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Biomechanical analysis of a modified suture technique for septal extension grafts: Transloop suture

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Cartilage graft;
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Transloop suture

Summary *Background:* A successful rhinoplasty procedure requires a well-defined and properly projected nasal tip; however, surgical control of the nasal tip is difficult. The aim of this investigation was to assess the efficacy and safety of a modified suture technique, which can be used to fix the caudal septal extension graft during primary rhinoplasty of the Asian population and revision septorhinoplasties of the Caucasian population, and to compare it with those of other commonly used techniques.
Methods: After peeling of perichondrium of scapular cartilages, cartilage pieces of 3×1 cm in size and 2 mm in thickness were divided into two from the midline. These pieces were repaired end-to-end using three different repair techniques: two simple interrupted in Group A ($n = 40$), vertical figure-of-eight in Group B ($n = 40$) and modified vertical figure-of-eight (transloop) in Group C ($n = 40$). All repaired cartilage specimens were subjected to a biomechanical analysis, in which four different forces were applied: tension, lateral bending, shearing and buckling.
Results: According to the tensile test, Group C had statistically significantly higher strength than Group A at 2 mm range. The lateral bending test similarly revealed that Group C had statistically significantly higher strength at 1.5 mm and 2 mm range than Group A. However, there was no statistically significant difference between the three groups in the assessment of shearing and buckling forces.

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Conclusion: The modified transloop suture technique provides a more stable repair, and we consider that it can be used as an alternative suture repair method.

Introduction

In aesthetic rhinoplasty procedure, nasal tip plays a key role in aesthetic balance of the face; thus, controlling and remodelling of this particular area are very important.[1,2] A well-defined and properly projected nasal tip is required for a successful rhinoplasty procedure, but because of the difficulty of controlling, many secondary rhinoplasty techniques have been defined for the correction of the nasal tip and nostril.[3,4] In the Asian population, nasal tip defects can be seen as congenital and are characterised by a low nasal dorsum, short nose and under-projected nasal tip owing to underdeveloped alar cartilages, whereas in the Caucasian race, they occur due to trauma or iatrogenic causes.[5] During primary rhinoplasty, over-resection of the nasal dorsum, caudal septum or lateral crus of lower lateral cartilages may result in short nose deformity in this patient group.[6]

Correction of short nose deformity and lengthening of the nose is difficult, and therefore, a number of surgical techniques have been described.[7] Caudal septal extension grafts (CSEGs), which are rectangular cartilage grafts extending from the caudal septum and sutured between the caudal septum and medial crura, are the most commonly used grafts among the Asian patient population and are effectively applied in short nose correction, increasing and adjusting the tip position, nasal tip projection and setting the position.[5,8] To maintain maximum stability of these cartilage grafts and prevent possible asymmetries, CSEGs should be secured to the existing caudal septum using bilateral spreader grafts.[5] In most Asian and secondary rhinoplasty patients, septal cartilages are weak and/or inadequate and insufficient for an effective CSEG application.[8] Furthermore, cartilage grafts of the desired size cannot always be attained for these patient groups, and therefore, an additional donor site morbidity is created to meet the need for cartilage graft required for CSEG insertion into the septal cartilage. In cases where it is better to avoid this additional procedure, the existing CSEG should be placed in and secured to the septal cartilage in an end-to-end position (direct type).[9]

When modified direct-type CSEGs are used, cartilage grafts come into contact with the entire caudal septal cartilage and can effectively correct the nasal tip and columellar deformities.[10] In these cases, there is no overlap between the graft and the septum; thus, the amount of graft used for septal extension is minimised, eliminating the need to use other cartilage reserves such as conchal and costal cartilages, and if necessary, the remaining cartilage graft is used as a shield or cap graft.[10]

In the presence of a limited cartilage graft and during end-to-end CSEG applications, the suture technique is important to improve the stability and repair strength. The type of suture technique used and the resulting structure are the most important factors determining the stability and strength of the graft repair line. Numerous studies have been conducted on fixation methods, with the most common techniques being direct simple repair or horizontal figure-of-eight suture. Among these methods, securing CSEGs with horizontal figure-of-eight locking sutures is known to increase tensile strength and provide endurance against shear and buckling forces.[9]

The aim of this investigation was to assess the efficacy and safety of a modified suture technique, which can be used to fix the CSEG during primary rhinoplasty in the Asian population and revision septorhinoplasties in the Caucasian population, and to compare it with those of other commonly adopted techniques.

Material and method

This study was approved by the local ethics committee of the institution, where the study was undertaken (protocol number: 0082-809). Scapular cartilages of ram lamb weighing approximately 60 kg were used for the study. After the scapular cartilages were removed, the perichondrium was stripped and long cartilage strips were prepared. The thickness of the point where the cross-section was 2 mm was marked with a Castroviejo caliper, and using this point as the midpoint, cartilage grafts of 1 cm width and 2 cm length were prepared. These grafts were divided into two from the marked point (exact centre) for use in repairs.

Three different end-to-end cartilage repair suture techniques were used for the assessment. The repair was performed using two simple interrupted sutures in Group A ($n = 40$), one vertical figure-of-eight suture as described by Han et al. in Group B ($n = 40$) and one modified vertical figure-of-eight suture (transloop suture) in Group C ($n = 40$). All sutures were placed at a distance of 2 mm from the free edge of the cartilage and spaced 5 mm apart, with the centre at the midpoint on the same side. 5/0 polypropylene sutures with round ends (Dogsan, Turkey) were used for repairs (Video) (Figures 1 and 2).

Cartilage grafts were prepared, applied and tested within two hours after repairs. During this time, the cartilage pieces were kept between layers of gauze soaked in saline in a cold environment to prevent drying and deformation.

The repaired cartilage strips were subjected to biomechanical analysis. For this purpose, the following four types of force were applied to the cartilages using the Lloyd Instruments LRX 5 K (Lloyd Instruments Limited, UK) materials testing machine, and the results were recorded in Newton (N) unit (Figures 3 and 4):

(A) Tensile force: each cartilage specimen was placed within two clamps of instrument at a gage length of 1 cm, and tensile force was applied by pulling apart the specimen at a rate of 2 mm/min. The tensile strength at

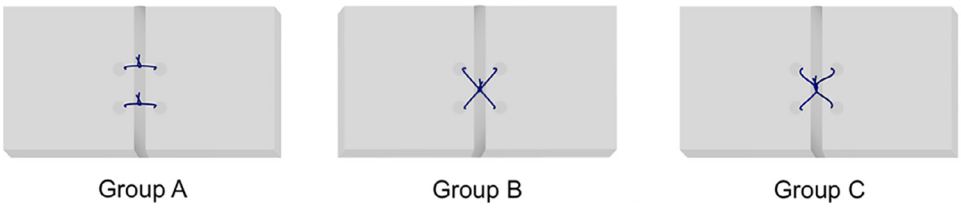

Figure 1 Schematic view of the groups tested in the study: (A) two simple interrupted sutures, (B) vertical figure-of-eight suture and (C) transloop suture.

Figure 2 Septal extension graft fixed using the modified vertical figure-of-eight suture technique.

0.5 mm, 1 mm, 1.5 mm and 2 mm deformation was measured.

(B) Shearing force: each cartilage specimen was placed within clamps of distance 1 cm apart in a horizontal position, and shearing force of 2 mm/min was applied to one end of the specimen in the vertical direction. The tensile strength at 0.5 mm, 1 mm, 1.5 mm and 2 mm deformation was measured.

(C) Bending force: one end of the cartilage specimen was secured in the clamp, and bending force was applied to the middle of the free end at a rate of 2 mm/min with the help of a bended 1.5 mm Kirschner wire grasped and pulled by the free grip. The tensile strength at 0.5 mm, 1 mm, 1.5 mm and 2 mm deformation was measured.

(D) Buckling force: both ends of the cartilage specimen were secured within clamps at a gage length of 1 cm in the vertical direction. Buckling force of 2 mm/min was applied by moving the upper clamp towards the lower fixed clamp. The maximum strength of the grafts before overlapping of the repair lines was measured.

Statistical analysis

Statistical analyses were conducted using SPSS version 20 (SPSS, Inc., IBM Company, Armonk, NY, USA). The variables were compared using the one-way analysis of variance (ANOVA) test and post-hoc Bonferroni test. A p value of < 0.05 was accepted as statistically significant.

Results

The statistical analysis results of the three repair techniques were as follows:

The tensile test revealed no statistically significant difference between the three groups in terms of the strength values obtained at 0.5 mm, 1 mm and 1.5 mm gap distances. However, at 2 mm gap distance, Group C had a statistically significantly higher tensile strength than Group A, but no significant difference was observed between Groups A and B and between Groups B and C.

The lateral bending force test showed no statistically significant difference between the three groups for the strength values obtained at 0.5 mm and 1 mm gap distances. At 1.5 mm and 2 mm gap distances, Group C had a statistically significantly higher strength value than Group A, but no statistically significant difference was detected between Groups B and C in any of the four gap distance values.

Shearing and buckling force assessments did not reveal any statistically significant difference between the three groups (Figure 5 and Table 1).

Discussion

Short nose deformity can be congenital, developmental, traumatic or acquired due to surgical interventions. Our main goals in correcting this deformity were to augment inadequate tissues, ensure face harmony and protect the nasal function.[11,12] Short nose correction is a very difficult procedure, and the nasal tip plays a key role in achieving the desired outcome. In these patients, tip projection should be increased, the nose should be extended and the dorsum should be augmented to obtain the ideal nasal tip shape.[5,13] Corrective operations for lengthening the nose, often involving the use of cartilage graft techniques and augmentation of nasal tip projection and definition, are one of the most complicated and challenging issues in the field of rhinoplasty.

The tripod theory of nasal tip described in 1966 by Anderson paved the way for the identification of various important techniques, including suture methods and columellar strut and septal extension grafts.[13] The latter two methods determine the position of the nasal tip and the relationship between the tip cartilage and the septum, thus providing tip projection and rotation.[14] Septal extension grafts were first described by Byrd et al. in 1997 to replace columellar strut grafts for the control of nasal length, tip projection, rotation, and shape. Septal extension grafts have now become

Figure 3 Cartilage grafts analysed for tension strength.

the most commonly used method for the correction of short noses.[15] In a study comparing collateral strut and septal extension grafts in the rhinoplasty operations, the latter provided better results and a more stable and permanent nasal position.[14] Septal extension grafts have also been shown to be more reliable in controlling tip projection than columellar strut grafts and are reported to have benefits for both primary and secondary rhinoplasty cases, especially in high-risk patients, such as those with an inverted V deformity, alar retraction or polly beak deformity.[14,16]

There are three main types of septal extension grafts: spreader, batten and direct caudal.[1] The amount of cartilage grafts obtained from the septum is often small and insufficient, and therefore, they should be placed end-to-end in the correction of short noses.[9] In these grafts, stabilisation is important in achieving better long-term results, and if they are not firmly secured, they can easily deviate from the midline, leading to dropping of the tip or deformation of the graft.[15] Furthermore, application of these grafts is more challenging in patients of Far Eastern origin than the European patient group owing to their thicker nasal skin and smaller and weaker septal cartilage.[9,17]

Autologous cartilage grafts should be used in the most effective manner to correct a short nose. For this reason,

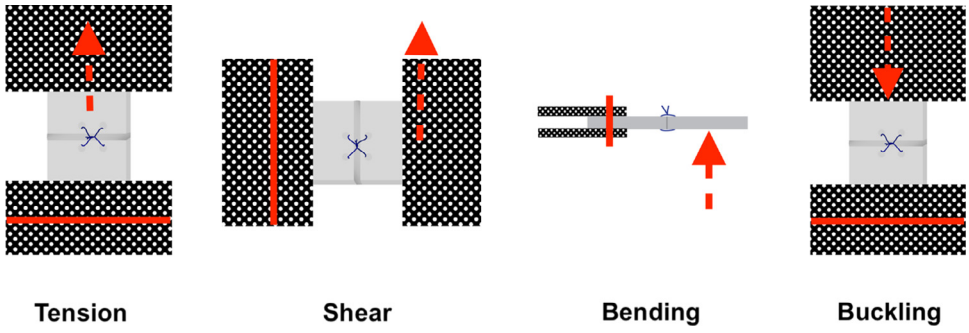

Figure 4 Type of forces applied to the sutured cartilage grafts. ▩ indicates the grids of the machine, red bar indicates the fixed grid, and red arrow indicates the direction of the force applied.

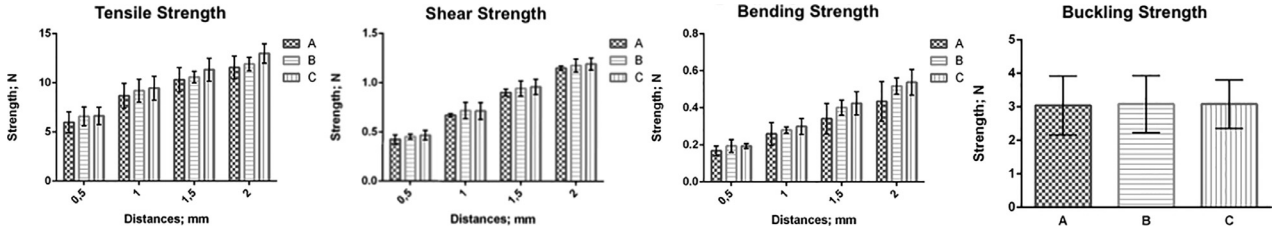

Figure 5 Strength of different suture repair techniques against tensile, shearing, bending and buckling forces: (A) two simple interrupted sutures, (B) vertical figure-of-eight suture and (C) transloop suture.

Table 1 The results of strength analysis of different suture techniques against tensile, shear, bending and buckling forces.

					Bonferroni post-hoc test p^* value		
	A (Simple interrupted)	B (Vertical figure-of-eight)	C (Transloop)	ANOVA p value	A vs. B	A vs. C	B vs. C
Shear strength (N)							
0.5 mm	0.42±0.05	0.45±0.02	0.47±0.05	0.070	0.368	0.073	>0.999
1 mm	0.67±0.01	0.72±0.08	0.71±0.09	0.255	0.407	0.531	>0.999
1.5 mm	0.9±0.03	0.94±0.08	0.96±0.08	0.149	0.499	0.183	>0.999
2 mm	1.15±0.02	1.17±0.07	1.19±0.06	0.201	0.785	0.236	>0.999
Tensile strength (N)							
0.5 mm	5.97±1.06	6.58±0.95	6.62±0.89	0.259	0.512	0.430	>0.999
1 mm	8.68±1.25	9.20±1.16	9.45±1.20	0.356	>0.999	0.487	>0.999
1.5 mm	10.31±1.23	10.59±0.59	11.33±1.15	0.094	>0.999	0.111	0.361
2 mm	11.55±1.15	11.90±0.69	12.98±0.99	0.007	>0.999	0.008	0.056
Bending strength (N)							
0.5 mm	0.17±0.03	0.19±0.03	0.19±0.01	0.051	0.100	0.105	1.000
1 mm	0.26±0.06	0.28±0.02	0.30±0.04	0.146	0.912	0.156	>0.999
1.5 mm	0.34±0.08	0.40±0.04	0.42±0.06	0.020	0.129	0.021	>0.999
2 mm	0.44±0.11	0.52±0.04	0.54±0.07	0.015	0.075	0.019	0.075
Buckling strength (N)							
	3.04±0.88	3.08±0.85	3.08±0.73	0.990	>0.999	>0.999	>0.999

* p value of < 0.05 was accepted as statistically significant.

the suture technique used to attach septal extension grafts to the septum should be reliable, durable and stable. The suture technique is also important considering the improvements that occur in the suture material with time. These techniques are mostly selected based on the surgeon's experience, ease of use and, more importantly, their long-term results. In this study, we aimed to conduct a biomechanical analysis of a suture technique we previously modified and routinely use to fix septal extension grafts in our clinic and compare it with other existing suture techniques. As a result, we showed that the modified suture technique was at least equally, if not more, usable than the other suture techniques.

Different suture techniques are used in end-to-end apposition of cartilage grafts, for example, simple interrupted suturing, horizontal figure-of-eight described by

Byrd et al.[16] and vertical figure-of-eight locking suture described by Han et al.[18] In the vertical figure-of-eight locking suture technique, the suture does not pass between the cartilage graft and caudal septum and thus has a tighter grip, resulting in a single-unit structure of the cartilage graft and septum, called septal integration graft.[9] For the end-to-end apposition of cartilage grafts, the vertical figure-of-eight suture technique described by Han et al. was shown to better withstand shearing and buckling forces than the horizontal figure-of-eight method described by Byrd et al., with no significant difference for the shearing force. However, there was no statistical evidence that the vertical figure-of-eight suture technique offered better strength against tension, shearing and buckling forces than the use of two simple interrupted sutures.[18] In the current study, when the repair lines of transloop suture and vertical figure-of-eight suture techniques were compared, the former resulted in higher strength values against each of the three forces, but this was not statistically significant. However, in contrast to Han et al., who reported no significant difference between the original vertical figure-of-eight and simple interrupted repair techniques, we obtained superior results from the modified technique in tensile and lateral bending tests. We consider that in the modified suture technique, since the cross-suture structures on one side of the mid-line of the cartilage repair line are linked to each other, the force applied to one arm affects both suture arms and in part leads to a more stable repair line.

Another reason for end-to-end application of CSEGs is to provide maximum airway patency.[19] Bilateral supportive grafts are often needed to tightly secure CSEGs to the caudal septum. The materials used as strut should have sufficient rigidity to support the new CSEG, which leads to additional obstructions to the airway. The other available technique that involves overlapping the CSEG with the septal cartilage may also cause partial blocking of the nasal airway. Various sutures and fixation techniques have been described to secure the septal extension graft in the presence of adequate cartilage, for example, the multi-lock system, the tongue-and-groove technique described by Guyuron and fixation methods using absorbable foreign material such as polydioxanone.[7,19-21]

The long-term outcomes of repairs using the vertical figure-of-eight technique did not reveal buckling or displacement. These results indicate that direct extension grafts remain stable for a long time and can resist stress.[10] With the suture technique used in the current study, we obtained similar results as those of the original vertical figure-of-eight method, and we believe that stable results can be similarly acquired in the long term.

In CSEG applications, to reduce the risk of nostril asymmetry and increase the strength of the graft, the ideal way is to apply the graft to both sides of the caudal septal cartilage. However, in reality, it is difficult to obtain the amount of cartilage graft required to apply the graft to both sides; thus, it is only applied to one side. In unilateral septal extension grafts, the graft is placed on one side of the L-shaped septal cartilage. In cases with thick and strong septal cartilage, as the graft is not placed at the anterior and midline, this procedure tends to result in the nasal tip deviating towards the side of graft application.[1] In contrast, in some patients with very thin and weak cartilage, septal extension graft and existing septal cartilage can be tilted in the opposite direction of the graft. Therefore, the nasal tip is deviated in cases where unilateral septal cartilage graft is used, and if implant augmentation is performed in these patients, this technique can also lead to the deviation of the implant. Although bilateral spreader grafts are a more stable option, because of their requirement of a greater amount of cartilage, they can only be used in patients with large septal cartilage.[1] In such cases, end-to-end septal extension graft is more practical and tight fixation of the grafts is important.

As mentioned previously, use of direct extension grafts is limited owing to the lack of a reliable fixation. The most commonly used fixation method is overlapping. For a stable and firm fixation of CSEGs, there should be an overlap of at least 3-4 mm between the caudal septum and the graft, and nylon or PDS 5-0 suture is usually employed to establish the fixation between the graft and the L-strut.[22] We consider that the transloop suture technique can also be integrated into these overlapping methods, and in clinical practice, we safely perform this technique in cases of requiring overlapping cartilage graft repair procedures, such as microtia.

Correction of a septal deformity in cleft lip nose deformities ranges from simple repositioning to extracorporal reconstruction of the septum. In these patients, septal extension grafts are frequently employed in shaping the nasal tip. CSEG application is also a frequent procedure performed for various reasons in non-cleft rhinoplasty.[4] In this patient group, which requires a higher amount for cartilage grafts, the existing suture technique can be easily undertaken.

In their analysis, Han et al.[18] used pig cartilage grafts with a thickness of 1 mm and 2 mm. In the current study, we only used 2 mm cartilage grafts considering that previous research reported cartilage grafts with mean thickness of 1.95 mm taken from the middle or basal portion of the nasal septum.[23] With the increase in thickness of cartilage grafts, the repair lines become more stable. To the best of our knowledge, our study was the first to use ram scapular cartilage in this type of tension analysis. In other studies, pig scapular cartilages were utilised. We think that ram scapular cartilage can easily be used for similar studies in geographical areas where pig cartilage is difficult to access.

One of the limitations of the study was that we performed an in vitro analysis on the strength of a different suture technique in the cartilage tissue. It should be remembered that cartilage grafts are living tissues, also supported by the surrounding soft tissue. Therefore, there is a need for further research to investigate the results of this technique under in vivo conditions and in the long term.

Conclusion

When cartilage grafts are limited in amount, direct septal extension grafts are frequently used through an end-to-end application with no overlap of the graft and the caudal septum in any area. This is an effective method for the correction of the nasal tip and columella in Asian noses that require autogenous cartilage, as well as correction of short noses. However, fixation of these grafts is difficult and requires special attention and effort. The modified transloop suture technique provides a more stable repair line than the

other currently available suture techniques, and we believe that it presents as an effective alternative suture repair technique.

Conflict of interest statement

The authors declare there are no conflicts of interest—financial or otherwise—related to the products and devices mentioned in this manuscript. In addition, this study did not receive any form of funding.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2019.05.046.

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