



Do turbinate reduction procedures restore epithelial integrity in patients with turbinate hypertrophy secondary to allergic rhinitis? A histopathological study

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Abstract

Purpose Consensus has not been reached regarding the optimal reduction procedure for inferior turbinate hypertrophy in allergic rhinitis and whether such procedures result in improvement in mucosal architecture.

Methods Twenty-nine patients aged 18–45 years (mean 26.8 years), with allergic rhinitis and inferior turbinate hypertrophy not responsive to medical therapy who underwent endoscopic submucosal diathermy (ESMD) (14 patients) or endoscopic submucosal resection (ESMR) (15 patients) with intraoperative and 3–6 months postoperative inferior turbinate biopsies, were included in the study. Epithelial and mucosal architecture was compared between the two groups.

Results Both groups showed a significant decrease in epithelial denudation ($p < 0.001$), reversal of basement membrane thickening ($p < 0.001$) and increase in density of cilia ($p < 0.001$). The degree of improvement in histological characteristics between ESMD and ESMR groups was not significant.

Conclusions Surgical intervention for inferior turbinate hypertrophy by both ESMD and ESMR results in significant restoration of nasal mucosal epithelium in patients with allergic rhinitis as early as 3-month postoperatively. There was, however, no significant difference in the histological changes between those who underwent ESMD and ESMR.

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Keywords Inferior turbinate · Submucosal diathermy · Submucosal resection · Histopathology · Epithelial denudation · Fibrosis

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Introduction

The size of the inferior turbinate is an important determinant of the nasal airway. Many factors can cause abnormal turbinate hypertrophy which can result in an increased nasal resistance to airflow. Common causes of turbinate hypertrophy include allergic rhinitis, vasomotor rhinitis, rhinitis medicamentosa, and compensatory turbinate hypertrophy opposite a large nasal septal deviation. Inferior turbinate reduction can be performed by various techniques that resect, displace, or decrease the volume of the turbinate. Electrocautery, cryosurgery, laser surgery, and submucous resection, have been used to reduce the bulk of the turbinates by inducing scarring or by direct destruction. No clear consensus has been reached as to which is the optimal technique for the reduction of turbinate size [1]. The goal of turbinate surgery is to improve the airway without a change in the mucosal function.

The normal histology of the inferior turbinates and histological changes in inferior turbinate hypertrophy have been described by Berger et al. [2]. They reported that in hypertrophic turbinates, thickening of mucosa on the medial aspect of the turbinate as well as generalised increase in the width of the lamina propria were responsible for the increased width of the turbinate. They also found that the relative proportion of connective tissue, submucosal glands and vessels remained unchanged. The authors also described venous sinusoid engorgement within the hypertrophied turbinate. Other studies have shown that in compensatory hypertrophy of the inferior turbinate due to a deviated nasal septum, it was the expansion of the bone of the turbinate rather than the mucosa that produced the enlargement [3, 4].

Postoperative changes in the inferior turbinate after specific reduction procedures have also been studied by a few authors. One study reported little improvement in the postoperative ultrastructural epithelial architecture on long term follow-up after surgical turbinate reduction, in cases in which hypertrophy was not allergic in aetiology [5]. Another reported on long term histological changes following coblation turbinectomy in patients who failed the procedure, comparing those changes with histological features in a group that had not undergone that procedure. The authors found marked fibrosis, depletion of submucosal glands and venous sinusoids, epithelial shedding and areas of squamous metaplasia in the ablated areas [6]. Neri et al. showed that epithelial architecture of the nasal mucosa following microdebrider-assisted turbinoplasty improved significantly, both when viewed under the light microscope and electron microscope [7]. Despite the large number of interventions currently available for the treatment of inferior turbinate hypertrophy, comparisons of histological changes following various surgical interventions for inferior turbinate hypertrophy have not been extensively studied.

Preservation of the mucosal surface epithelium postoperatively is important for maintenance of the mucociliary clearance. Hence, any procedure aimed at reducing the size of the turbinates to improve airway should additionally result in improvement or preservation of mucosal morphology, if intact, in these patients. Other epithelial features like density of epithelial goblet cells, glands in the lamina propria, vascularity and tissue eosinophilia could also give an indication of the restoration of epithelial function. A study comparing the epithelial integrity of nasal mucosa in allergic and non-allergic rhinitis showed that shedding of epithelium is more common in allergic rhinitis [8]. Turbinate reduction procedures which can considerably alter nasal mucosal architecture, are often done in patients with allergic rhinitis and it is, therefore, important to know the effect of these procedures on turbinate mucosal histology.

This study aimed to compare the histological structure of inferior turbinate mucosa before and after two types of

surgical intervention for inferior turbinate hypertrophy in patients with allergic rhinitis with a specific interest in epithelial integrity, fibrosis, vascularity and glandularity of the lamina propria. The interventions studied were endoscopic submucosal diathermy (ESMD) and endoscopic submucosal resection (ESMR) of the inferior turbinate.

Materials and methods

Patients included in this study were recruited as a part of a randomised controlled trial involving 50 patients which compared two techniques, viz. ESMD and ESMR, for the treatment of inferior turbinate hypertrophy. This has been previously published [9]. Permission to conduct the study was obtained from the Institutional Review Board and Ethics committee and the trial was registered in the National Clinical Trials Registry.

Patients with nasal obstruction due to mucosal hypertrophy of the inferior turbinate, presenting to the out-patient clinic of the ENT Department of our tertiary care centre, were included in the study if they met the following criteria: (1) age ≥ 18 years (2) failure to respond to medical management with antihistamines, saline sprays and topical steroids for at least 3 months. Patients with a previous history of inferior turbinate surgery or those with any other turbinate pathology like a tumour or polyp or bony hypertrophy of the turbinate were excluded. Recruited patients underwent diagnostic evaluation consisting of a complete history, clinical examination and rigid nasal endoscopy. Allergen skin testing and serum IgE estimation were done for all cases to diagnose allergic rhinitis. Informed consent was obtained from all individual participants included in the study.

Subjective assessment of nasal symptoms like obstruction, discharge and sneezing was done with a four-point (0–4) grading system. Objective assessment of nasal airway was done by two methods. The first was by rigid nasal endoscopy, using the following criteria: grade-1: posterior wall of nasopharynx can be seen through $\geq 50\%$ of posterior choana (score 1); grade-2: posterior wall of nasopharynx can be seen through $< 50\%$ of posterior choana (score 2); grade-3: posterior wall of nasopharynx not visible at all (score 3). The second method for objective assessment of nasal airway was done using a Gertner–Podoshin plate as has been previously described [10]. The same scoring systems were used for postoperative assessment of airway.

All patients, regardless of the surgical procedure, had an intraoperative turbinate mucosal biopsy for histological examination during the surgery. The biopsy was taken with a cup forceps from the medial surface of the inferior turbinate, 1 cm posterior to its anterior end, i.e., from the anterior third of the turbinate. The two techniques were performed as follows:

The ESMD technique: the inferior turbinate was first decongested by covering with a cotton pattie containing oxymetazoline solution for 10–15 min. A bipolar diathermy forceps was inserted submucosally at three fixed points in the anterior, middle, posterior parts of inferior turbinate and diathermy was applied for 10 s at a setting of 25 at each point.

The ESMR technique: an incision was made, and a mucosal flap raised on the septal side of the inferior turbinate, followed by resection of bone along with lateral surface mucosa using forceps. The conserved mucosa on the medial side was re-draped over the resection site.

Five patients underwent concurrent septoplasty for septal deviation towards the side opposite to that of the turbinate hypertrophy. Turbinate surgery was only performed on the side opposite to the deviation. In these patients, inferior turbinate surgery and pre and postoperative assessment were only done for the side on which turbinate surgery was performed.

Routine postoperative care with saline and steroid sprays was followed for all cases and a postoperative turbinate mucosal biopsy was taken at the end of 3 months from the same location, under local anaesthesia, in the outpatient clinic.

Histological parameters assessed

The biopsies were coded with random numbers, processed for light microscopy and five micron thick serial section were stained with hematoxylin and eosin. Light microscopic images were acquired with an Olympus BX43 microscope connected to an Olympus DP21 camera and morphometric analysis was done using Cellsens image processing software (ver.1.4). Qualitative data obtained included a description of the epithelium oedema and fibrosis of the lamina propria, and perivascular fibrosis. Oedema and fibrosis were graded as nil=0, mild=1, moderate=2 or severe=3 based on pre-determined standardized slides. Perivascular fibrosis was classified as either present or absent. Quantitative data included number of sub-epithelial capillaries, number of tissue eosinophils and number of glandular cross sections for a total sub-epithelial area of 50,00,000 μm^2 . These were studied under the high power (40 $\times$) objective from every fourth of the serial sections, and the final data expressed as values per mm^2 area. In addition, the total length of epithelium was measured along the basement membrane. The lengths of normal epithelium (entire epithelium with cilia and goblet cells visualized), partially denuded epithelium (1–2 nuclear layers seen close to the basement membrane), completely denuded epithelium (basement membrane with no cell layers seen), hyperplastic epithelium and areas with squamous metaplasia were measured and expressed as percentages of the total length.

Once measurements were completed, biopsy numbers were decoded and analysed. Comparison of intra and post-operative mean symptom scores was performed using the unpaired *t* test. Comparison of epithelial and lamina propria characteristics measured was done between the groups using the Mann–Whitney *U* test as well as chi-squared test for categorical variables. Software for statistical analysis used was IBM SSPS version 21.

Results

Demography

A total of 29 patients in whom both intraoperative and post-operative histological data were available were included in this study. Fourteen of these patients had undergone ESMD and 15 had undergone ESMR. There were 22 male and 7 female patients, with ages ranging from 18 to 45 years (mean 26.8 years).

Clinical features

Preoperatively, nasal obstruction was the predominant symptom followed by nasal discharge and sneezing. All patients had grade 3 inferior turbinate hypertrophy. Mean preoperative symptom scores for nasal obstruction were 2.14 in the ESMD group and 2.27 in the ESMR group.

Postoperative status

Postoperatively, there was a significant reduction in symptoms of nasal obstruction in the ESMD group at 1 week ($p=0.002$) and 12–24 weeks ($p<0.001$). In the ESMR group, too, there was a significant reduction of nasal obstruction both at 1 week ($p<0.001$) and at 12–24 weeks ($p<0.001$). At week 1 after surgery, patients in the ESMR group appeared to have greater relief of nasal obstruction than the ESMD group ($p=0.003$). However, at 12–24 weeks after surgery, patients in both groups had good relief of nasal obstruction and there was no significant difference in the nasal obstruction symptom scores between ESMD and ESMR groups ($p=0.92$). Objective assessment using endoscopic scores and the Gertner–Podoshin plate also showed significant improvement of airway in both groups postoperatively.

Histology of the inferior turbinate

Qualitative assessment

Histopathological examination of the preoperative biopsies showed intact pseudostratified ciliated columnar epithelium

in some areas with large areas of epithelial denudation, either in the form of complete denudation or loss of superficial layers (Fig. 1). Goblet cell numbers showed variations, being absent in some, normal in distribution in some and hyperplastic in others. Several biopsies showed thickening of basement membrane (Fig. 1). The lamina propria showed varying degrees of fibrosis, varying from none in some biopsies to severe in others. Perivascular fibrosis was noted in several biopsies (Fig. 1). Tissue oedema in most cases was absent or mild, although a few had moderate oedema. Blood vessels and glandular architecture in the lamina propria appeared normal. A few biopsies showed areas of squamous metaplasia or epithelial hyperplasia. Several biopsies showed infiltrates of inflammatory cells.

The postoperative biopsies showed similar features with regards to oedema, fibrosis, glands and vessels in the lamina propria. However, there did appear to be significant restoration of epithelium, with larger areas of normal epithelium. While there were still areas of partial denudation and hyperplasia, there were very few areas showing complete denudation of epithelium and no areas of squamous metaplasia.

Quantitative assessment

Comparison of intraoperative biopsies (Table 1) Intraoperative biopsies showed large proportions of denuded areas. The lengths of epithelium measured, as well as proportions of intact epithelium, partial denudation, complete denudation, epithelial hyperplasia and squamous metaplasia were found to be similar between the ESMD and ESMR groups. Goblet cell and ciliary distribution could not be commented upon in a sizable percentage of biopsies because of extensive epithelial denudation. Other epithelial and lamina propria

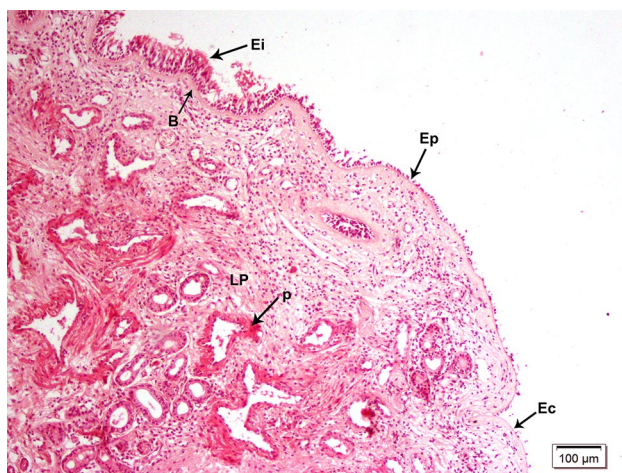


Fig. 1 Intraoperative biopsy showing areas of intact epithelium (Ei), partial denudation (Ep) and complete denudation (Ec) resting on a thickened basement membrane (B); the lamina propria (LP) shows moderate interstitial and perivascular fibrosis (p)

characteristics were also found to be similar in the two groups.

ESMD group-comparison of intraoperative and postoperative biopsies (Table 2) There was a significant increase in the percentage of intact epithelium ($p < 0.001$) as well as a decrease in percentages of completely denuded epithelium ($p < 0.001$), 3 months after diathermy (Fig. 2). Additionally, the percentage of epithelial hyperplasia had significantly increased ($p = 0.009$) and squamous metaplasia was not seen in any postoperative biopsy ($p = 0.035$). In the postoperative group the percentages with normal basement membrane architecture and normal cilia were significantly higher ($p < 0.001$) than the preoperative group (Fig. 2). Goblet cell numbers increased significantly postoperatively ($p = 0.003$). Lamina propria characteristics were not significantly different between the groups. Post-operative biopsies showed less perivascular fibrosis (Fig. 2) although the difference did not reach statistical significance ($p = 0.058$).

ESMR group-comparison of intraoperative and postoperative biopsies (Table 3) There was a significant increase in the proportion of intact epithelium ($p < 0.001$) and a decrease in complete epithelial denudation ($p < 0.001$) following inferior turbinate resection. Although there was an increase in epithelial hyperplasia and no squamous metaplasia seen postoperatively, these differences were not statistically significant. Postoperative ESMR biopsies also showed significant improvement in basement membrane thickening, as well as significant increase in cilia and goblet cell numbers. There was also a significant decrease in perivascular fibrosis postoperatively ($p = 0.004$).

Comparison of postoperative biopsies of ESMD and ESMR groups (Table 4) No significant differences were seen between the two postoperative groups with regards to improvement in epithelial integrity and architecture as well as features in the lamina propria. Although there were lower grades of oedema and fibrosis in the postoperative ESMR group, this difference was not statistically significant.

Discussion

The findings of the present study suggest that both ESMD and ESMR greatly help restore histological changes that occur in patients with inferior turbinate hypertrophy caused by allergic rhinitis. Patients with allergic rhinitis are known to have several histological changes in the nasal mucosa which include thickening of epithelium and basement membrane, squamous metaplasia and epithelial denudation [4, 8]. These findings are consistent with the mucosal findings in our intraoperative biopsies in both groups of patients.

Restoration of epithelial integrity postoperatively was a significant finding of this study. In a study by Grindos et al. [5] on patients with non-allergic causes of inferior turbinate

Table 1 Comparison of mucosal data between intraoperative ESMD and ESMR biopsies

Characteristics	ESMD intraop (<i>n</i> = 14)	ESMR intraop (<i>n</i> = 15)	<i>p</i> value*		
Epithelium	Mean ± SD	Mean ± SD			
Length of epithelium studied	10.58 ± 6.92	11.03 ± 6.08	0.881		
Epithelial integrity	Mean ± SD	Mean ± SD	<i>p</i> value*		
Analysis of epithelial integrity/structure (each component expressed as percentages of total length measured)					
Percentage of intact epithelium	4.08 ± 8.53	6.55 ± 18.35	0.954		
Percentage with partial denudation	31.65 ± 30.91	28.01 ± 24.82	0.844		
Percentage with complete denudation	48.23 ± 40.53	63.73 ± 31.31	0.336		
Percentage with epithelial hyperplasia	0.22 ± 0.81	1.09 ± 4.23	1.000		
Percentage with squamous metaplasia	15.83 ± 29.91	1.06 ± 4.10	0.097		
Other epithelial characteristics	Number (%)	Number (%)	<i>p</i> value		
Basement membrane					
Normal	1 (7.14)	3 (20)	0.598		
Thickened	13 (92.86)	12 (80)			
Cilia					
Normal	2 (14.29)	2 (13.33)	0.868		
Decreased/absent	4 (28.57)	3 (20)			
Unable to comment	8 (57.14)	10 (66.67)			
Goblet cells					
Normal	1 (7.14)	2 (13.33)	0.803		
Decreased/absent	4 (28.57)	3 (20)			
Unable to comment	8 (57.14)	10 (66.67)			
Hyperplasia	1 (7.14)	0			
Lamina propria	Mean number/mm ² ± SD	Mean number/mm ² ± SD	<i>p</i> value		
Capillaries	45.229 ± 32.279	45.080 ± 34.834	0.727		
Tissue eosinophils	7.275 ± 12.724	9.067 ± 10.557	0.678		
Glands	52.40 ± 25.419	34.133 ± 20.577	0.032		
	Number (%)	Mean grade (range)	Number (%)	Mean grade (SD)	<i>p</i> value
Interstitial oedema					
Absent (grade 0)	5 (35.71)	0.79 (0–2)	8 (53.33)	0.56 (0–2)	0.658
Mild (1)	7 (50)		6 (40)		
Moderate (2)	2 (14.29)		1 (6.67)		
Severe (3)	0		0		
Lamina propria fibrosis					
Absent (grade 0)	2 (14.29)	2.00 (0–3)	1 (6.67)	1.81 (0–3)	0.290
Mild (1)	2 (14.29)		6 (40)		
Moderate (2)	4 (28.57)		1 (6.67)		
Severe (3)	6 (42.86)		7 (46.67)		
Perivascular fibrosis	Number (%)		Number (%)		<i>p</i> value
Present	10 (71.43)		17 (70.83)		1.00
Absent	4 (28.57)		7 (29.17)		

**p* value < 0.05 taken as significant

hypertrophy, results of various surgical techniques for turbinate reduction were compared. It was reported that despite volume reduction being achieved, epithelial restoration was not achieved by any method other than ultrasound turbinate

reduction. In fact, loss of cilia, squamous metaplasia and goblet cell hyperplasia were reported as consistent post-operative findings. This study, albeit, on cases of allergic aetiology, shows quite a different result. Not only was there

Table 2 Comparison of intraoperative and post-operative ESMD biopsies

Characteristics	ESMD intraop (<i>n</i> = 14)		ESMD postop (<i>n</i> = 14)		<i>p</i> value*
Epithelium	Mean ± SD		Mean ± SD		
Length of epithelium studied (mm)	10.58 ± 6.92		11.02 ± 5.33		0.659
Epithelial integrity	Mean ± SD		Mean ± SD		<i>p</i> value
Analysis of epithelial integrity/structure (each component expressed as percentages of total length measured)					
Percentage of intact epithelium	4.08 ± 8.53		65.10 ± 19.90		< 0.001
Percentage with partial denudation	31.65 ± 30.91		12.85 ± 14.68		0.266
Percentage with complete denudation	48.23 ± 40.53		0		< 0.001
Percentage with epithelial hyperplasia	0.22 ± 0.81		22.04 ± 23.11		0.009
Percentage with squamous metaplasia	15.83 ± 29.91		0		0.035
Other epithelial characteristics	Number (%)		Number (%)		<i>p</i> value
Basement membrane					
Normal	1 (7.14)		10 (71.43)		< 0.001
Thickened	13 (92.86)		4 (28.57)		
Cilia					
Normal	2 (14.29)		11 (78.57)		< 0.001
Decreased/absent	4 (28.57)		3 (21.42)		
Unable to comment	8 (57.14)		0		
Goblet cells					
Normal	1 (7.14)		5 (35.7)		0.003
Decreased/absent	4 (28.57)		5 (35.7)		
Unable to comment	8 (57.14)		0		
Hyperplasia	1 (7.14)		4 (28.6)		
Lamina propria	Mean number/mm ² ± SD		Mean number/mm ² ± SD		<i>p</i> value
Capillaries	45.229 ± 32.279		46.757 ± 26.281		0.818
Tissue eosinophils	7.275 ± 12.724		12.600 ± 20.856		0.713
Glands	52.40 ± 25.419		38.929 ± 35.830		0.270
	Number (%)	Mean grade (range)	Number (%)	Mean grade (range)	<i>p</i> value
Interstitial oedema					
Absent (grade 0)	5 (35.71)	0.79 (0–2)	3 (21.4)	1.07 (0–2)	0.555
Mild (1)	7 (50)		7 (50)		
Moderate (2)	2 (14.29)		4 (28.6)		
Severe (3)	0		0		
Lamina propria fibrosis					
Absent (grade 0)	2 (14.29)	2.00 (0–3)	5 (35.7)	1.14 (0–3)	0.304
Mild (1)	2 (14.29)		4 (28.6)		
Moderate (2)	4 (28.57)		3 (21.4)		
Severe (3)	6 (42.86)		2 (14.3)		
Perivascular fibrosis	Number (%)		Number (%)		<i>p</i> value
Present	10 (71.43)		5 (35.7)		0.058
Absent	4 (28.57)		9 (64.3)		

**p* value < 0.05 taken as significant

significant increase in normal epithelium, there were no areas of complete denudation in postoperative ESMD and very few areas of complete epithelial denudation in postoperative ESMR cases. Moreover, there was no postoperative

squamous metaplasia and there was significant improvement in ciliary architecture with both procedures. Although further ultrastructural studies would be warranted to more definitively document restoration of ciliary architecture,

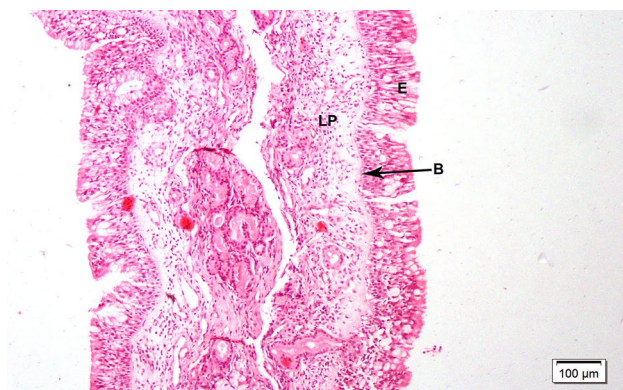


Fig. 2 Postoperative biopsy from the same patient as in Fig. 1 from the ESMD group showing restoration of epithelium (E) which appears hyperplastic; basement membrane (B) is of normal thickness and fibrosis of the lamina propria (L) is no longer present

findings of this study suggest that there is anatomical and physiological restoration after surgery. Improvement in epithelial architecture was consistent with the significant clinical improvement in patients following surgery with either type of procedure.

Hypertrophic turbinates not only reduce the nasal airway but also cause increased accumulation of secretions on the mucosal surface of the turbinates by obstructing normal drainage. This increases the mucosal inflammatory response of the turbinates. We speculate that the restorative changes in the architecture of the turbinate mucosa following both these procedures are due to an improved airway as well as reduced accumulation of secretions on the mucosal surfaces of the turbinates. Further, the efficacy of topical saline and steroid sprays is enhanced by greater exposure to the mucosal surface of the turbinate, resulting in a more normal turbinate both endoscopically as well as histologically.

In both ESMD and ESMR, there is loss of mucosa and submucosa following surgery. Following ESMD, the mucosa superficial to the area that has been cauterised tends to slough off in the first week after surgery. This could account for the higher mean subjective scores for nasal obstruction after the first week in patients who underwent ESMD compared to those who underwent ESMR. The epithelium appears to be restored postoperatively by 3 months. In ESMR there is restoration of normal mucosa after resection of some submucosal tissue, perhaps by reducing the amount of inflamed tissue produced by underlying allergy.

Epithelial shedding has been reported as a feature of allergic rhinitis [8, 11]. In this study, classification of epithelial denudation was done in a manner similar to Berger et al. [8] who showed both partial and complete denudation of epithelium in inferior turbinate mucosal biopsies. In addition, proportions of epithelium showing squamous metaplasia and epithelial hyperplasia were also documented.

It was stated that this epithelial denudation could indicate disruption of the mucosal barrier [2]. Ordonez et al. [12] while studying endobronchial biopsies of patients with bronchial asthma comparing them with normal controls found equal desquamation in patients and controls and, therefore, concluded that these areas of denuded epithelium were, in fact, artefacts. In the present study, because both intraoperative and postoperative biopsies were performed, it could be ascertained that the desquamation noted preoperatively significantly improved in the postoperative biopsies and hence these are unlikely to be sectioning artefacts. The clinical consequences of surgical intervention are that patients experience significant improvement in symptoms postoperatively and this restoration of epithelium correlates with clinical improvement in these patients.

Basement membrane thickening was seen in 92.86% of ESMD patients and 80% of ESMR patients preoperatively. However, this feature was present only in 28.57% of ESMD and 20% of ESMR patients postoperatively. Features of mucosal remodelling have been well documented in various upper and lower airway diseases. These changes include thickening of the basement membrane, interstitial fibrosis, lymphocytic infiltration, angiogenesis, epithelial destruction, goblet cell and mucosal glandular hyperplasia [13–15]. While there are several associations between allergic rhinitis and asthma, similar changes were not found consistently in the upper airways in allergic rhinitis [14, 16]. Basement membrane thickening has been described in patients with allergic rhinitis and chronic rhinosinusitis [13, 17]. The restoration of basement membrane to a normal state postoperatively in our study may be due to the effect of these procedures in reducing the allergic inflammation. It also supports the theory of remodelling occurring in the upper airways [15].

Mucociliary clearance requires not only intact epithelium but well-functioning cilia and adequate secretions from goblet cells and mucosal glands [18]. Epithelial thickness, cilia, goblet cells and mucosal glands were observed in this study to assess whether structurally the epithelium was suited towards mucociliary clearance in any particular group. While there were no significant changes in glandular numbers, both postoperative groups showed significant improvement in cilia and goblet cell distribution.

Berger et al. demonstrated that fibrosis of the lamina propria was a common abnormality in the hypertrophied inferior turbinate [2]. It was also reported that the radiofrequency cold ablation technique caused worsening of epithelial integrity and increase in sub-epithelial fibrosis [6]. In the present study, the mean grade of fibrosis was higher preoperatively than postoperatively in both groups, although the improvement postoperatively did not reach statistical significance. Perivascular fibrosis, however, significantly improved in the ESMD group. In the setting

Table 3 Comparison of intraoperative and postoperative ESMR biopsies

Characteristics	ESMR intraop (<i>n</i> = 15)	ESMR postop (<i>n</i> = 15)	<i>p</i> value*		
Epithelium	Mean ± SD	Mean ± SD			
Length of epithelium studied (mm)	11.03 ± 6.08	11.22 ± 6.61	0.741		
Epithelial integrity	Mean ± SD	Mean ± SD	<i>p</i> value		
Analysis of epithelial integrity/structure (each component expressed as percentages of total length measured)					
Percentage of intact epithelium	6.55 ± 18.35	67.45 ± 21.24	<0.001		
Percentage with partial denudation	28.01 ± 24.82	20.09 ± 13.71	0.648		
Percentage with complete denudation	63.73 ± 31.31	0.35 ± 0.88	<0.001		
Percentage with epithelial hyperplasia	1.09 ± 4.23	12.09 ± 20.25	0.062		
Percentage with squamous metaplasia	1.06 ± 4.10	0	0.317		
Other epithelial characteristics	Number (%)	Number (%)	<i>p</i> value		
Basement membrane					
Normal	3 (20)	12 (80)	<0.001		
Thickened	12 (80)	3 (20)			
Cilia					
Normal	2 (13.33)	14 (93.33)	<0.001		
Decreased/absent	3 (20)	1 (6.67)			
Unable to comment	10 (66.67)	0			
Goblet cells					
Normal	2 (13.33)	10 (66.67)	<0.001		
Decreased/absent	3 (20)	3 (20)			
Unable to comment	10 (66.67)	0			
Hyperplasia	–	2 (13.33)			
Lamina propria	Mean number/mm ² ± SD	Mean number/mm ² ± SD	<i>p</i> value		
Capillaries	45.080 ± 34.834	46.600 ± 18.702	0.431		
Tissue eosinophils	9.067 ± 10.557	10.147 ± 13.463	0.740		
Glands	34.133 ± 20.577	46.611 ± 26.311	0.152		
	Number (%)	Mean grade (SD)	Number (%)	Mean grade (SD)	<i>p</i> value
Interstitial oedema					
Absent (grade 0)	8 (53.33)	0.56 (0–2)	6 (40)	0.60 (0–1)	0.466
Mild (1)	6 (40)		9 (60)		
Moderate (2)	1 (6.67)		0		
Severe (3)	0		0		
Lamina propria fibrosis					
Absent (grade 0)	1 (6.67)	1.81 (0–3)	1 (6.67)	1.40 (0–2)	0.004
Mild (1)	6 (40)		7 (46.67)		
Moderate (2)	1 (6.67)		7 (46.67)		
Severe (3)	7 (46.67)		0		
Perivascular fibrosis	Number (%)		Number (%)		<i>p</i> value
Present	17 (70.83)		6 (40)		0.272
Absent	7 (29.17)		9 (60)		

**p* value < 0.05 taken as significant

of improvement of epithelial integrity and basement membrane architecture, this reduction in fibrosis postoperatively could be indicative of reduced inflammation postoperatively.

Schmidt et al. compared mucosal biopsies from patients with vasomotor rhinitis, allergic rhinitis and compensatory turbinate hypertrophy in septal deviation [19]. The authors reported that the cause for reduced nasal patency in cases of

Table 4 Comparison of data from postoperative biopsies after ESMD and ESMR

Characteristics	ESMD postop (<i>n</i> = 14)		ESMR postop (<i>n</i> = 15)		<i>p</i> value*
Epithelium	Mean ± SD		Mean ± SD		
Length of epithelium studied (mm)	11.02 ± 5.33		11.22 ± 6.61		0.779
Epithelial integrity	Mean ± SD		Mean ± SD		<i>p</i> value
Analysis of epithelial integrity/structure (each component expressed as percentages of total length measured)					
Percentage of intact epithelium	65.10 ± 19.90		67.45 ± 21.24		0.885
Percentage with partial denudation	12.85 ± 14.68		20.09 ± 13.71		0.117
Percentage with complete denudation	0		0.35 ± 0.88		0.184
Percentage with epithelial hyperplasia	22.04 ± 23.11		12.09 ± 20.25		0.218
Percentage with squamous metaplasia	0		0		1.000
Other epithelial characteristics	Number (%)		Number (%)		<i>p</i> value
Basement membrane					
Normal	10 (71.43)		12 (80)		0.682
Thickened	4 (28.57)		3 (20)		
Cilia					
Normal	11(78.57)		14 (93.33)		0.330
Decreased/absent	3 (21.42)		1 (6.67)		
Unable to comment	0		0		
Goblet cells					
Normal	5 (35.7)		10 (66.67)		0.299
Decreased/absent	5 (35.7)		3 (20)		
Unable to comment	0		0		
Hyperplasia	4 (28.6)		2 (13.33)		
Lamina propria	Mean number/mm ² ± SD		Mean number/mm ² ± SD		Mean number/mm ² ± SD
Capillaries	46.757 ± 26.281		46.600 ± 18.702		0.827
Tissue eosinophils	12.600 ± 20.856		10.147 ± 13.463		0.727
Glands	38.929 ± 35.830		46.611 ± 26.311		0.326
	Number (%)	Mean grade (range)	Number (%)	Mean grade (range)	<i>p</i> value
Interstitial oedema					
Absent (grade 0)	3 (21.4)	1.07 (0–2)	6 (40)	0.60 (0–1)	0.076
Mild (1)	7 (50)		9 (60)		
Moderate (2)	4 (28.6)		0		
Severe (3)	0		0		
Lamina propria fibrosis					
Absent (grade 0)	5 (35.7)	1.14 (0–3)	1 (6.67)	1.40 (0–2)	0.071
Mild (1)	4 (28.6)		7 (46.67)		
Moderate (2)	3 (21.4)		7 (46.67)		
Severe (3)	2 (14.3)		0		
Perivascular fibrosis	Number (%)		Number (%)		<i>p</i> value
Present	5 (35.7)		6 (40)		0.812
Absent	9 (64.3)		9 (60)		

**p* value < 0.05 taken as significant

allergic rhinitis was interstitial oedema. In the present study, severe interstitial oedema was not found in any of the biopsies preoperatively. The differences in interstitial oedema, preoperatively and postoperatively in both groups were not statistically significant. However, the postoperative ESMD biopsies had more oedema than the postoperative ESMR ones ($p = 0.076$).

The present study is a short-term follow-up histological study. Long term follow-up of the larger cohort for periods ranging from 12 to 24 months showed a consistent improvement in subjective scores. As several of our patients continued to use steroid nasal sprays postoperatively, treatment of underlying allergy also, perhaps, contributed to symptom relief. Some authors have found recurrence of nasal obstruction due to inferior turbinate hypertrophy in patients who underwent ESMD over the long term despite significant benefit in the short-term [20, 21]. This, however, was not seen in patients who underwent ESMR [20–22].

Conclusion

Surgical intervention for inferior turbinate hypertrophy secondary to allergic rhinitis refractory to medical management, both by endoscopic submucous diathermy as well as resection, results in the restoration of nasal mucosal epithelium on histopathological examination as early as 3 months postoperatively. There were, however, no significant differences in clinical improvement or postoperative histopathological differences between the two techniques at 3–6 months.

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Compliance with ethical standards

Conflict of interest The authors have no conflict of interest to declare.

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