy line for the evaluation of the mucosal damage. (a) Bone 1 cm inferior to the osteotomy line is fractured. (b) Bone 2 cm superior to the osteotomy line is fractured with a bone saw. (c) Separation of the bone segment is completed with a bone cutter. (d) Completion of the bone segment removal.

periosteum, skin, and overlying tissues were removed entirely. This enabled us to eliminate the factors unrelated to the tools and the technique of the osteotomy such as insufficient dissection. We believe that this would be nearly impossible to achieve in a clinical study, which increases the value of experimental cadaver studies in this field. In a previous cadaver study, the efficiency of a new piezo scalpel and the quality of the osteotomies in rhinoplasty were evaluated.[14] No residual bone deformity and nasal mucosal damage following the osteotomies were seen in this study. In another cadaver study by Robiony et al., the efficiency of piezo was evaluated in performing a segmental micro maxillary osteotomy to achieve a linear osteotomy line without nerve, vessel, and soft tissue damage.[18] Gerbault et al. performed a study in which osteotomy and hump resection with PMD were performed on 30 cadavers and 185 clinical rhinoplasty cases.[19] In this study, in contrast to the study by Robiony, extensive dissections were performed to visualize the asymmetries and deformities in the bone structures and to achieve continuous osteotomy lines. The authors concluded that PMD can provide more superior and precise alteration of the osseocartilaginous vault, thereby providing extensive exposure of the bony structure made before hump reduction and osteotomies.

In this study, we have performed the comparison of all three techniques on a caprine skull model. The quality of the osteotomies was evaluated with parameters such as bone gaps, comminuted fractures/spicules with a three-dimensional CT scan and the amount of nasal mucosal trauma.

The caprine nasal bone model has the benefit of containing structures similar to those of humans such as bones and cartilages. Because of this, it has been used as a rhinoplasty model in a previous study.[20] In addition, the caprine skull has the advantage of having a longer nasal bone, which is similar to that of rabbits. This enabled us to design a long osteotomy line. The mucosa around the soft tissue limits the visual inspection of the osteotomy. In addition, small bone fragments and spicules are difficult to inspect visually. Because of these reasons, a three-dimensional CT scan was used to evaluate the quality of the osteotomies. The dissection and the removal of the mucosa to visually assess the osteotomy line could have been performed instead of a CT evaluation. However, this could have displaced the bone fragments and could have resulted in inaccurate predictions.

Similar to the findings of previous studies, no mucosal damage or comminuted fractures were observed with the PMD. The gap between the bones at the osteotomy line was the lowest with the PMD when compared with the other techniques. Serrated osteotomy lines frequently observed with the external osteotomies are not seen with the PMD, which results in a smooth linear osteotomy line. PMD actually has the effect of resecting a narrow strip of the bone of approximately 0.35 mm, which is the width of the piezo tip, during the osteotomy. Despite this, the bone gap was

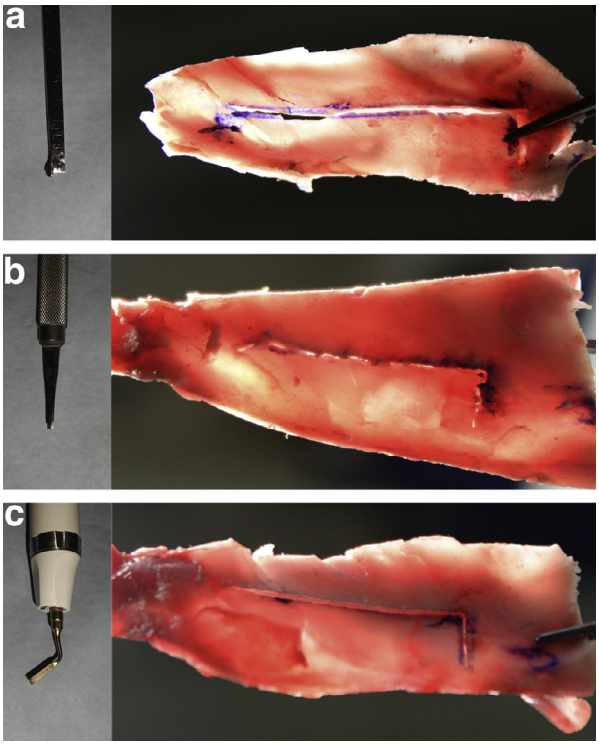

Figure 4 Photographs illustrate the mucosal surfaces of the removed bone segments. (a) Endonasal osteotomy image shows extensive mucosal damage along the osteotomy line. (b) Percutaneous osteotomy image shows minimal mucosal damage. (c) Piezo osteotomy image shows absence of mucosal damage.

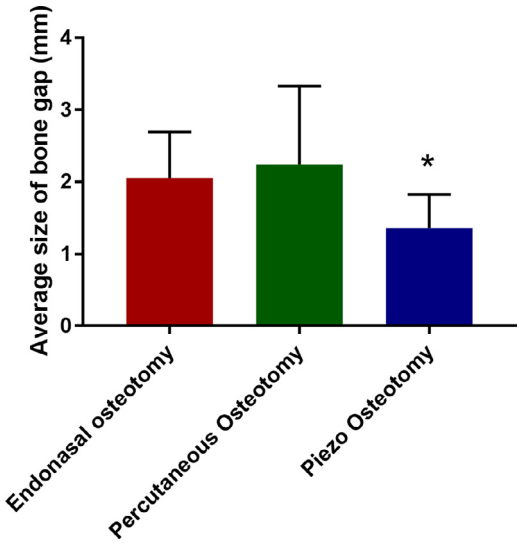

Figure 5 Average size of the calculated bone gap from a three-dimensional CT scan in each group ($^{*}p < 0.05$) (Endonasal Osteotomy vs. Piezo Osteotomy $p = 0.0369$; Percutaneous Osteotomy vs. Piezo Osteotomy $p = 0.0402$).

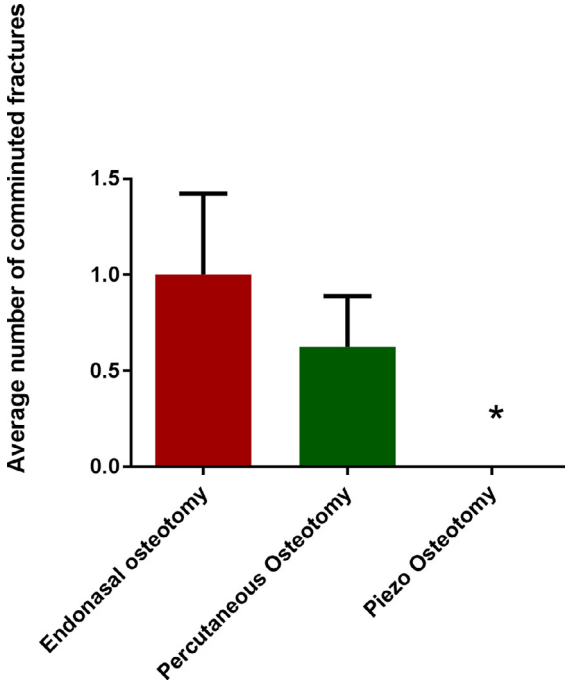

Figure 6 Average number of comminuted fractures in each group (* $p < 0.05$) (Endonasal Osteotomy vs. Piezo Osteotomy $p = 0.0263$; Percutaneous Osteotomy vs. Piezo Osteotomy $p = 0.0657$).

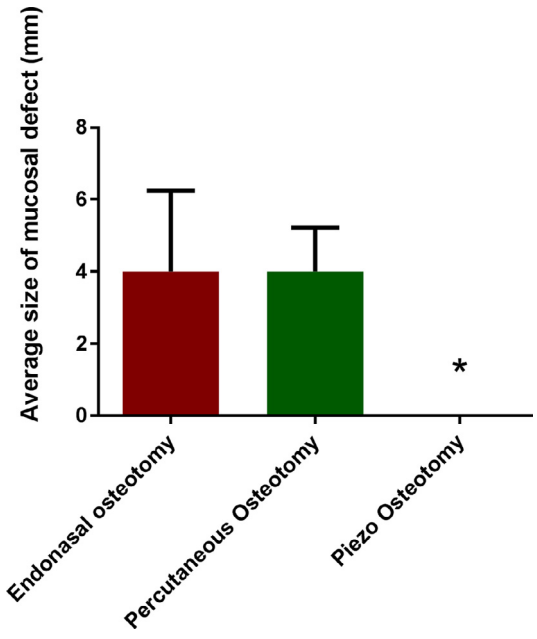

Figure 7 Average size of a mucosal defect in each group ($^{*}p < 0.05$) (Endonasal osteotomy vs. Piezo Osteotomy $p = 0.0277$; Percutaneous Osteotomy vs. Piezo Osteotomy $p = 0.0038$).

lowest with the PMD because comminuted fractures and serrated osteotomy lines were not seen with this technique as opposed to conventional and percutaneous approaches. Conventional osteotomies have a sharp and narrow tip that gradually becomes thicker, thereby contributing to the formation of these comminuted fractures. The most significant

Table 1. Detailed results of the measurements for each subject.

	Bone gap (mm)	*Number of comminuted fracture*	*Mucosal defect size (mm)*	*Time required to complete the osteotomies (s)*	*Osteotomy line quality*
Endonasal #1	1.02	0	19	182	Serrated
Endonasal #2	1.52	3	0	130	Serrated
Endonasal #3	2.51	0	0	260	Smooth
Endonasal #4	1.51	1	5	261	Smooth
Endonasal #5	2.24	0	2	228	Smooth
Endonasal #6	2.37	2	0	252	Smooth
Endonasal #7	2.33	0	4	216	Serrated
Endonasal #8	2.93	2	2	209	Smooth
Endonasal average	***2.05***	***1.00***	***4.00***	***217.25***	
Percutaneous #1	1.8	2	11	248	Serrated
Percutaneous #2	1.14	1	4	310	Serrated
Percutaneous #3	1.3	0	5	257	Serrated
Percutaneous #4	4.44	1	0	380	Serrated
Percutaneous #5	1.78	0	4	261	Serrated
Percutaneous #6	2.3	0	0	322	Serrated
Percutaneous #7	1.94	1	3	335	Serrated
Percutaneous #8	3.2	0	5	295	Serrated
Percutaneous average	***2.24***	***0.63***	***4.00***	***301.00***	
Piezo #1	1.13	0	0	362	Smooth
Piezo #2	1.13	0	0	372	Smooth
Piezo #3	1.78	0	0	241	Smooth
Piezo #4	0.743	0	0	304	Smooth
Piezo #5	1.14	0	0	284	Smooth
Piezo #6	1.89	0	0	276	Smooth
Piezo #7	2.01	0	0	304	Smooth
Piezo #8	1.05	0	0	315	Smooth
Piezo average	***1.36***	***0.00***	***0.00***	***307.25***	

disadvantages of PMD seem to be the steep learning curve and the prolonged operation time. In a previous study, it was shown that the increase in the operating time with PMD was approximately 30 min.[19] In this study, the required time to complete a unilateral osteotomy was similar in the transcutaneous and the piezo groups and was significantly shorter in the endonasal group.

New techniques are constantly being developed to achieve better results in rhinoplasty. As a natural consequence to technological developments, new devices are being introduced into rhinoplasty practice. Piezo is one of such devices. In the current study, the osteotomy quality of piezo, classical endonasal, and percutaneous perforating techniques was compared while omitting the factors related to dissection of the periosteum and soft tissues. We have found that piezo osteotomy resulted in a low amount of bone gap, comminuted fractures, and nasal mucosal damage. We believe that piezo can be safely used in rhinoplasty practice until newer and more reliable technologies are developed.

Conflict of interest

None of the authors has a financial interest in any of the products, devices, or drugs mentioned in this manuscript.

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