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ORIGINAL STUDY

Transnasal Endoscopic Piezoelectric Surgery for the Repair of Choanal Atresia

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Abstract

Background: Restenosis and reclosure of the choana are challenging complications after repair of choanal atresia. Modifications to bone drilling with no injury to the surrounding nasal soft tissues may reduce postoperative reclosure.

Objectives: Our study aims to assess the effectiveness of piezoelectric device in the preservation of mucoperiosteal flaps and its outcome in reducing postoperative granulation tissue formation and restenosis.

Patients and methods: In all, 20 patients with unilateral bony or bony membranous choanal atresia underwent removal of the atretic plate using the piezoelectric device with preservation of the mucoperiosteal flap to cover the borders of the neo-choana. Checkup of the cases ranged from 6 months to 2 years duration.

Results: Fifteen patients out of 20 showed patent choana postoperatively and throughout the follow-up period with a success rate of 75%. Only five patients developed reclosure of the choana with a failure rate of 25%.

Conclusion: Results of the study revealed that drilling of the bony atretic plate using the piezoelectric device was effective in the preservation of the mucoperiosteal flap, thus reducing the postoperative granulation tissue formation and reclosure of the choana.

Keywords: Choanal atresia, Piezoelectricity, Reclosure, Transnasal endoscopic

1. Introduction

Choanal atresia (CA) is closure of the posterior opening of the nose, which may be congenital or acquired [1]. Its incidence is approximately one in 5000–7000 live births [2]. It usually affects one nasal side than both (60 vs. 40%). It happened in females than in males (ratio 2 : 1) [3]. Congenital atresia results from a failure of the embryologic nasobuccal membrane of Hochstetter to rupture that usually occurs during the fifth or sixth week of uterine development [4]. The posterior choana is stenosed by a thick pterygoid plate laterally and a thickened vomer medially [5].

Congenital atresia is accompanied by malformations in 41–72% of the cases [6]. Bilateral atresias are associated with defects of the maxillofacial development [7]. Acquired choanal atresia results from

rhinopharyngeal injury as after adenoidectomy or complications of chemical cauterization, radiotherapy, and complication of complementary and alternative medical treatment of allergic rhinitis [5]. Most acquired cases are fibrous membranous stenosis [5]. Generally, 90% of atresias are bony, and 10% are membranous [7]. Recently mixed atresia is affecting 70% of the cases [8].

The anatomic abnormality includes a narrow nasal cavity, lateral thick pterygoid plate, medial thickened vomer, and a bony or membranous closure [9]. In bilateral atresia, infants have attacks of respiratory difficulties with cyanosis that improves with crying [10]. Feeding troubles with choking because of the inability to breathe and feed at same time [11]. Diagnostic methods of choanal atresia are putting a feeding catheter into the nasopharynx, computed tomography (CT), and

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endoscopic examinations [12]. CT and endoscopic examination are the standard method for assessment with good visualization of the atretic plate by endoscopy [7].

CT plays a significant role before surgery [13]. It gives an evaluation of the type of choanal atresia and the thickness of the atretic plate. Surgery is the definite repair for choanal atresia [14]. Several surgical options including sublabial, transnasal, transantral, transpalatal, transseptal, or external approaches for the repair [15]. Surgery aims to make a patent nasal pathway with minimal injury to the surrounding structures [16]. Transpalatal approach produces hazards such as bleeding, palatal flap necrosis or fistula, crossbite, and palatal deformity [15]. Transnasal endoscopic approaches are satisfactory and effective nowadays [17].

Piezosurgery is a method of bone drilling utilizing ultrasound vibrations [18]. Its main advantages are conservation of soft tissues, and it can be used in fine spaces [19]. Over the past 5 years, many authors have presented their experience with the use of this tool in ENT, including cortical mastoidectomy, stapedectomy, osteoplastic flap procedure, removal of osteomas of the frontal bone, and revision of endoscopic sinus surgery [20].

The piezoelectric work comes from the passage of an electric current through a ceramic substance, so that it moves and expands [21]. The vibrations created are amplified and transferred to the piezoelectric blade [22]. A mechanical cutting effect exclusively on mineralized tissues is achieved [18]. Piezosurgery has the ability to cut mineralized tissues without cutting neurovascular bundles, thereby maintaining a hemostatic field, better visualization, and high precision [23]. Conservation of soft tissues is an important advantage of piezoelectric surgery making it a useful tool in improving the action of endoscopic transnasal surgery with direct visual assessment of any bony lesions of the nose [24].

2. Patients and methods

2.1. Study design and patient selection

The study is a nonrandomized controlled prospective study carried out at the Otorhinolaryngology Department of Beni-Suef University Hospital during the period from January 2019 to January 2021. The study was conducted after approval from our local ethics committee (No. FMBSUREC/05032019) and written informed consent was obtained from all patient sponsors. The study was carried out on 20 patients who suffered from

unilateral bony or bony membranous choanal atresia. The piezoelectric device was used to remove the atretic bony plate with preservation of the mucoperiosteal flaps to cover the bony borders of the neo-choana and to restore the normal communication between the nose and the nasopharynx.

Patients with the following criteria were included in the study: age more than 2 years to up to 18 years, fit for surgery and general anesthesia with unilateral congenital bony or bony membranous choanal atresia. Symptoms were consistent with persistent nasal obstruction and nasal discharge with diagnosis of failure of passage of feeding catheter through the nasopharynx. CT detected the presence of bony or bony membranous atretic plate. Patients with contraindications to general anesthesia of age younger than 2 years or older than 18 years old, with membranous atresia. Clinical nasal examination or CT of the nose and the nasopharynx showed nasal obstruction by lesions other than choanal atresia were excluded from the study.

2.2. Preoperative assessment

All patients involved in the study were subjected to preoperative assessment protocol which included the following.

- (1) Full ENT history.
- (2) Full ENT examination:
 - (a) Failure of passage of feeding catheter from the nose through the nasopharynx.
 - (b) Anterior rhinoscopy examination revealed accumulation of unilateral nasal discharge.
 - (c) Nasal endoscopy and nasopharyngoscopy revealed the presence of unilateral choanal atresia.
- (3) Preoperative investigations as:
 - (a) CT on the nose and the nasopharynx detected the presence, type, thickness of the atretic plate, and excluded other nasal congenital anomalies (Fig. 1).
 - (b) Routine preoperative laboratory investigations.
- (4) Informed consent was taken from their parents or sponsors.

2.3. Surgical techniques

The surgical operation was done under general anesthesia. The patient was placed in a supine position and intubated with an orotracheal tube in the left side of the mouth. The nasal cavity was filled with 0.05% oxymetazoline hydrochloride-soaked

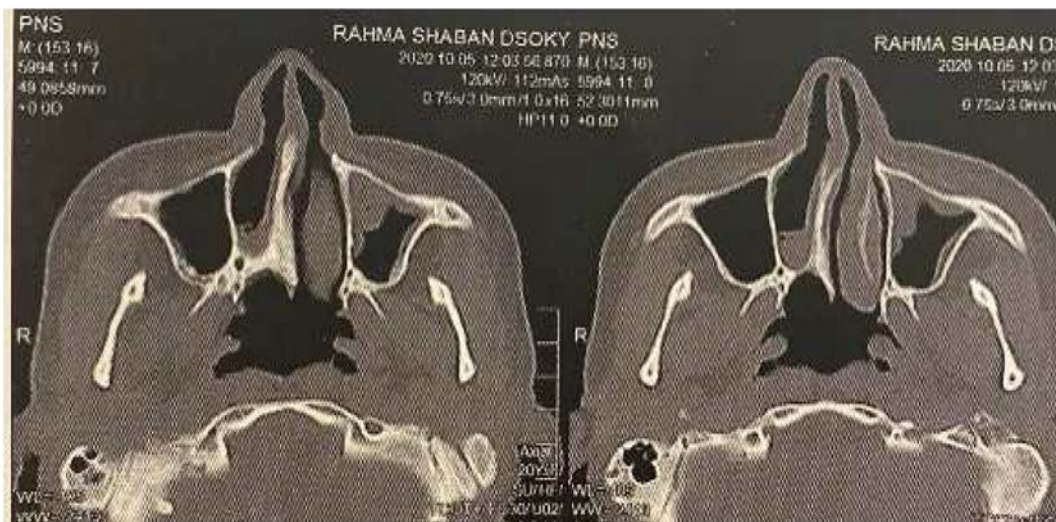


Fig. 1. Preoperative CT showing the right-side bony choanal atresia. CT, computed tomography.

cotton packages for nasal decongestion. At the beginning of intervention, the nasoseptal mucosa, inferior turbinate, and edges of the plate were injected with a 1% lidocaine and a 1 : 200 000 epinephrine solution (Fig. 2). The procedure was begun with transnasal endoscopic examination with a 0-degree endoscope (Karl Storz, Tuttlingen, Germany, diameter 2.7 or 4 mm) (Fig. 3).

Conventional endoscopic sinus instruments and the piezoelectric tool were used. C-shaped incision with an inferior base was done by a sickle knife in front of the atretic plate in the nasal face of the

atretic plate, and the mucoperiosteal flap was raised using a dissector. The mucoperiosteal flap was reflected anteriorly and rested at the nasal floor to reach the atretic bony plate (Figs. 4 and 5).

After the bony atretic plate was exposed, the piezoelectric device was used meticulously to incise and drill the bony atretic plate and the vomer bone (Fig. 6).

We used the piezoelectric device plus, which had two channels of different power types with independent electronics to which sterile single-use inserters can be connected. The piezoelectric device

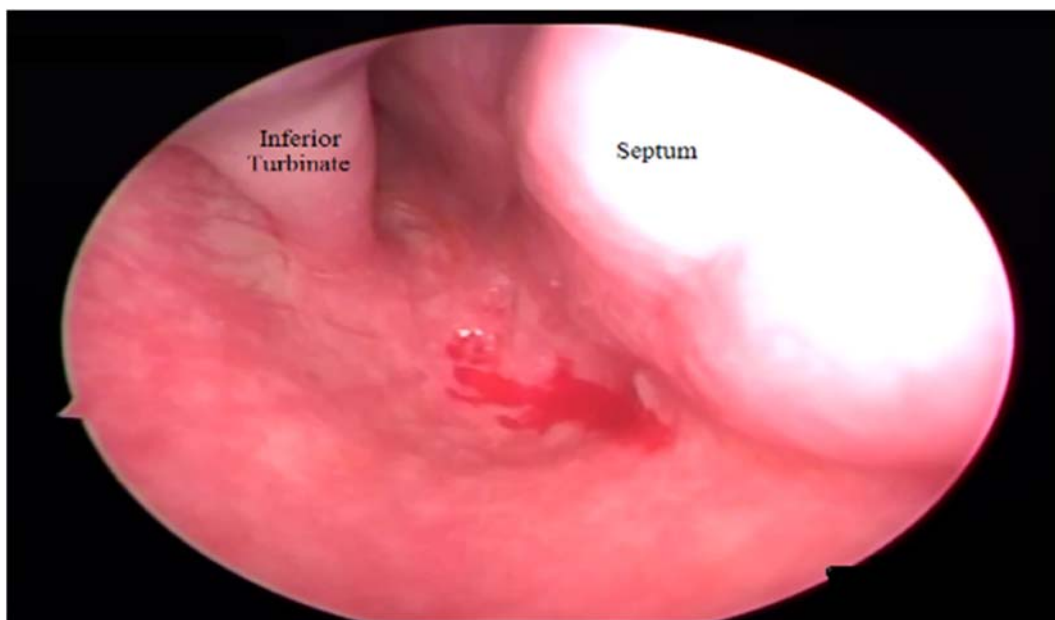


Fig. 2. Infiltration of the right side nasoseptal mucosa, inferior turbinate, and borders of the atretic plate with a 1% lidocaine and a 1 : 200 000 epinephrine solution.

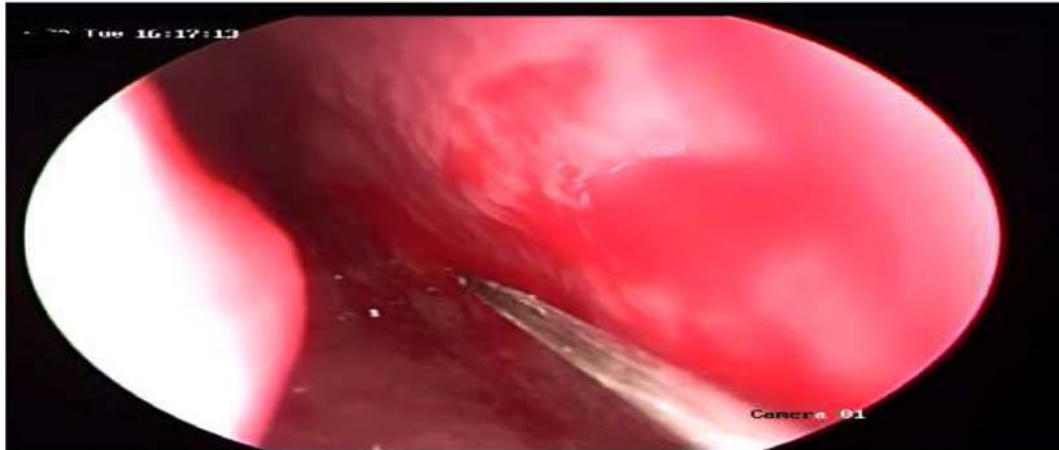


Fig. 3. Endoscopic view showing the right-side choanal atresia.

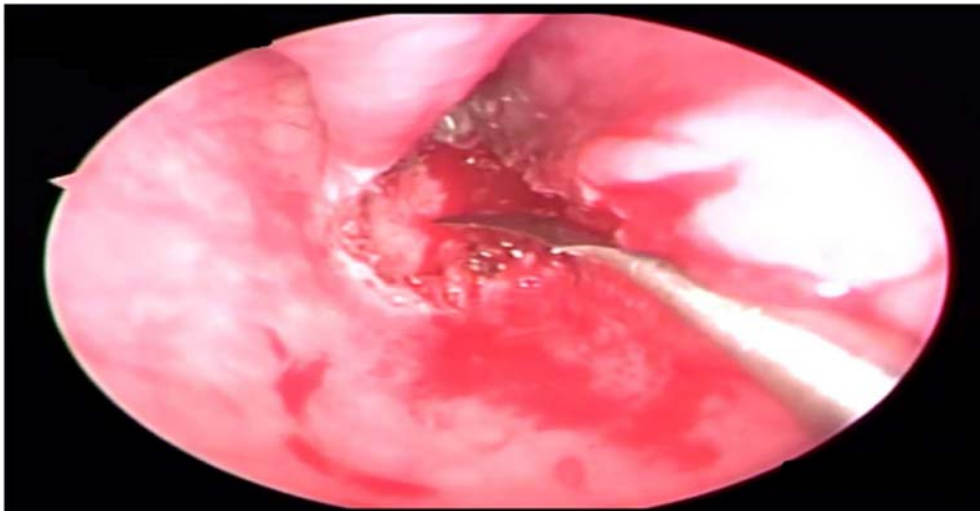


Fig. 4. C-shaped incision with an inferior base, performed by a sickle knife anterior to the atretic plate.

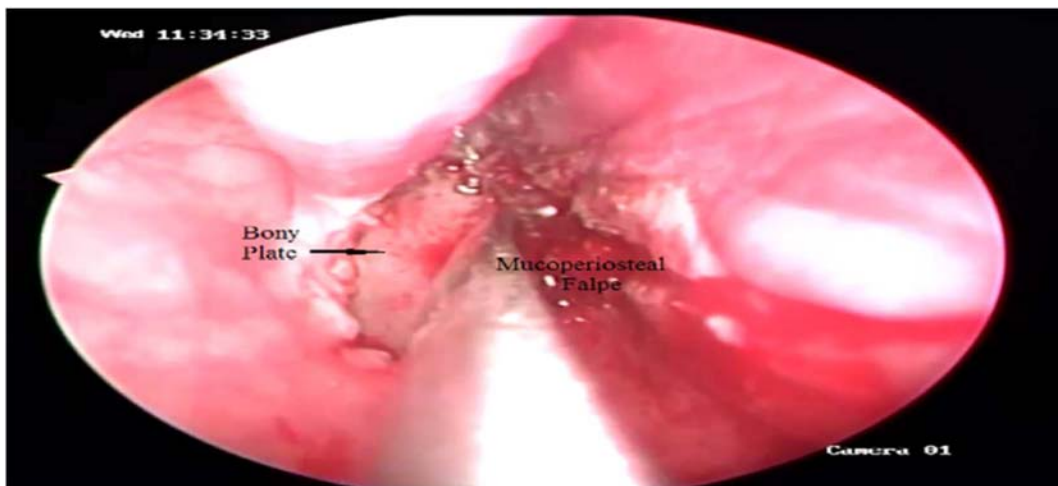


Fig. 5. The mucoperiosteal flap was reflected anteriorly, rested at the nasal floor, and the atretic bony plate was revealed.

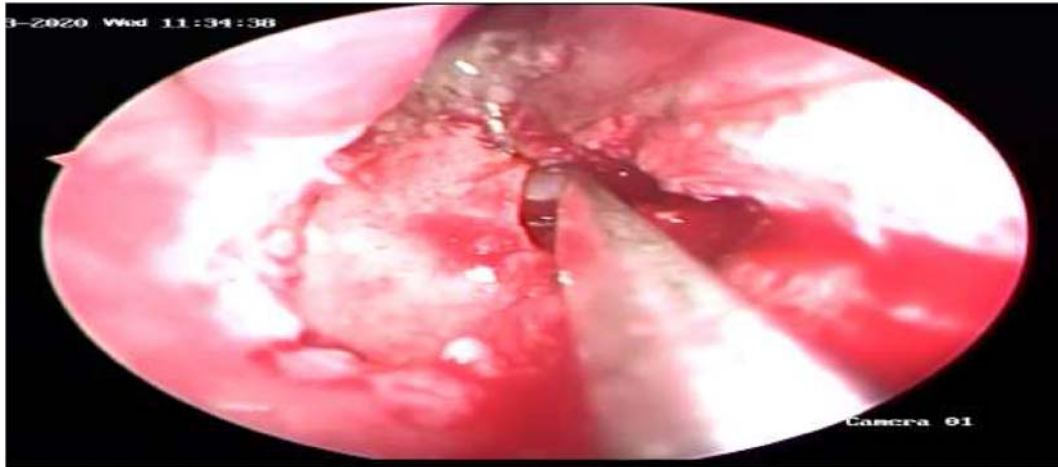


Fig. 6. Drilling of the bony atretic plate and the vomer bone by the piezoelectric tool.

has a touch screen, footswitch, and irrigation to cool the operative site. Inserters used in the choanal atresia were.

- (1) MP5L is a long osteoplasty circular surgical inserter with a shank length of 25 mm, scalpel width of 4 mm, and a total length of 98 mm.
- (2) MP6L is a long osteoplasty trapezoidal surgical inserter with a shank length of 28 mm, scalpel width of 3 mm, total length of 112 mm, and a thickness of 0.8 mm (Fig. 7).

The neo-choanal aperture was widened to the approximate size of the corresponding normal nasal side. The neo-choana aperture was created connecting the nose with the nasopharynx (Fig. 8). The reflected nasal mucoperiosteal flap was reflected medially and posteriorly to cover the bony borders of the neo-choana (Fig. 9).

Hemostasis was achieved after completion of the surgical procedure by insertion of the ipsilateral

meroceles which was left in the nose for 48 h and then removed.

2.4. Postoperative care and follow-up

All patients were admitted to the hospital for 48 h postoperatively and then discharged. Medications were administered postoperatively for 7 days in the form of amoxicillin trihydrate and potassium clavulanate (dose is given according to age and body weight) every 12 h, in addition to anti-inflammatory drugs every 8 h, anti-edematous drugs every 8 h, and alkaline nasal wash every 12 h after removal of the merocele. A nasal endoscopic examination was done 2 weeks postoperatively to detect the patency of the choana and absence of granulation tissue formation and stenosis. All the cases were subjected to postoperative routine follow-up every month by nasal endoscopic examination either by rigid or flexible endoscopy to



Fig. 7. The piezoelectric device and the handpiece and the inserters of the piezoelectric device used in the study.



Fig. 8. Widening of the right-side neo-choanal aperture by the piezoelectric tool infero-medially.

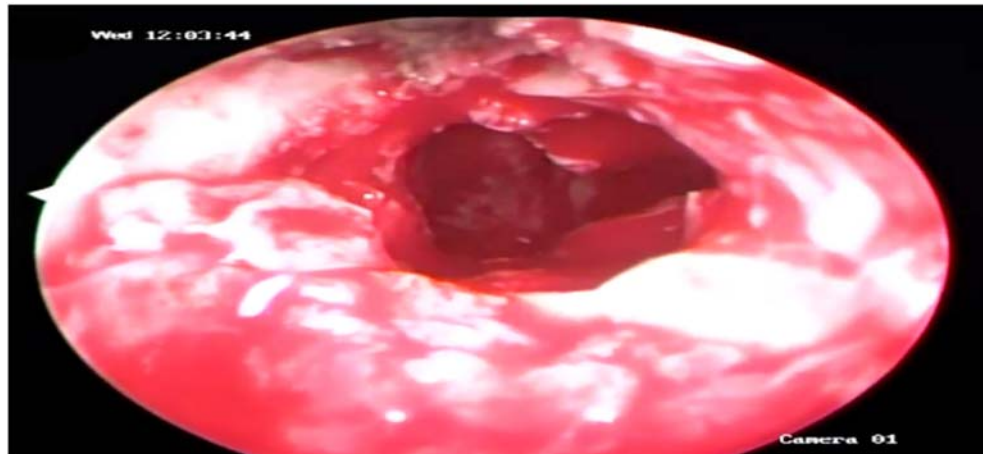


Fig. 9. Bony borders of the right side neo-choana were covered with the mucoperiosteal flap.

check the patency of the choana for a follow-up period ranging from 6 months to 2 years (Fig. 10). If the narrowing of the aperture of the neo-choanae was less than 50% 6 months after the operation, the

surgery was considered successful. If the patients had narrowed by more than 50%, the surgery was considered a failure. This is also confirmed by CT (Fig. 11).



Fig. 10. One-month postoperative endoscopic view and CT of the right-side neo-choana of the same patient. CT, computed tomography.



Fig. 11. Two years postoperative CT showing opening of the right nasal side more than 50%. CT, computed tomography.

3. Results

The study was conducted on 20 patients with congenital unilateral bony or bony-membranous choanal atresia aged between 2 and 18 years fit for surgery and general anesthesia during the period from January 2019 to January 2021. The results was as follows:

The mean age of the patients was 12.3 ± 4.9 years, ranged from 5 to 18 years and the median was 12.5 years (Table 1).

Most of the studied patients were females (85%) and only 15% were males (Table 2).

The right side was the most affected side (65%) and only 35% were on the left side (Table 3).

All cases underwent removal of the bony atretic plate with preservation of the mucoperiosteal flap (Table 4).

Table 1. Age distribution of the studied patients.

Items	Values (N = 20)
Age (years)	
Mean \pm SD	12.3 \pm 4.9
Range (minimum–maximum)	5.00–18.00
Median	12.50

Table 2. Sex distribution of the studied patients.

Items	Values (N = 20) [n (%)]
Sex	
Female	17 (85.0)
Male	3 (15.0)

Table 3. Laterality of choanal atresia among the studied patients.

Items	Values (N = 20) [n (%)]
Laterality	
Left	7 (35.0)
Right	13 (65.0)

Table 4. Operative circumstances among the studied patients.

Items	Values (N = 20) [n (%)]
Removal of atretic plate	20 (100)
Preservation of the mucoperiosteal flap	20 (100)

No recorded cases had postoperative bleeding and only 25% of cases had postoperative reclosure of choana, formation of granulation tissue, and postoperative infection, so the success rate was 75% and failure was seen in 25% of cases (Tables 5 and 6).

The mean operating time was 42.2 ± 2.1 min, ranged from 40 to 45 min, and the median time was 41.5 min (Table 7).

Table 8 shows that there was a statistical relationship between the formation of postoperative granulation tissue and the occurrence of infection as all cases that had granulation tissue formation after the operation had postoperative infection as well.

Table 5. Postoperative circumstances among the studied patients.

Items	Values (N = 20) [n (%)]
Postoperative bleeding	0
Postoperative reclosure	5 (25.0)
Postoperative formation of granulation tissue	5 (25.0)
Postoperative infection	5 (25.0)

Table 6. Success rate of the operation among the studied patients.

Items	Values (N = 20) (%)
Success rate	75.0
Failure rate	25.0

Table 7. Operative time among the studied patients.

Items	Values (N = 20)
Operative time	
Mean \pm SD	42.2 \pm 2.1
Range (minimum–maximum)	40–45
Median	41.5

Table 8. Relation between the formation of granulation tissue and the occurrence of infection among the studied patients.

	Postoperative infection		Total
	No	Yes	
Formation of granulation tissue			
No			
Number (%)	15 (100.0)	0	15 (75.0)
Yes			
Number (%)	0	5 (100.0)	5 (25.0)
Total			
Number (%)	15 (100.0)	5 (100.0)	20 (100.0)
P value	<0.001 ^a		

^a P value is significant.

4. Discussion

Restenosis is due to injury of the nasal mucosa by pressure, scarring, granulation tissue formation, bacterial contamination, and reduction of mucociliary drainage [19]. Flap techniques can reduce reclosure, which is usually with bilateral atresia with bony atretic plate, associated with maldevelopment [18]. Endoscopic transnasal technique is performed where the anterior mucosa overlying the atretic plate is incised vertically, and the mucosal flap is elevated medially and laterally [17].

Piezosurgery produces bone cutting by ultrasound vibrations. Its first demonstration was in 1880 by Pierre Curie and Jacques Curie [23]. Piezosurgery has the ability to cut mineralized tissue without affecting the nerves, blood vessels, other soft tissues, thereby decreasing bleeding and allowing excellent vision [19].

Our study was carried out at the Otorhinolaryngology Department of Beni-Suef University's Hospital during the period from January 2019 to January 2021. We used the piezoelectric device to remove the bony atretic plate of the choana with preservation of the mucoperiosteal flap to cover the bony borders of the neo-choana and restore the normal communication between the nose and the nasopharynx.

The study was carried out on 20 patients who suffered from unilateral congenital bony or bony membranous choanal atresia aged between 2 and 18 years, fit for surgery and general anesthesia with age mean \pm SD of 12.3 ± 4.9 years ranging from 5 to 18 years and the median was 12.5 years.

Of the total 20 patients, 17 cases were females (85%, $n = 20$) and only three cases (15%, $n = 20$) were males. The study showed that the right side was the most affected side as 13 cases (65%, $n = 20$) and only seven cases (35%, $n = 20$) were on the left side. The study showed that all the 20 (100%) cases underwent optimal removal of the bony atretic plate

by the piezoelectric device, preservation of the mucoperiosteal flap with sparing of the neurovascular tissues without the placement of nasal stents.

The study showed that there was improvement of breathing, relief of nasal obstruction in 15 cases (75.0%, $n = 20$) with residual symptoms in only five cases (25%, $n = 20$) of the studied patients. The study showed that no cases had postoperative bleeding and 25% of cases had postoperative reclosure of choana, formation of granulation tissue, and postoperative infection. The study showed that the success rate was 75%, and the failure rate was seen in 25% of cases.

There was statistical relationship between the formation of granulation tissue, and the occurrence of infection as all cases that had granulation tissue formation after the operation had postoperative infection as well. The 15 patients showed patent nasal choana. In the five patients who developed restenosis and reclosure of the choana, the choana was completely blocked by the granulation tissue.

Our study was conducted on 20 patients with unilateral congenital bony or bony membranous choanal atresia, which is nearly close to the number of patients of the study of Stamm and Pignatari [25], who operated on 22 patients with unilateral choanal atresia. Our number of studied patients is larger than the number of patients in the study of Eitan et al. [14], which was 11 unilateral patients and also larger than the number of patients in the study of Antonio et al. [2], which was seven patients and Ranko et al. [17], who operated on only six patients with unilateral choanal atresia.

In our study, we removed the bony atretic plate using the piezoelectric device with preservation of the mucoperiosteal flaps while others as Eitan et al. [14], Antonio et al. [2], Stamm and Pignatari [25], and Ranko et al. [17] removed the bony atretic plate using the drill or the shaver with marked effort to preserve the mucoperiosteal flaps. No intraoperative complications as injury to neurovascular tissues or other nasal soft tissues, palatal fistula, or skull base injury were reported in our study, and this is consistent with the results of studies of Eitan et al. [14], Antonio et al. [2], Stamm and Pignatari [25] and Ranko et al. [17], where there were no intraoperative complications reported.

The mean operative time of our study was 42.2 min ranging from 40 to 45 min duration. Our mean operative time is longer than that of the study of Eitan et al. [14], which was 16.9 min and Antonio et al. [2], as their mean time was 16.85 min. Our mean operative time is also longer than that of the study of Stamm and Pignatari [25], which was

18.27 min and also longer than the operative time of Ranko et al. [17], which was 17.66 min. The longer duration of our study's operating time is due to the slow motion of the piezoelectric device, which is one of its drawbacks and flaws.

In our study, five (25%) patients out of the 20 patients developed postoperative granulation tissue formation and restenosis of the choana. Our results are superior to Stamm and Pignatari [25], where 10 (45.4%) patients out of 22 patients developed postoperative granulation tissue formation and reclosure of the choana. Our results are inferior to the results of Eitan et al. [14], where only one (9%) patient out of the total 11 patients developed postoperative restenosis. Also, our results are inferior to the results of the study of Antonio et al. [2], where no patient of the total seven patients developed postoperative restenosis. The same was with the study of Ranko et al. [17], where none of the total six patients developed postoperative restenosis or granulation tissue formation.

All our patients were followed up in a period ranging from 6 months to 2 years duration with a mean follow-up period of 15 months. Our follow-up period is nearly consistent with the follow-up period of the study of Antonio et al. [2] and Ranko et al. [17], which ranged from 6 months to 3-year duration. Our follow-up period is superior to the follow-up period of the study of Stamm and Pignatari [25], which was of 1-year duration only, but inferior to the follow-up period of the study of Eitan et al. [14], which ranged from 10 to 60 months duration.

In our study, the success rate was 75% with a failure rate of 25% which is superior to the success rate. In the study of Stamm and Pignatari [25], it was 54.5% with a failure rate of 45.5%. Our higher success rate may be due to the use of the piezoelectric device, which preserved the mucoperiosteal flap properly. Our success rate is inferior to the success rate of the study of both Antonio et al. [2] and Ranko et al. [17], with a success rate of 100% and no restenosis. Also, the success rate in the study of Eitan et al. [14], was 91% with a failure rate of 9%, where only one case developed postoperative stenosis.

Our study included the unilateral cases of choanal atresia as it is not an emergency condition and can be operated on at an older age of the patients with a wider lumen of the nasal cavity, which facilitates the proper fashioning of the mucoperiosteal flaps. This study was done on older children with unilateral choanal atresia and should be regarded as the initial step to establish the role of the piezoelectric device in bilateral CA.

The number of patients in this study was only 20 cases which is a narrow scale of a study, but this is

due to the high cost of the piezoelectric device, which cannot be afforded for a larger number of patients. The high cost and expenses of the piezoelectric device is one of the limitations of our study with repeated needs for changing its blades which is costly and cannot be readily popularized in all hospitals.

Our study operating time is relatively long compared with the time taken while using other conventional drilling devices. This is due to the slow motion of the piezoelectric device, which may limit its use in patients with contraindications to lengthy operations. A short follow-up period is one of our study limitations, which makes it better to be longer in further studies.

5. Conclusion

Our study concluded that transnasal endoscopic piezoelectric surgery is safe, simple, and effective in the removal of the bony atretic plate of the choana, preservation of the mucoperiosteal flaps, soft tissues of the nose, and in sparing the neurovascular tissues with no intraoperative complications. It minimizes the postoperative complications such as granulation tissue formation, bleeding, and reclosure of the choana. We recommend further studies using the transnasal endoscopic piezoelectric device on a larger scale of patients with bilateral choanal atresia with longer follow-up period to justify its long-run efficacy and benefits and to ensure long-term patency of the nasal choana.

Conflict of interest

None declared.

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