Caudal septoplasty, a literature review

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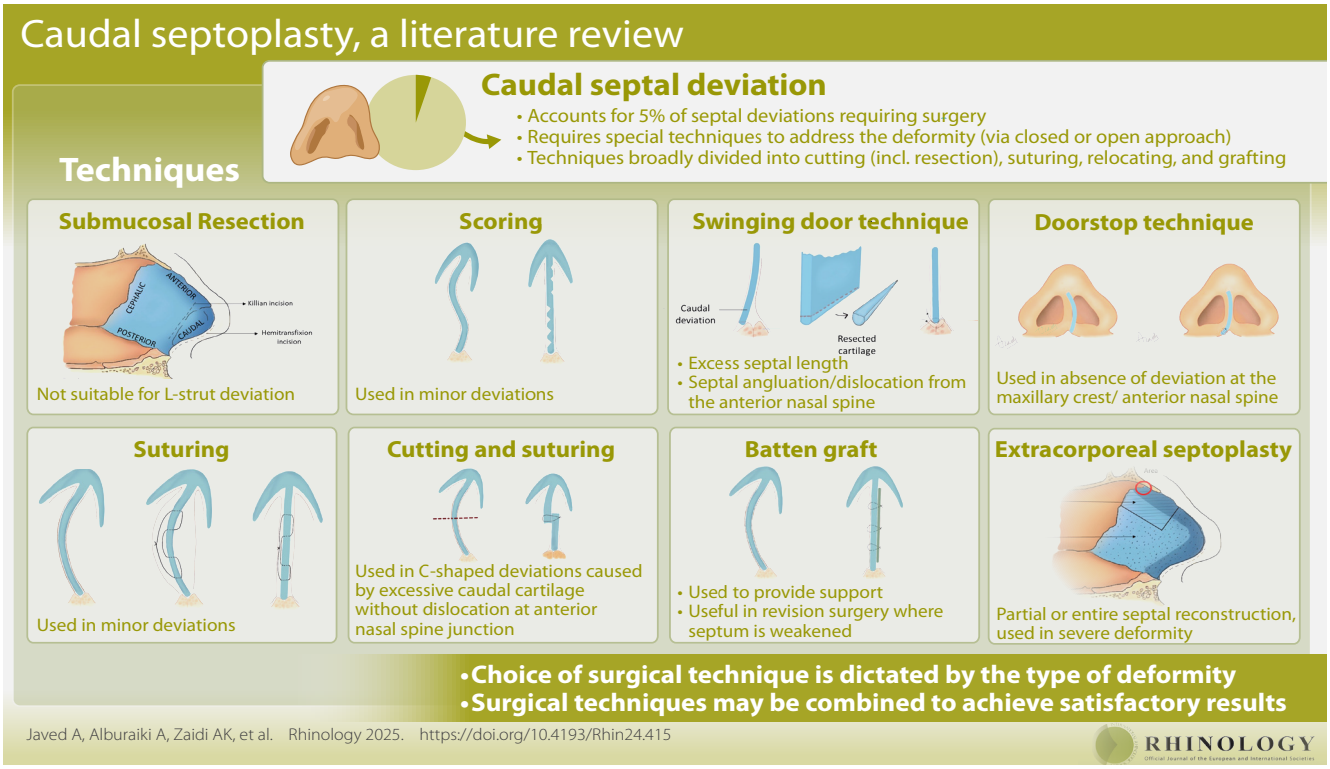

Abstract

Background: Caudal septal deviation accounts for around five percent of patients with septal deviations that require surgery. The caudal septum provides support to the nasal tip and the deviations can narrow the nasal airway and lead to marked asymmetry in nostril shape. Over-resection of this area can compromise the structural support leading to tip collapse or saddle nose deformity. This necessitates alternative techniques to submucosal resection for surgical correction of caudal septal deviations.

Methodology: This study provides a review of different surgical techniques, including open and closed septoplasty in the literature to address caudal septal deviation. Each technique is described along with a surgical illustration, its advantages, limitations, and examples of case studies with surgical outcomes.

Results: The submucosal resection is a commonly used method but can only be used if the septal deviation is not involving the L-strut. Other methods include scoring, swinging door, doorstop, and suturing techniques either as a stand-alone or used combined with cutting techniques. Batten graft can be used alone or in conjunction with the other methods. Extracorporeal septoplasty is used in cases of severe deformity.

Conclusions: There is a variety of methods to address caudal septal deviation. Correcting the caudal septal deviation requires proper pre-operative planning and accurate execution of surgical techniques. More research on surgical outcomes is needed to improve the evidence base.

Key words: caudal septoplasty, septoplasty, septal deformity, caudal septal deviation, anterior septal deviation, surgical technique

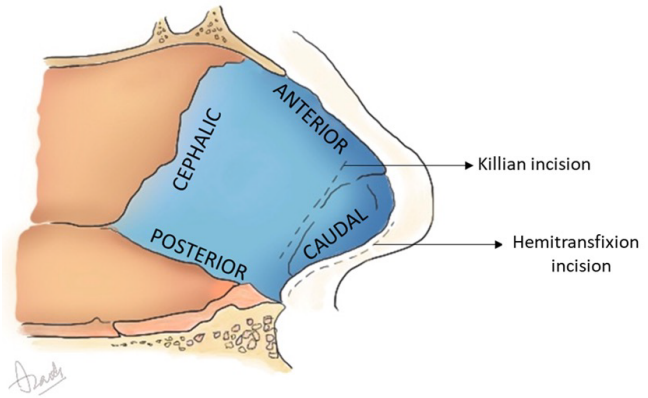

Figure 1. Sagittal view of the septum with orientation. Killian and Hemitransfixion incisions are demonstrated.

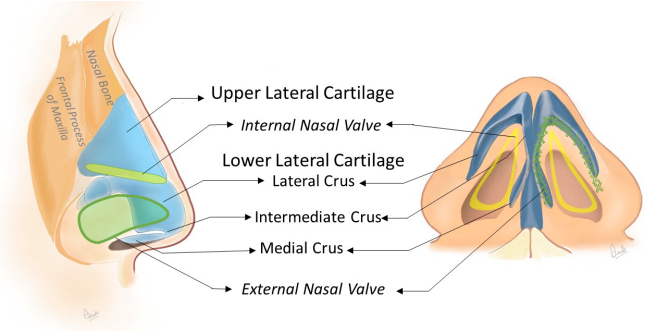

Figure 2. Upper and lower lateral cartilages and their relationship to the septum. The external nasal valve is highlighted in green and the internal nasal valve is in yellow.

Introduction

The caudal septum is an essential component of the septum that supports the nasal tip and plays a significant part in maintaining the patency of the nasal airway. Deviation of the caudal septum can lead to significant nasal obstruction and asymmetry in the shape of the external nose [1, 2].

Some studies report that caudal septal deviations account for approximately five percent of all septal abnormalities that require surgical management, and a significant proportion frequently require further revision surgery [3, 4]. Over-resection of the caudal septum can lead to nasal tip deformity deprojection (owing to the caudal septum role in the tip support mechanism) and may also cause supratip depression. Surgery to correct this deviation is thus challenging and requires alternative techniques to the commonly used submucosal resection (SMR), which per se does not address the caudal septum but is still required for harvesting relevant grafts required for certain surgical techniques [1, 5].

The objective of this paper is to provide a review of surgical techniques to correct caudal septal deviation.

Anatomy

The nasal septum, comprising bony and cartilaginous components, partitions the nasal cavity into two cavities. Both components are respectively covered by mucoperiosteum and the mucoperichondrium, which provide innervation and vascular supply.

The nasal septum is formed by the perpendicular plate of the ethmoid bone cephalically, and by the quadrangular cartilage caudally (Figure 1) [6]. The hard palate serves as a barrier separating the nasal cavity from the oral cavity and is comprised of the horizontal plate of the palatine bone posteriorly in the nasal cavity and the palatine process of the maxillary bone anteriorly. These bones articulate at the midline where the septal cartilage attaches to the maxillary crest. The maxillary crest holds the vomer posteriorly in the nasal cavity and the caudal part of the quadrangular cartilage (known as the posterior septal angle) rests on the most anterior part of the maxillary crest (known as the anterior nasal spine). On average, the posterior septal angle sits 5mm proud of the anterior nasal spine [7].

Nasal septal cartilage is thicker along the border regions at the keystone area and posterior septal angle and is thinner at the anterior septal angle with the thinnest at the junction of dorsal and caudal septum [8].

At the nasal tip, the cartilaginous septum is connected to the lower lateral cartilages forming the external nasal valve (Figure 2). The lower lateral cartilages can be conceptualised as a tripod with the fused medial crura connected to the caudal septum. This explains the role of caudal septal edge in nasal tip support; hence caudal septal edge deviation or resection may have an impact on the positon of columella and the nasal tip. The upper lateral cartilages (ULC) are in unison with the quadrangular septal cartilage. The caudal edge of the ULC, together with the head of the inferior turbinate laterally and the septum medially, forms the internal nasal valve area. This is the narrowest part of the nose, and the angle between the ULC and the septum measures approximately 10-15 degrees in Caucasians and significantly more in Asian and African ethnicities [9].

The caudal nose is defined by all the structures distal to the upper lateral cartilages [10]. This involves the nasal spine, the caudal septum and the lower lateral cartilages on either side of the septum.

Importance of caudal septum

The caudal septum has an outsized importance in nasal anatomy and function. It provides support to the nasal tip with deficiencies leading to a collapsed nasal tip [1]. The caudal septum is connected to the dorsal strut which is attached to the upper

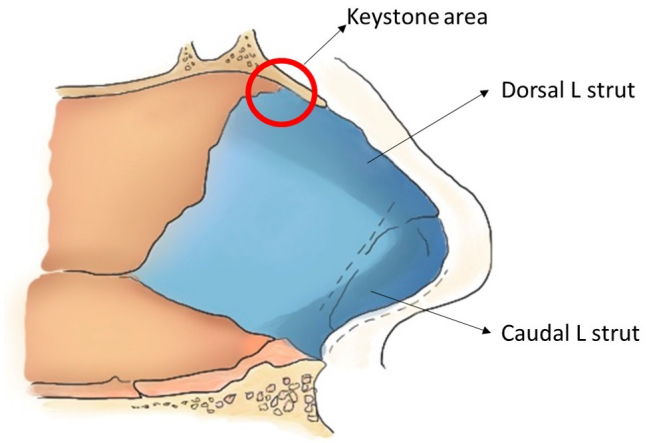

Figure 3. Sagittal view highlighting the keystone area and the L-strut (shaded deep blue).

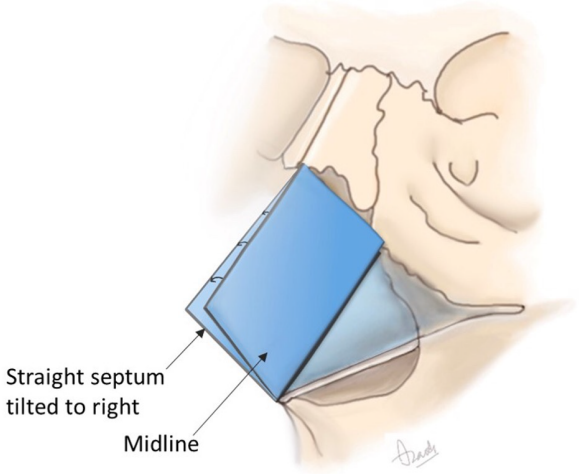

Figure 4. Septal tilt, Guyuron classification I.

lateral cartilages which are in contact with the keystone area (Figure 3), resection of which can lead to a saddle deformity [11]. Deviations in the caudal septum can narrow the internal and the external nasal valve areas [2]. Aesthetically, gross caudal septum deviations can lead to a marked asymmetry in the shape of the nostrils and the nasal tip [1].

Incidence of caudal deviation

Patients with caudal septal deviation account for around 5% of patients with septal deviations requiring surgery [3]. Importantly, persistent caudal septal deviations account for a significant number of revision surgeries. Three separate single-centre studies reporting on revision septoplasties found persistent caudal septal deviation cases ranging from 31% to 81% [2, 5, 11]. A review of 494 septoplasty patients [12] found persistent septal deviation postoperatively in 27% of patients with anterior septal deviation (defined as caudal and/or dorsal septal deviation) compared to no cases of persistent posterior septal deviation. One study [5] reviewing revision septoplasty cases found many patients with caudal deviations had no evidence of any previous attempts to correct them - the risks of tip collapse and saddle deformity can potentially deter surgeons from operating on the caudal septum. The limited access in the closed approach for complex caudal septal deformities may have been the contributing factor in some of the failed cases. Open approach septal surgery offers better visualisation, assessment and implementation of the surgical techniques in complex septal deviations.

Assessment of caudal deviation

Guyuron [10] offers a comprehensive review on the assessment of the caudal nose. An in-depth assessment of the caudal septum, medial crura and nasal spine along with the lower lateral cartilages should be carried out to identify all the structural abnormalities present. A careful history is essential to explore

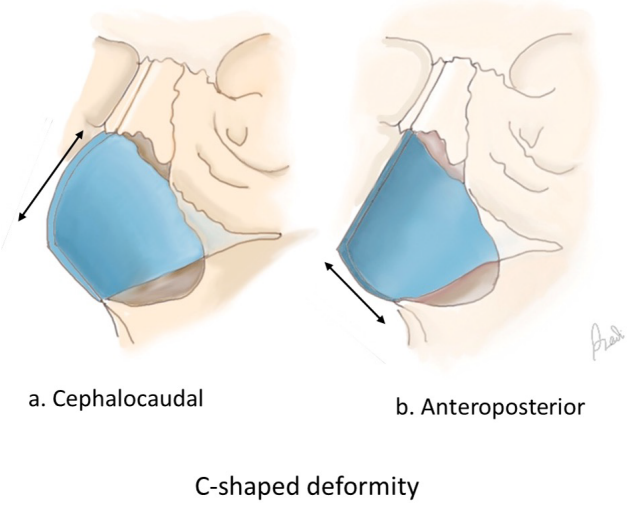

Figure 5. C-shaped deformity, Guyuron classification II and III.

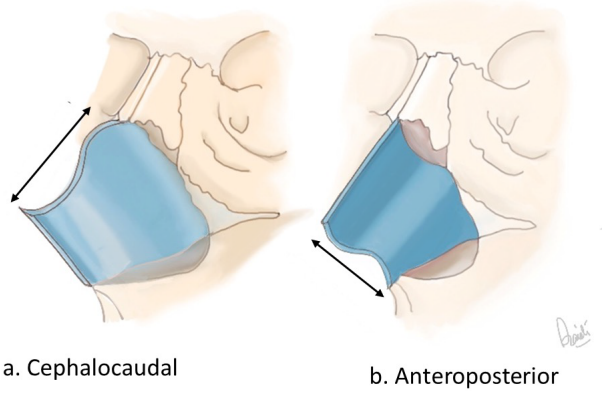

Figure 6. S-shaped deformity, Guyuron classification IV and V.

non-structural causes of nose obstruction. Turbinate hypertrophy and chronic rhinosinusitis should be addressed and excluded as patients may have a compensatory turbinate hypertrophy on the opposite side of the septal deviation [11]. Given the scope of this review, we will only focus on caudal septal deformities. There are several different ways to categorise septal deviations which can be applied to the caudal septum.

Rohrich's classification classifies septal deviations into three basic types: caudal, concave dorsal and concave/convex dorsal deformities [13]. Amongst caudal deviations, there can either be a C or S shaped curvature of the septum. This can be in an anteroposterior or a cephalocaudal direction. 'Septal tilt' is a septal deformity whereby there is no curve in the septum, but it is tilted to one side anteriorly and the other side posteriorly.

Guyuron's classification [14] classes septal deviations in five categories. Class I involves a septal tilt, II is a C-shaped anteroposterior deviation, III is a C-shaped cephalocaudal deviation, IV is a S-shaped anteroposterior deviation and V is a S-shaped cephalocaudal deviation (Figure 4, 5 and 6).

Objective measures such as acoustic rhinometry and rhinomanometry can be used during the patient assessment, but they often do not correlate with patients' symptoms and are rarely used in clinical practice or outside of research settings [15]. Subjective measures include questionnaires such as the Nasal Obstruction Symptom Evaluation scale (NOSE), a standardised assessment of patient symptoms and satisfaction with procedure [16]. NOSE questionnaire contains 5 domains scoring nasal congestion, nasal obstruction, and trouble sleeping or breathing through the nose during exercise on a scale of 0-4 with a score range of 0-100 (NOSE score calculated as scale times by 5) [15]. A systematic review of 31 articles reported the mean NOSE for patients with nasal airway obstruction as 65 compared to 15 in asymptomatic individuals [17]; the mean postsurgical NOSE score was 23. A study on septoplasty outcomes (without turbinate surgery) found the Minimally Clinically Important Difference (MCID) for the NOSE score to be between 5 and 7.5 (the mean change in this study was 35.2 points) [18].

Surgical techniques

There is a variety of surgical techniques to address caudal septal deviations depending on the type and degree of the septal deformity. Each section summarises the method and describes the advantages, limitations, and examples of case studies for each method.

Submucosal resection (SMR)

The most widely used technique in septoplasty surgery was first described by Ingals [19] in 1882 but popularised by Killian [20] after he modified and published the technique in 1905.
An incision is made roughly 1cm cephalic to the caudal edge of the septum and the sub-perichondrial flap is raised. In septal deviations involving the caudal end of the cartilage, a hemitransfixion incision (Figure 1) is placed at the caudal edge of the septum to provide access to the entire septum [21]. The deviated septum is freed from surrounding bone and cartilage attachments and excised conservatively. The harvested septum can be discarded or used as a graft in reconstructive efforts or reinserted after straightening [21].

An L-shaped strut involving the caudal and dorsal cartilage (Figure 3) is always preserved to provide structural support and avoid tip collapse and saddle nose deformity [21]. It is commonly recommended that the width of this strut be at least 10 to 15mm [22]. However, there is considerable variation in this based on surgeon preference [23] with some authors recommending a 6mm width sufficient for adequate support [24].

The main drawback in this method is that most caudal deviations cannot be corrected using septal excision as that would compromise the L-strut. If the septal deviation involves the caudal aspect of the L-strut and cannot be excised by a submucosal resection then different techniques can be used which are detailed below. Apart from extracorporeal septoplasty, the remaining methods are often used in conjunction with submucosal resection (to harvest the graft).

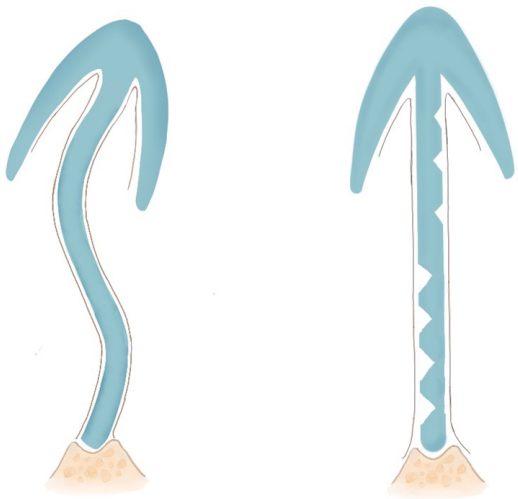

Figure 7. Scoring technique.

Scoring

This method (Figure 7) is most suited for minor deviations of the caudal septum.
It involves the use of partial or full thickness incisions on the concave side to allow the septal deviation to correct back to

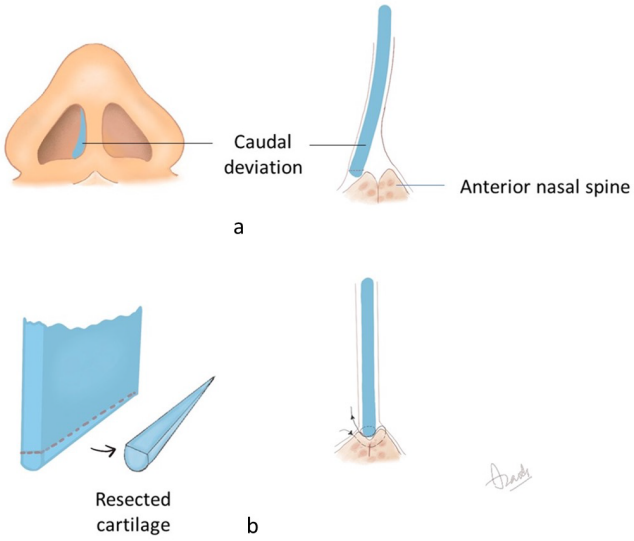

Figure 8. Swinging door technique.

a central position [1]. Scoring can also be done in the form of cross-hatching incisions. These incisions break the tension and counter the bending of the cartilage, and a secondary healing process supports the straightening of the septum [25]. This principle was first brought to the attention of the surgeons by Gibson and Davis [26].

This is based on a mechanism of interlocked stresses accounting for the bend which can be disrupted and overcome with the incisions [27]. However, studies show this mechanism to be based on the molecular properties of the cartilage with the gross appearance of the cartilage having little predictive value in predicting its behaviour to the incision [28].

There are risks involved in the approach including under or over scoring which is hard to predict intraoperatively and may not manifest until weeks after surgery [29]. Partial incisions may not effectively overcome cartilage memory and can lead to under correction [28]. Conversely, overscoring can cause deviation contralaterally; a single-centre study with 1124 participants found that 2% of patients developed overcorrection [29]. The resultant weakening of the caudal septum from full thickness incisions may cause tip ptosis or saddle nose deformity [30].

Scoring by itself can only be effective in mild septal deviations and is more often used in conjunction with other methods as will be discussed later.

Swinging door technique

This technique (Figure 8) is most suited towards caudal deviations with excess length of the septum or a septal tilt where there is an angulation or dislocation of the caudal septum from the anterior nasal spine [31].

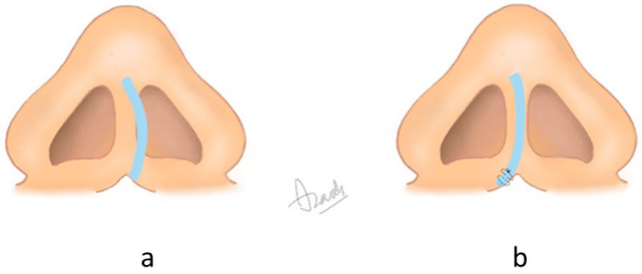

Figure 9. Doorstop technique.

This technique was first described by Metzenbaum [32] and it is used when caudal septum is deviated while it is either resting on midline or dislocated from the maxillary crest. Often there is an excess length in the caudal septal cartilage which is addressed by excising a sliver of septal cartilage from the posterior aspect of caudal septum and repositioning it over the nasal spine without any tension. Sutures can then secure the caudal septum to the anterior nasal spine [32].

The risk associated with this technique is the risk of excessive cartilage resection from the posterior caudal septum leading to supratip depression and reduction in the tip projection. Also, if the corrected cartilage is not properly secured in place by sutures, the septum dislodges from the crest leading to an undercorrected deformity [25].

Sedwick [3] utilised this method in a case series of 62 patients. 95% of the patients had complained of pre-operative nasal obstruction, a number which reduced to 18% post-operation. The rate of revision septoplasty was 8%.

Doorstop technique

This technique (Figure 9) is a modification of the swinging door technique, and it is used when the maxillary crest and the nasal spine are not deviated.

This technique was first mentioned by Pastorek [33] and is similar to the swinging door method except that when the caudal septum is disarticulated from the nasal spine it is repositioned to the other side often without any cartilage resection. The nasal spine acts as a doorstop, securing the septum in a straighter position. A suture can be applied between the caudal septum and the soft tissue lateral to the nasal spine to provide additional stability. If the caudal septum is excessively long then a portion of it can be excised, but care needs to be taken to be more conservative than in the swinging door technique otherwise the caudal septum will be too short for the nasal spine to act as a doorstop.

The benefit of this method to the swinging door technique is that the nasal spine acts as a bulwark to the cartilaginous sep-

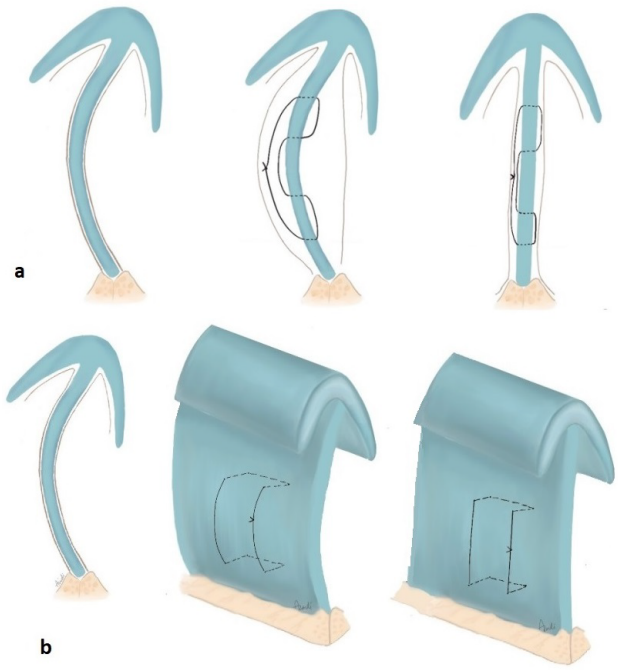

Figure 10. Suturing technique. A) Vertical mattress suture. B) Horizontal mattress suture.

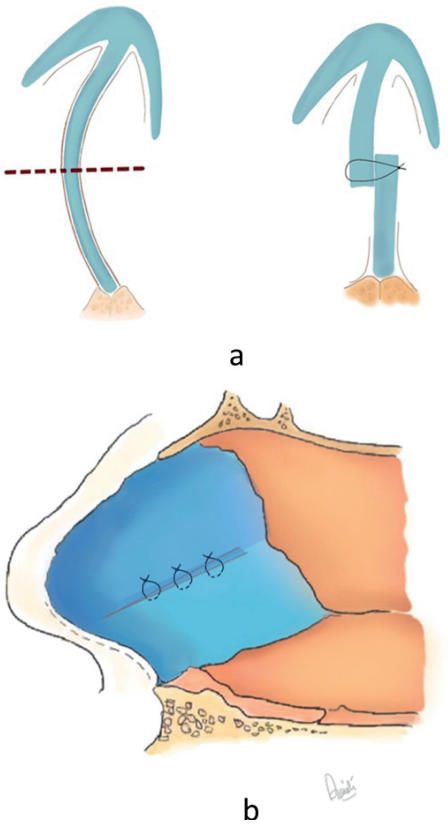

Figure 11. A) Cutting and suture method. B) Sagittal view showing the modified version.

tum which is prone to reverting to its original position due to its intrinsic 'memory'. Scoring or methods that weaken the caudal cartilage would be counterproductive to the doorstop technique, hence why this technique may have limited use in revision septoplasty cases where the cartilage is already weak [33].

Suturing techniques

This technique can be used in mild cases of caudal deviation, and it was first described by Ellis [34]. The technique involves using permanent submucosal sutures to straighten bent cartilage into a more central position. There are different techniques described in the literature [35, 36]. A modified Killian incision is used for access on the concave side followed by the raising of mucoperichondrial flaps. Excess cartilage can be estimated by pushing the cartilage to the midline and then excised by a full thickness wedge incision. There should be an anterior margin preserved of at least 5mm for tip support and the cartilage should not be disarticulated from the anterior nasal spine. Byrd [37] used vertical mattress sutures tying the knots on the convex side of the septal deviation (Figure 10a) whereas Gruber [38] utilised a horizontal mattress suture (Figure 10b) spaced 7 to 10mm apart to good effect on the caudal septum. Seo used a traction suture applied through the mucosal incision site to pull the deviated septum towards midline. This was achieved after excess cartilage was partially resected [36].

The suture technique preserves the structural support of the caudal cartilage as the junctions between cartilage and bone are preserved and there is less thinning or cutting of the caudal cartilage. This is thus unlikely to cause severe post-operative complications such as tip ptosis or saddle nose deformity [35]. Unlike scoring it is also reversible if the surgeon has under or overcorrected the curvature [38]. Its effectiveness may be limited in more severe deviations of the caudal septum.

Seo [36] utilised a suture technique on 67 patients with a C-shaped deviation without dislocation from the anterior nasal spine. This was accompanied with volume reduction of the inferior turbinate. The mean Visual Analog Score (VAS) decreased from 7.3 pre-operatively to 1.4 after 6 months post-operatively ($p<0.001$). There were no post-operative complications.

Cutting and suturing

This technique (Figure 11a) is most effective for C-shaped deviations caused by excessive caudal cartilage without any dislocation at the anterior nasal spine junction.

This technique involves cutting the caudal septal cartilage at its most convex part and then overlapping the cut pieces of the caudal strut together in the midline before suturing them together [39].

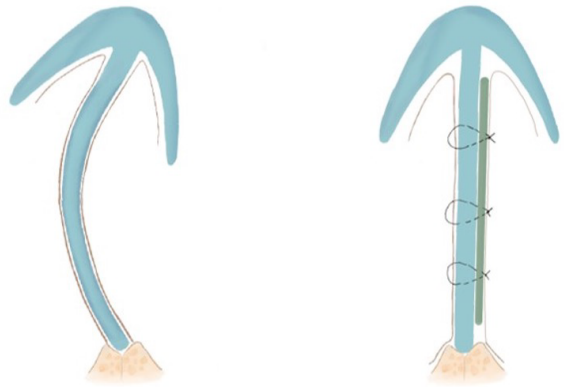

Figure 12. Batten graft technique.

The benefit of this method is that the strong junction between the nasal spine and caudal septum is preserved [40]. The cartilaginous incision breaks the spring of the cartilage and therefore has a lower risk of recurrence. This method may benefit from concomitant septal batten grafting. This technique runs the risk of shortening the length of caudal septum resulting in a saddle nose deformity or tip lowering if overlapping has been performed excessively [35].

Jang [40] published a case series involving 45 patients with C-shaped anteroposterior caudal septal deviation without nasal spine dislocation who underwent surgery using this technique. Subjective nasal obstruction using VAS showed a significant improvement overall, from 7.93 preoperatively to 3.63 after operation. Sixty eight percent of patients reported their symptoms were much improved, compared to 17% who reported no change in symptoms. There was one case of saddle nose deformity due to loosening of connection between the two cut ends which required revision surgery.

A modified version of this technique involves only partial cutting of the caudal septum preserving 2mm of the anterior portion (Figure 11b) followed by suturing [41, 42]. This preserves some of the cartilage strength and stability reducing the chance of collapse [41]. Two case series [41, 42] with a combined 53 patients undergoing this modified technique showed a significant reduction in the NOSE score and no cases of saddle deformity or loss of tip projection.

Batten graft

The batten graft method is useful to provide support in caudal septoplasty cases (5); its role is particularly beneficial in revision surgery where the caudal septum has lost its integrity. It also overcomes the cartilage memory and allows better assessment of septal deviation correction to be judged intraoperatively.

This method involves using either the patient's own cartilage or bone (from a conservative submucosal resection), or a homologous graft and suturing it to the caudal septum once it is in the desired position.

The batten graft can be used as a stand-alone method (Figure 12), where the concave aspect of the septum is supported and straightened with the batten graft inserted submucosally and sutured together [43, 44]. This method is most suited in caudal septal deviations without any angulation or dislocation of the caudal septum from the anterior nasal spine.

The batten graft can also be used with other methods to provide support (Figure 13) [39, 45]. The batten graft does not have to be straight to address the septal deviation. A concave batten graft can be used to counterbalance the convexity of the septum (eg the concave graft facing the septal concavity) to straighten the deviated septum (Figure 13c).

A potential drawback is the increase in thickness of the septum which can reduce the nasal airway so accurate positioning of

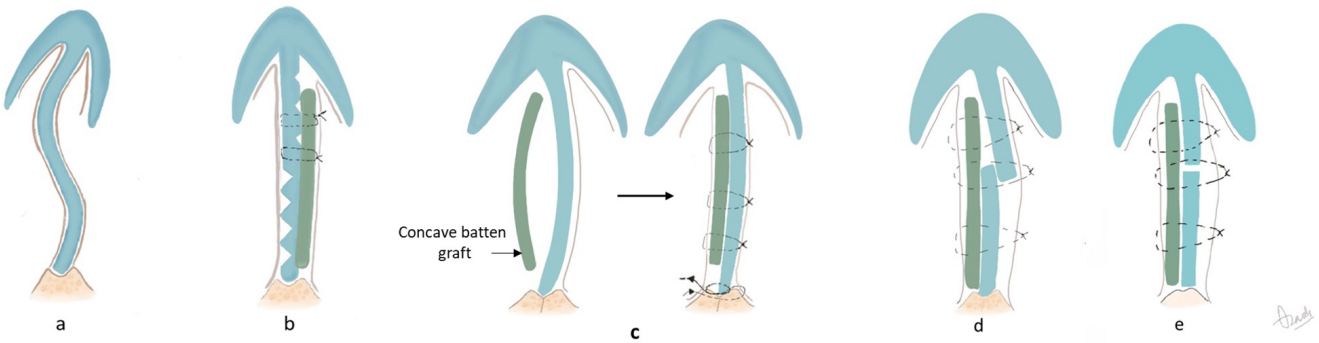

Figure 13. A) Deviated septum. B) Scoring supported by a batten graft. C) Counterbalancing/supporting with a batten graft along with the swinging door technique. D) Cutting and overlapping the excess cartilage supported with a batten graft. E) Excising the excess cartilage and supporting with a batten graft.

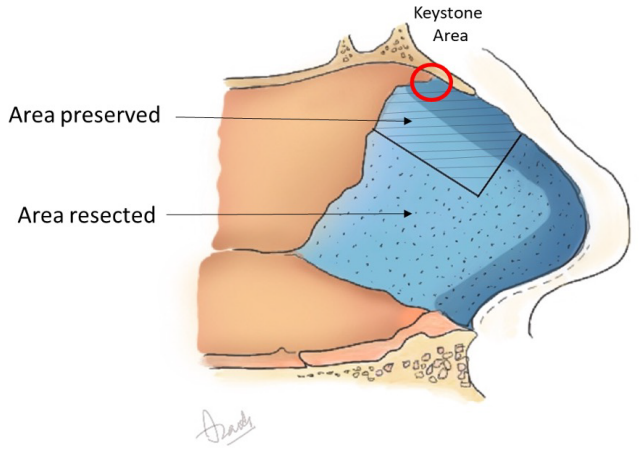

Figure 14. Anterior septal reconstruction.

the graft is paramount [43].

Kim [43] describes the use of the batten graft as a stand-alone technique in a case series of 56 patients. Bilateral submucoperichondrial flaps are elevated after a hemitransifixion incision followed by a submucosal resection. The harvested septal cartilage is fitted to the deviated septum using counter-curvature usually on the concave side and is sutured with three or four 5-0 polydioxanone sutures. The gap between the posterior portion of the graft and the caudal septum is closed by one or two transcartilage sutures followed by closure of the hemitransfixion incision using through and through transmucosal sutures. In 56 patients, the mean VAS score improved from 6.86 pre-operatively to 1.70 post-operatively with no cases requiring revision surgery. One patient had a small perforation and there was one case of chondritis and one septal abscess which were successfully managed conservatively.

Extracorporeal septoplasty

The extracorporeal approach, first described by King and Ashley [46], involves taking the entire septum out, reconstructing it and then replacing it. This is most often used in a severely deformed caudal deviation where the previous methods are less likely to succeed or in cases where other structures contributing to the caudal nose are also involved [47].

The main drawback of this method is the risk of destabilisation of the keystone area, and the resultant development of saddle-nose deformity. Gubisch popularised this method and noted a revision rate of 9% in his series [47].

Most [48] has proposed a modification to this method (ie the anterior septal reconstruction) where the dorsal strut is preserved as the rest of the septum is excised, thereby reducing the risk of compromise to the keystone area (Figure 14). The upper lateral cartilage is released from the septum but, instead of removing the entire cartilaginous septum, a dorsal strut is preserved approximately 1.5cm along. The vertical height of this strut is maximal at the keystone area, around 1 cm. If the in-stu segment of the dorsal strut is deviated, a graft is created from the harvested cartilage and then placed on the concave side of the midvault dorsal septal segment and sutured between the strut and the upper lateral cartilage to act as a spreader graft and splint. The fixation at the posterior septal angle can be carried out by creating a space on the anterior nasal spine to a depth of 3-4mm, carving a notch in the graft and positioning the septum in the groove within the anterior nasal spine [48].

Using this method on 12 patients, Most's study showed the mean NOSE score reduced from 76.7 to 12.9 after the operation ($p<0.01$). There was no saddling noted after surgery. Surowitz [49] carried out this method on 77 patients with a mean pre-operative NOSE score of 68.2 and a VAS of 7.2. Four months after surgery, mean NOSE score was 15.8 and VAS of 1.4 ($p<0.0001$). Only one patient required revision septoplasty.

Discussion

Caudal septal deviation cannot be fully addressed by submucosal resection alone, therefore special techniques need to be employed to address the septal deformity involving the caudal L-strut. Submucosal resection however forms an essential part of most septal operations relieving the obstruction as well as providing the graft needed to correct the caudal septal deviation. Attention to the specifics surrounding the submucosal resection and the resultant L-strut is crucial in operative planning and success of the surgery.

Anatomical studies have shown nasal septal cartilage to be thinner (compared to the rest of the septum) at the junction of dorsal and caudal septum [8]. When the L-strut weight bearing properties were studied, the greatest pressure was often at this very junction [50]. Rather than a perpendicular incision at this junction between the caudal and dorsal strut, curving the incision can provide additional width and support at this critical juncture when our L-strut is of a narrow width (Figure 15). The central area of quadrangular cartilage commonly resected in submucosal resections is also a thicker and stronger part of the septum [8], which should be conservatively excised to provide the best possible support after septoplasty.

Studies have also looked at the minimum amount of contact between the caudal septum and the maxillary crest required for stability. This osseocartilaginous junction is an important area of support for the caudal septum and decreased contact area leads to increased stress on the caudal strut [50]. At least 40% of the caudal strut should be in contact with the maxillary crest to

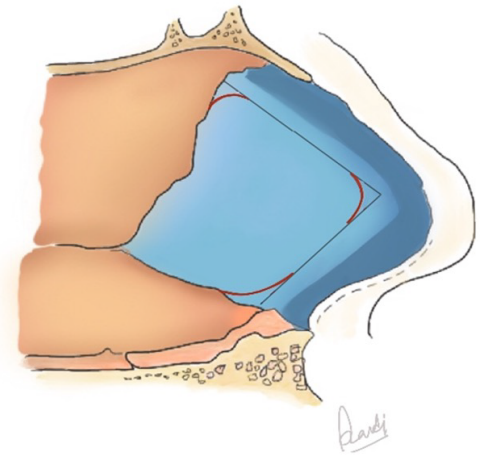

Figure 15. L-strut with curved incisions to provide more support.

provide adequate support [50]. This means that for a 10mm wide caudal strut, at least 4mm of the strut should be in contact with the maxillary crest. The posterior septal angle may sit proud of the anterior nasal spine by 2-8 mm in Caucasians [7]. This relationship should be observed when performing an SMR and harvesting the graft. This would lead to different measurements for a patient with a 2mm distance between posterior septal angle and anterior nasal spine compared to a patient with an 8mm distance. If necessary, the incision at this end can be curved back to leave additional contact between the two structures at this junction (Figure 15).

Paul et al. [8] showed that the thickness of the L-strut is also important in determining whether the residual width of the L-strut can provide adequate support. There is considerable variability in septal cartilage thickness between patients. With a thicker L-strut, the width can be comparatively less without compromising on strength. A 10mm wide L-strut with a thickness of 1.5mm has similar strength to a 5mm wide strut with a thickness of 2mm [49]. When the septoplasty leaves behind a narrow L-strut, we can add support in the form of a batten graft to compensate for this. One important caveat is that these studies were performed on the septum in isolation without considering the possible effects from the relationship to the surrounding anatomy (eg attachment of the septum to the upper lateral cartilage).

There is considerable literature on the different approaches to a caudal septoplasty. However, all the studies the authors have reviewed on this topic were single centre case series, often involving one primary surgeon only. The authors could not identify a single study where different approaches were compared. Furthermore, different measures were used to judge the success of procedure making it very difficult to compare different techniques.

There also seems to be a disparity between literature on caudal septoplasty and the frequency of different methods used in clinical practice. Voizard [15] conducted a survey of clinicians in North America and found that the most popular method was the swinging door technique (69.5% of respondents) followed by extracorporeal septoplasty (46.7%) and cartilage scoring (45.3%). In comparison, batten graft techniques were quoted most often in the literature. Cartilage scoring, according to Voizard's study, is a popular technique amongst the survey respondents but there is limited literature on its use for caudal septal deviations.

Future studies should consider use of standardised assessment tools including the NOSE score to measure operative success. Higher quality of evidence including the use of comparative trials studying different methods is required to improve the evidence base.

Conclusion

There is a variety of surgical techniques to correct caudal septal deviations. The techniques broadly include cartilage scoring, cartilage resection, cartilage relocation, suturing techniques and grafting techniques; these techniques can be used in isolation or in combination. Each method has certain advantages and limitations that need to be considered by the operating surgeon. Every septal deviation needs to be individually assessed taking into consideration the type and complexity of deviation to plan the surgery and tailor the surgical technique accordingly. Complexity of the septal deviation and the surgeon's experience with different techniques and approaches (open versus closed) often dictate the type of technique used to correct a deviated septum. This article provides the reader with an armamentarium of surgical techniques available in the literature to address a deviated septum. With proper assessment of the septal deformity and pre-operative planning, the surgeon can employ the appropriate surgical technique resulting in a favourable outcome.

Authors' contributions

AJ and AA were co-first authors and were involved in all stages of the review, AKZ was the illustrator for all figures, MUF was involved in the write up and editing, JL was involved in the literature search, editing and reviewing, SA was the senior author and supervisor who was involved in all stages of the review.

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Conflicts of interest

The authors have no competing interests.

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