European Journal of Plastic Surgery (2019) 42:423–430
https://doi.org/10.1007/s00238-019-01508-y

ORIGINAL PAPER

Single centre review of the use of costal cartilage for reconstruction of the nasal dorsum

Serena Martin[1] · Michael McBride[1] · Robbie Stewart[1] · Greg McBride[2] · Chris Hill[1]

Received: 22 June 2018 / Accepted: 4 February 2019 / Published online: 23 February 2019

Abstract

Background Reconstruction of the nasal skeleton aims to allow optimal air passage as well as a cosmetically pleasing appearance. Autogenous graft materials are the gold standard due to low extrusion and infection rates. A larger source of cartilage is required for complex secondary nasal reconstruction which makes costal cartilage an ideal source of autogenous material.

Methods We performed a retrospective review of all patients undergoing nasal reconstruction with autogenous costal cartilage between the years 2005 to 2016. All procedures were performed by a single surgeon across two hospital sites. Patient charts were reviewed to determine aetiology, indication for surgery, referral source, post-operative complications, need for revision surgery and the length of follow-up.

Results There was a total of 28 patients, 68% male with an average age of 37 years. The majority were referred from ENT (50%) followed by plastic or maxillofacial surgeons (21%). The commonest indication for surgery was previous nasal trauma (53%), and 88% of patients with trauma as the aetiology had previous nasal surgery prior to costal cartilage reconstruction. The commonest complication was warping of the costal cartilage graft; this occurred in 18% of patients; a slipped costal cartilage graft occurred in 4%. The revision rate was 32%. There were no cases of pneumothorax, pleural tear and post-operative infection.

Conclusions Despite the availability of alternative cartilage sources and the risk of cartilage warping, autogenous costal cartilage is still the ideal cartilage source for complex nasal reconstruction. It is readily available, durable and versatile. Several recent studies have reported alterations in surgical technique to reduce warping. This will subsequently reduce rates of revision surgery and ensure this versatile cartilage source continues to be utilised by surgeons in future.

Level of Evidence: Level IV, therapeutic study

Keywords Costal cartilage · Septorhinoplasty · Dorsal reconstruction · Costal graft · Warping · Rhinoplasty

Introduction

The major structure responsible for nasal support is the nasal septum. The nasal skeleton, including the septum, can be subject to damage from various sources, resulting in poor nasal support and airway compromise [1]. Reconstruction of the nasal skeleton aims to optimise the airway, and in addition, ensure a cosmetically pleasing appearance. Various options are available depending on the nature of reconstruction required.

The use of autogenous graft material is the gold standard for multiple reasons, including low rates of extrusion and infection as well as the benefit of having no immunogenicity [2]. The source of autogenous graft may be septal, conchal or from costal cartilage. Both septal cartilage and cartilage harvested from the ear provide a quickly harvested graft with low donor-site morbidity. However, the major drawback of these two sources, especially in complex secondary nasal reconstruction, is the amount of donor graft available. In addition, due to the nature of secondary nasal reconstruction, there is unlikely to be sufficient septal cartilage available for use. A larger autogenous cartilage source will usually be required making autogenous costal cartilage the ideal source.

The use of autogenous costal cartilage in septal and nasal skeleton reconstruction is not a new technique. It has been

✉ Serena Martin
Smartin381@qub.ac.uk

[1] Department of Plastic Surgery, Ulster Hospital, Dundonald, Belfast, UK

[2] Department of Otolaryngology, Altnagelvin Hospital, Londonderry, UK

increasingly used over recent years with one main issue, a high rate of cartilage warping. Multiple studies recently have attempted to vary the surgical technique with the aim of reducing warping rates. Despite this complication, autogenous costal cartilage remains an ideal source for secondary nasal reconstruction as it is readily available, durable and versatile.

Methods

A retrospective review was performed of all patients who had a rhinoplasty for reconstruction using a costal cartilage graft over an 11-year period, from 2005 to 2016. All operations were performed by a single plastic surgeon over two hospital sites. Twenty-eight patients met the criteria for inclusion. Patient charts were reviewed to determine the aetiology of nasal skeleton collapse, indication for surgery, referral source, type of procedure, post-operative complications, need for revision surgery and length of follow-up.

Surgical technique

The technique involves an open nasal approach and dissection to make a dorsal pocket for the cartilage graft. The pocket is created without entering the nasal septum. Measurements are then taken to give an approximate graft size prior to harvesting the costal cartilage. Costal cartilage is harvested from the 5th rib, in the infra-mammary crease in female patients or the pectoral crease in male patients. The anterior perichondrial edge is used; either the upper or lower half of the costal cartilage is harvested, and the remaining half is left intact to reduce post-operative pain.

The costal cartilage is carved and split into two pieces: a dorsal and a columellar strut. The perichondrial edge is removed from both lateral edges of the graft. The cartilage is pre-drilled with a green needle to allow passage of suture material. This removes the need for passage of a cutting needle through the cartilage. A 'tongue and groove' design is carved to allow both pieces of cartilage to interlock when

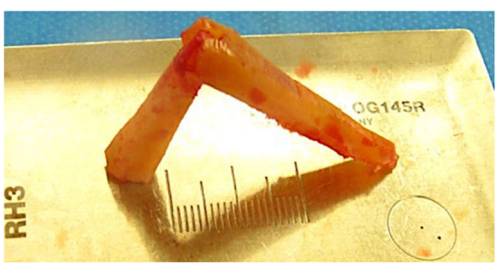

Fig. 1 Both costal cartilage struts interlocked

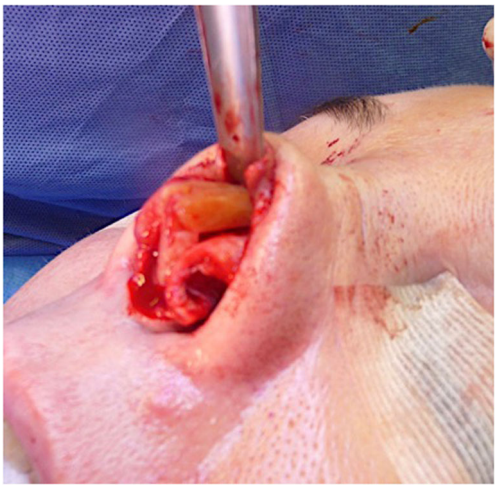

Fig. 2 Costal cartilage struts inserted to check length

placed in situ (Fig. 1). The cartilage struts are then inserted and the length is checked (Fig. 2). Any adjustment in length is performed if required at this stage. The alar cartilages are elevated over the costal cartilage, the tip cartilages are reassembled and the wound closed. Pre- and post-op images can be seen (Figs. 3, 4, 5, and 6).

This surgical technique has been used since 2013. Prior to this, the dissection and placement of the struts were the same. The only difference was the part of the costal cartilage graft inserted, which previously included costal cartilage with the perichondrium in situ. We now remove the perichondrial edge from both sides of the strut prior to insertion of the graft.

Results

Over the 11-year review period, from 2005 to 2016, 28 patients had nasal reconstruction using autogenous costal cartilage. The majority of patients, 68%, were male, with 32% female. The average patient age at time of surgery was 37 years, this ranged from 16 to 62 years.

Referral source was mainly via secondary care with 71% referred by surgical colleagues. Fifty percent of patients were referred directly to plastic surgery from an ENT surgeon. Twenty-one percent were referred by another plastic or maxillofacial surgeon. Eleven percent were self-referred. Only 7% were direct referrals from a primary care physician.

Indications for surgery

The aetiology of the nasal deformity was divided into congenital, malignant, traumatic, infective, previous surgery and other (see Table 1 below). The commonest

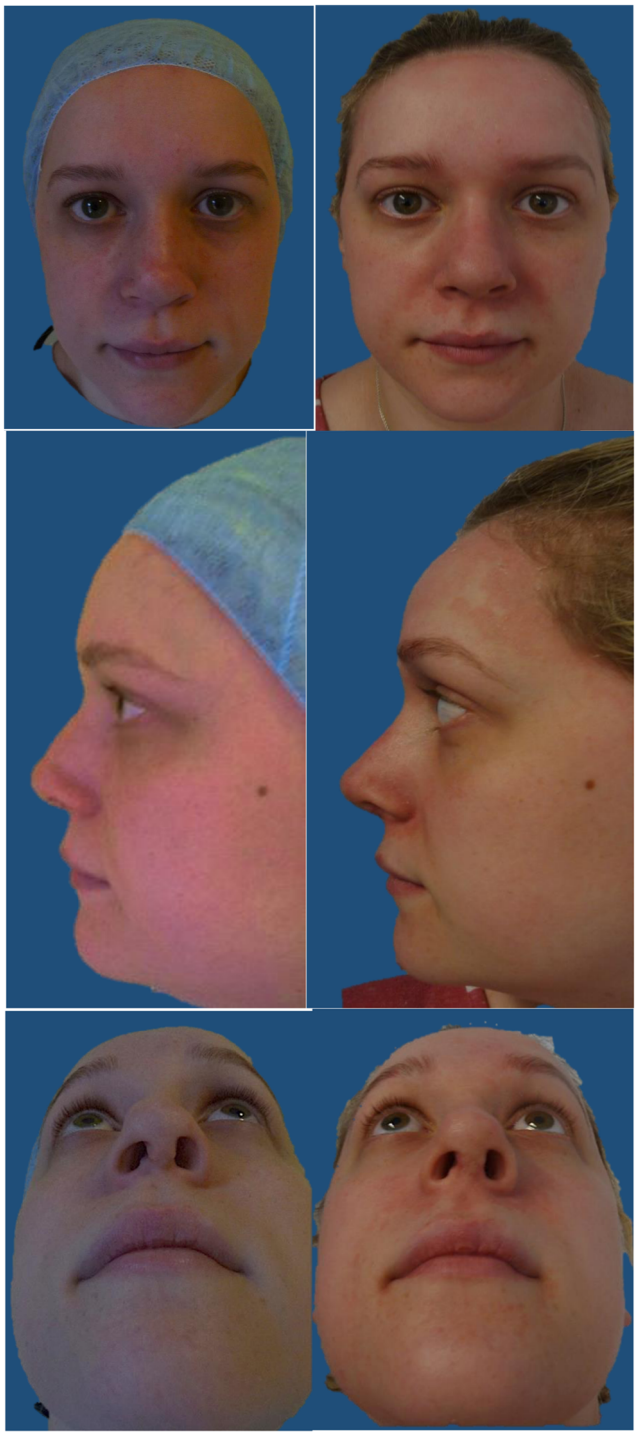

Fig. 3 Pre and post-op images patient 1

cause was trauma: 57% of patients, 21% for congenital reasons, and 11% had previous nasal surgery without any other contributing factor. Only one patient (4%) required reconstruction for infective reasons. This was following infection of a silastic implant that had been placed during surgery in Thailand. A further one patient

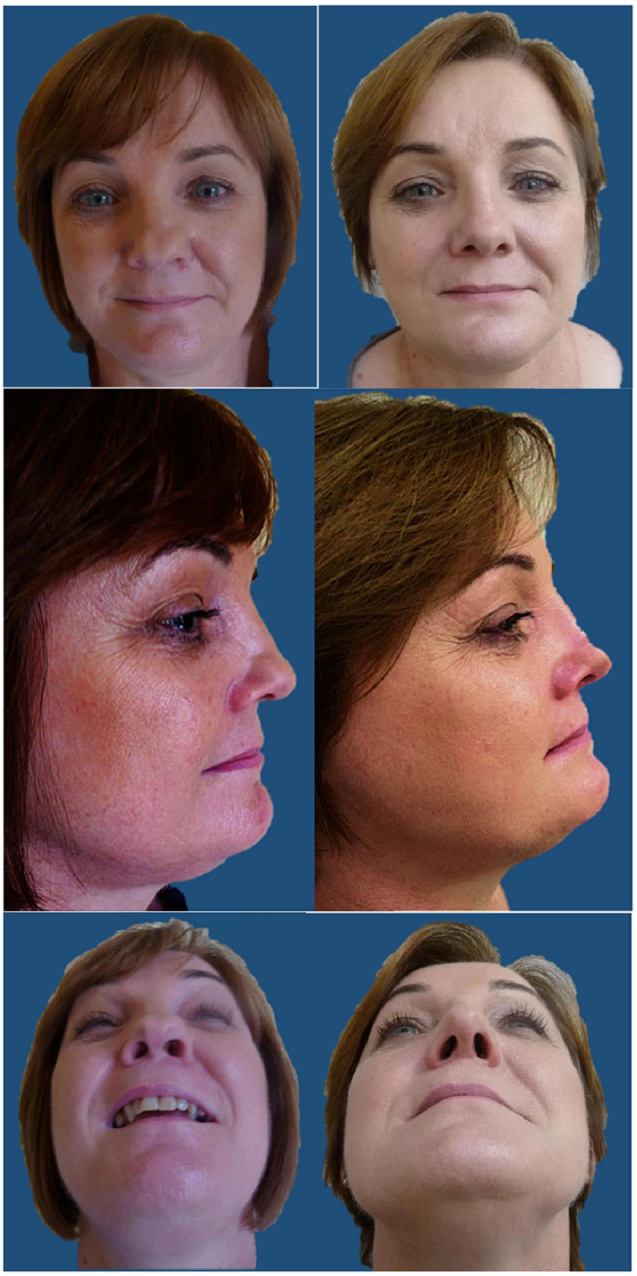

Fig. 4 Pre and post-op images patient 2

(4%) required reconstruction due to damage of the septal cartilage by the granulomatous condition sarcoidosis (Table 2). It must be noted that of the 57% of patients with trauma as the aetiology; 88% of these patients also had previous nasal surgery prior to secondary reconstruction using costal cartilage graft. None of the patients in this series used cocaine or any other nasally administered illicit drug.

Complications

We had no intra-operative complications during the study period. None of the patients in the study

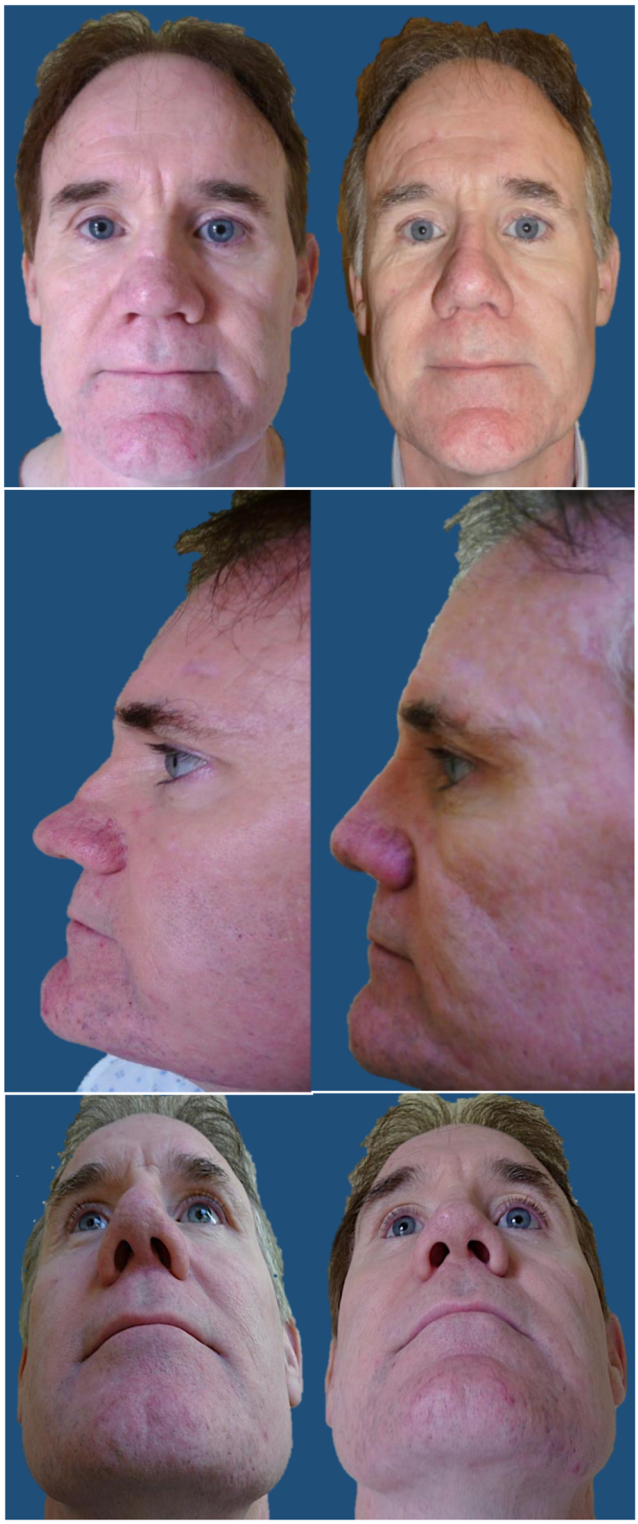

Fig. 5 Pre and post-op images patient 3

developed any donor-site complications; this included post-operative infection, pleural tear, pneumothorax or problems with hypertrophic or keloid scarring at the donor site.

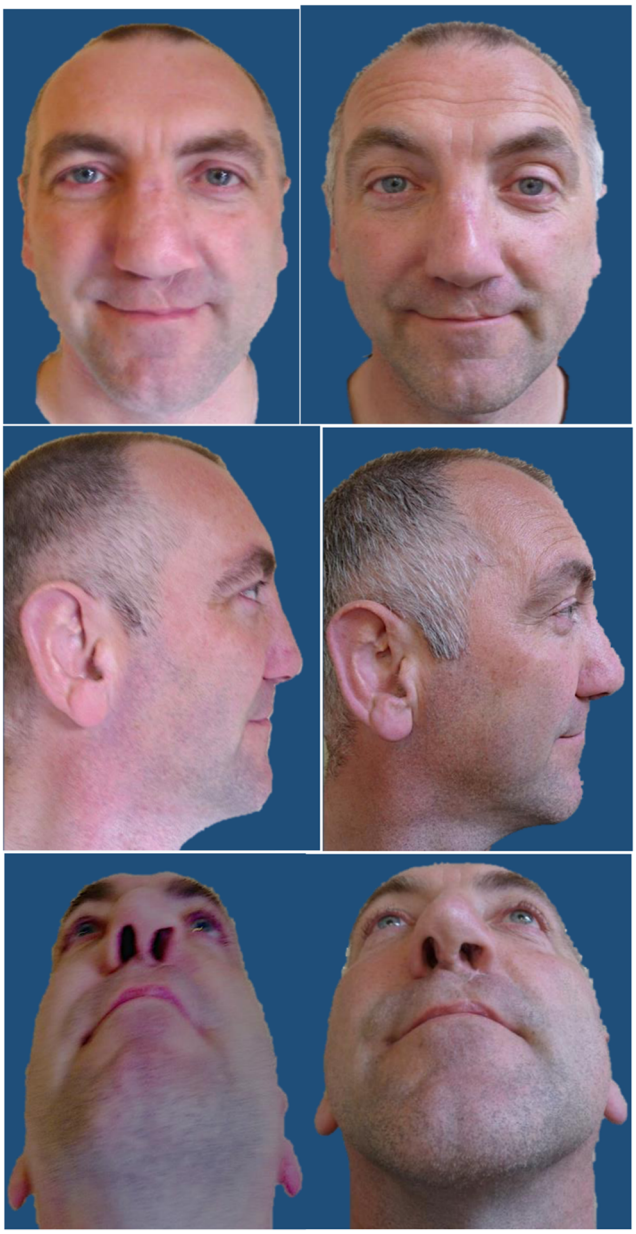

Fig. 6 Pre and post-op images patient 4

The most common post-operative complication was warping of the costal cartilage graft which occurred in five patients (18%). Following an alteration in surgical technique in 2013 which is described above, no patient has developed warping since then. The warping rate from 2013 to the present day remains at 0%. The costal cartilage graft slipped in one patient (4%). One patient developed telangiectasia over the graft which was treated successfully with laser therapy.

Overall, nine patients (32%) required further revision surgery. The indication for revision in five patients (18%) was warping of the costal cartilage graft. For the remaining four patients, revision surgery was performed due to a contour deformity of the costal cartilage graft (14%). All revision procedures required were minor. A closed technique was

Table 1. Aetiology of the nasal deformity

Aetiology	Number (%)	Previous surgery (%)
Congenital (e.g. cleft, craniofacial)	6 (21%)	4 (67%)
Malignancy	1 (4%)	1 (100%)
Trauma	16 (57%)	14 (88%)
Infective	1 (4%)	1 (100%)
Other	1 (4%)	1 (100%)
Post-surgery (no other contributing factor)	3 (11%)	3 (100%)

performed with either rasping or adjustment of the in situ costal cartilage graft.

Follow-up

Overall, the 28 patients attended a total of 47 outpatient review appointments, on average 1.6 appointments each, ranging from one review appointment to four review appointments. Follow-up appointments were included for all patients up until the time revision surgery was booked. At the time of writing this paper, six patients are still under active follow-up.

Discussion

The gold standard cartilage graft is autologous cartilage, either from the septum, the ear or costal cartilage. Harvesting cartilage from the septum or the ear is time-efficient and has a low donor-site morbidity. The limiting factor is the amount of cartilage available for use. This is particularly important in patients who have had previous nasal trauma or previous nasal surgery which will limit both the quality and quantity of septal cartilage available for use.

In complex secondary nasal reconstruction, there is unlikely to be sufficient, good quality, septal cartilage available to use, and certainly, conchal cartilage can only be harvested in small amounts. In these cases, the surgeon is faced with the option of using an alloplastic implant or harvesting autogenous cartilage from the costal cartilage of the patients' ribs with the associated donor-site morbidity and increased surgical time. Alloplastic implants are readily available worldwide, and options include the use of synthetic implants like silicone or polyethylene or the use of irradiated homologous costal cartilage [3].

Table 2. Indication for surgery

Indication	Number (%)	With perforation (%)
Cosmetic	3 (11%)	
Septal collapse ± septal perforation	11 (38%)	5/11 (45%)
Dorsal nasal collapse	5 (18%)	
Nasal valving	3 (11%)	
Septal aplasia	2 (7%)	
Other	4 (14%)	

The first use of irradiated costal cartilage (ICC) was in 1961 [3]. This gives the added benefit of availability and quantity. Without the need to harvest autogenous costal cartilage, both the operative time and donor-site morbidity will be lower. Studies have shown it to be easy to shape with low rates of both extrusion and infection. A review of 67 patients treated with ICC reported a low warping rate of 1.3% at 33 months. One of the benefits of using ICC over synthetic alloplastic implants is the low rate of infection and extrusion, which are both more common with the use of non-biologic implants [2, 3]. Despite some promising results and the low complication rates reported, the risk of transmission of prion disease or viral disease remains a concern [2].

The use of autologous costal cartilage allows for a larger graft harvest. The main disadvantages of harvesting costal cartilage are the potential for high donor-site morbidity, post-operative pain and the risk of pneumothorax. The incidence of pneumothorax reported in the literature is zero in most case series as indeed it was in our review.

In our series, costal cartilage was carved into dorsal and columellar struts. Other techniques for reconstruction of the nasal dorsum with autogenous cartilage are well known, and this includes the use of diced cartilage wrapped in deep temporalis fascia. The cartilage source used in this technique can be conchal, septal or costal cartilage. Regardless of the donor source, the cartilage should be diced into a cube shape with a size of 0.5–1 mm. The first published articles on the use of diced cartilage were in the 1940s. It was initially described for reconstruction of calvarial defects and for microtia surgery. Diced cartilage for reconstruction of the dorsum of the nose became popularised decades later [4, 5].

In the early years, Erol wrapped the diced cartilage grafts in Surgical® (oxy methylcellulose) and this was subsequently referred to as the 'Turkish delight' graft [4]. Concerns over graft resorption and the need for revision surgery were raised when Rollin Daniel used this technique in the USA. These concerns led Calvert and colleagues to perform a histological analysis on this so-called Turkish delight graft. Along with Rollin Daniel, Calvert started a new era of using deep temporalis fascia

as the 'wrap' around the diced cartilage grafts. Histological analysis comparing both of these techniques demonstrated that cartilage wrapped in fascia maintained normal histological characteristics with viable chondrocytes, in comparison to the grafts wrapped in Surgicel® which showed irregular fibrosis and loss of the normal cartilaginous architecture [6].

Diced cartilage wrapped in deep temporalis fascia is now a popular technique around the world, and it can be used in both primary and secondary rhinoplasty. This technique is suitable for reconstruction of the nasal dorsum in secondary rhinoplasty, and it can also be used to achieve and define dorsal aesthetic lines and to build up the radix height. Calvert has also shown it to be of benefit in immediate reconstruction following removal of infected implants [5].

Complications

Cartilage warping

Warping is considered one of the most common complications of using costal cartilage as a strut graft and is one of the main concerns that deter surgeons from using it. The rate of cartilage warping in our study was 18% overall; however, the rate dropped to 0% from the year 2013 onwards following a change in surgical technique (described above). The average age of patients who developed warping was 36 years compared to 33 years for those who did not develop warping. Interestingly, a study of 157 cases by Balaji showed a significant reduction in warping with increasing age [7]. They theorised this was likely due to an increase in calcium deposition with age and therefore stiffer costal cartilage which would be more resistant to warping. However, the results of our study do not follow this trend; if anything, they show the opposite, with a higher average age amongst the patients who developed warping.

Compared to our overall warping rate of 18%, several studies in the literature have reported lower warping rates. Moshaver et al. reported an 8% warping rate out of 37 patients in a similar patient number to our study [2]. Sherris and Kern reported no warping or graft resorption in 14 patients at an average follow-up of 12.5 months [8]. A systematic review published in 2015 which combined the results of 21 studies revealed an overall warping rate of 5.2%. Interestingly, the range between individual studies was from 0 to 26% [9]. A meta-analysis in 2015 showed an overall warping rate of 3%. This included 10 papers and a total of 491 patients. Interestingly, half of the papers included reported a warping rate of 0%. Of the remaining five papers, one paper reported a warping rate as high as 26% [10].

It is evident that the warping rate quoted in the literature remains extremely varied; in several studies, the reported rate is 0% whereas others studies have rates 50% higher than our overall warping rate of 18%. Given these varied results, multiple authors have reported variations on surgical technique in an attempt to conquer such high warping rates.

Multiple theories as well as alterations in the preparation of costal cartilage have been suggested to reduce warping. The use of a 3-dimensional-shaped costal cartilage graft was suggested by Billent and Kilinic [11]. A more recent study by Nuara et al. introduced the concept of multi-planar carving of the graft, and they reported no cartilage warping during their follow-up period which ranged from 3 to 36 months [12]. Another study compared perpendicular slicing of the graft to traditional carving techniques which resulted in significantly lower rates of warping [13].

In a systematic review of 21 published papers, the authors noted that studies which used the central segment of costal cartilage had significantly lower rates of warping. In all cases, the warping rate was < 10% when the central segment was used [9]. The so-called 'accordion technique' by Osturan et al. has shown very promising results [14]. The 'accordion technique' involves transecting 75% of the graft, on alternating sides at 2-mm intervals. When this was carried out on 23 cases, the rate of warping was 0% which was significant when compared to a warping rate of 39% in the comparison group of 18 patients. The authors also highlight that they have now been using this accordion technique for over 5 years, and their rate of warping remains at zero [14].

The authors of this paper have also demonstrated a significant reduction in warping rate after altering our surgical technique in 2013. The alteration in technique which we have found to reduce cartilage warping involves removing the perichondrium from both lateral sides of the graft prior to placement.

Despite the wealth of altered techniques in the literature, not all theories that have been tried and tested have resulted in lower warping rates. A study by Farkas et al. looked at warping rates depending on the level of graft harvest. They compared rates for cartilage harvested from the 6th though to the 10th rib level and concluded that harvest level makes no significant difference to warping rate [15].

All of the abovementioned methods for reducing warping involve altering the technique of cartilage shaping. In addition to a variation on technique, the combination of cartilage and rib bone together has also been shown to reduce warping rates. Hsaio et al. describe using a combination of cartilage and rib to form a single on-lay

graft for reconstruction. In their study of 31 patients which was published in PRS in 2014, there was a 0% rate of warping and only an additional 20 min of operating time required to incorporate both cartilage and bone into the on-lay graft [16].

Revision surgery

Overall in our study, nine patients (32%) required a further revision procedure. Lower rates of revision surgery have been reported in the literature which likely represents our higher rate of cartilage warping, and therefore, the rate of revision surgery has increased accordingly. A meta-analysis of seven papers revealed an overall revision rate of 14%; however, the individual rates from each study ranged from 2.4 to 30.8% which is similar to our rate [10].

Infection

We did not have any post-operative infections throughout our follow-up, neither at the donor nor recipient site. Infection rates reported throughout the literature tend to be similar to our study or only slightly higher. This is most likely attributable to the autogenous nature of the cartilage graft used. Sherris and Kern reported infection in 1 patient out of 14 (7%) [8]. A systematic review of 21 published studies also revealed low rates of infection. Overall, the donor-site infection rate was 0.6%, but their recipient site infection rate was higher at 2.5% [9]. A meta-analysis showed a range of infection rates from 0 to 6% across the 10 studies included [10]. Overall, all published results in the literature suggest that this technique of septal reconstruction using autogenous costal cartilage is associated with low and therefore acceptable rates of infection.

Pneumothorax

We had no incidence of pneumothorax in our study. This is similar to data throughout the literature which may reflect the strict and cautious dissection technique used by surgeons to avoid this potentially serious complication. A meta-analysis of eight studies revealed a 0% incidence of pneumothorax in every study [10]. A systematic review of 21 studies revealed a 0.1% rate of pneumothorax, one of which required treatment with a chest drain. They did report, however, a higher rate of pleural tear, 0.6% [9].

Conclusion

Despite the availability of alternative cartilage sources and the risk of warping, autogenous costal cartilage is still the ideal cartilage source for complex secondary nasal reconstruction, whether it is used as struts or diced cartilage. These novel techniques reported throughout the literature, including our own technique, will ensure that this versatile cartilage source continues to be utilised by surgeons in the future.

Compliance with ethical standards

Funding information No funding was received for any part of this study.

Conflict of interest Serena Martin, Michael McBride, Robbie Stewart, Greg McBride, and Chris Hill declare that they have no conflicts of interest.

Ethical approval Ethical approval was not required for this study.

Patient consent Informed consent was obtained from all individual participants included in the study. Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

References

1. Tastan E, Sozen T (2013) Oblique split technique in septal reconstruction. Facial Plast Surg 29(06):487–491
2. Moshaver A, Gantous A (2007) The use of autogenous costal cartilage graft in septorhinoplasty. Otolaryngol Head Neck Surg 137: 862–867
3. Demirkan F, Arslan E, Unal S, Aksoy A (2003) Irradiated homologous costal cartilage: versatile grafting material for rhinoplasty. Aesthet Plast Surg 27:213–220
4. Erol OO (2016) Long-term results and refinement of the Turkish delight technique for primary and secondary rhinoplasty: 25 years of experience. Plast Reconstr Surg 137(2):423–437
5. Calvert J, Kwon E (2015) Techniques for diced cartilage with deep temporalis fascia graft. Facial Plast Surg Clin North Am 23:73–80
6. Calvert JW, Brenner K, DaCosta-Iyer M, Evans GR, Daniel RK (2006) Histological analysis of human diced cartilage grafts. Plast Reconstr Surg 118(1):230–236
7. Balaji SM (2013) Costal cartilage nasal augmentation rhinoplasty: study on warping. Ann Maxillofac Surg 3(1):20–24
8. Sherris DA, Kern EB (1998) The versatile autogenous rib graft in septorhinoplasty. Am J Rhinol 12(3):221–227
9. Varadharajan K, Sethukumar P, Anwar M, Patel K (2015) Complications associated with the use of autologous costal cartilage in rhinoplasty: a systematic review. Aesthet Surg J 35(6):644–652

10. Wee JH, Park M-H, S O et al (2015) Complications associated with autologous rib cartilage use in rhinoplasty a meta-analysis. JAMA Facial Plast Surg 17(1):49–55
11. Bilen BT, Kilinç H (2007) Reconstruction of saddle nose deformity with three-dimensional costal cartilage graft. J Craniofac Surg 18(3):511–515
12. Nuara MJ, Randall B, Saxon SA (2016) Reconstructive rhinoplasty using multiplanar carved costal cartilage. JAMA Facial Plast Surg 18(3):207–211
13. Teshima TL, Cheng H, Pakdel A, Kiss A, Fialkov JA (2016) Transverse slicing of the sixth-seventh costal cartilaginous junction: a novel technique to prevent warping in nasal surgery. J Craniofac Surg 27(1):e50–e55
14. Ozturan O, Aksoy F, Veyseller B, Apuhan T, Yıldırım YS (2013) Severe saddle nose: choices for augmentation and application of accordion technique against warping. Aesthet Plast Surg 37:106–116
15. Farkas JP, Lee MR, Lakianhi C, Rohrich RJ (2013) Effects of carving plane, level of harvest, and oppositional suturing techniques on costal cartilage warping. Plast Reconstr Surg 132(2):319–325
16. Hsiao YC, Abdelrahman M, Chang CS, Chang CJ, Yang JY, Lin CH, Chang SY, Chuang SS (2014) Chimeric autologous costal cartilage graft to prevent warping. Plast Reconstr Surg 133(6):768e–775e