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Cartilage exposure following autologous microtia reconstruction: An algorithmic treatment approach☆

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Summary *Background:* Successful reconstruction of microtia involves fabrication of a cartilaginous framework and provision of thin, durable, soft tissue cover. Vascular compromise of this skin envelope can lead to exposure of the underlying cartilage, resulting in cartilage resorption and distortion of the final form of the ear construct. We describe our algorithm for management of this complication.
Methods: All patients who underwent autologous ear reconstruction by a single surgeon (NWB) from April 2006 to September 2012 were retrospectively reviewed to identify any that developed exposure of the underlying cartilage framework. Details related to timing, location, size and management of the cartilage exposure were collected.
Results: From a total of 230 autologous auricular reconstructions (median age at first stage, 11.4 years), 15 exposures of the cartilage framework were identified. All exposures occurred following the first stage of reconstruction (mean of post-operative day 29, range, 7–86 days). Large areas of exposure (>10 mm2) required surgical management, with debridement and coverage with either a cutaneous or fascial flap, depending on the location. Areas <10 mm2 were managed conservatively. All exposures were successfully treated with no adverse effects on the final aesthetic outcome.

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Conclusion: Cartilage exposure following autologous microtia reconstruction can be a devastating complication if not addressed in a prompt and effective manner. The management strategy we propose provides a concise algorithm to guide the treatment of cartilage exposure.
Level of evidence: Therapeutic, grade III.

Introduction

When preparing the mastoid skin to cover the cartilage framework, Nagata emphasized the importance of preserving a subcutaneous pedicle in the posterior mastoid skin flap to improve distal vascularity of this flap, which is used to cover the concha and posterior surface of the tragus.[1] Ishikura[2] noted the presence of small vessels in this subcutaneous pedicle and postulated that the posterior lobular flap and mastoid skin flap were perforator flaps, underlining the importance of preserving this subcutaneous pedicle as a means of augmenting the vascularity of the two skin flaps. However, Firmin[3] has questioned the contribution of this pedicle to the viability of the posterior (mastoid) skin flap, and noted instances of partial necrosis of the posterior flap when the Nagata technique was implemented. Instead, Firmin stresses the importance of soft tissue management[4] and her skin approach has evolved accordingly. With her approach, cases that are amenable to a lobule transposition with Z-plasty (Firmin type I skin approach; traditional Nagata skin approach) are now managed with a low transfixion incision (Firmin type II skin approach), thereby converting the tip of the flap from a 60- to 90-degree angle and increasing the vascularity of the skin covering the framework (Firmin, personal communication). Based on the one-stage technique for auricular reconstruction first described by Song and Song,[5] Park[6] introduced a single-stage, two-flap method for auricular reconstruction, where a superficial skin flap and deep fascial flap are used to cover the cartilage framework. The superficial skin flap is supplied by subcutaneous arterial perforators of the posterior auricular artery in the future conchal area and by the dermal plexus of the skin bridge at the flap's upper portion.

The firm apposition of the delicate skin envelope against the abrupt confluence of convexities and concavities of the rigid cartilaginous construct raises the potential for vascular compromise of the overlying skin. When this occurs, it can lead to exposure of the underlying cartilage, with resultant cartilage resorption and distortion of the final form of the reconstructed ear. This potentially devastating complication must be recognized early and managed appropriately. The incidence of cartilage exposure in autologous ear reconstruction is poorly reported and no detailed treatment strategies have been described.

We describe an algorithm for managing this complication based on our experience in a consecutive series of patients undergoing autologous ear reconstruction.

Methods

We reviewed the case notes of all patients who underwent autologous ear reconstruction by a single surgeon (NWB) from April 2006 to September 2012 at Great Ormond Street Hospital for Children NHS Trust (London, United Kingdom). Patients underwent auricular reconstruction with a two-stage procedure, as described by Nagata,[1,7-10] later modified by Firmin[2,3,11,12] and the senior author.[13]

Patients that suffered exposure of the underlying cartilage framework following either the first or second stage of reconstruction were identified. Notes were reviewed to ascertain the timing of exposure relative to the stages of reconstruction, as well as the sequence of events (e.g., skin necrosis, wire exposure and/or infection) and clinical observations that preceded exposure. The location and size of the exposed areas were noted. Details related to the management of the cartilage exposure were collected, and used to create a structured treatment algorithm.

Results

From April 2006 to September 2012, a total of 206 patients underwent autologous ear reconstruction (median age and age range at the first stage, 11.4 and 10–18 years, respectively). Twenty-four patients had bilateral auricular reconstruction and 182 reconstructions were performed for unilateral auricular deformity, for a total of 230 ear reconstructions. Among these patients, we identified 15 instances where the cartilage framework became exposed. All the patients had a lobular type microtia, with the exception of 1 conchal type microtia where the cartilaginous framework was placed into the existing skin envelope. All exposures occurred following the first stage of auricular reconstruction (mean of post-operative day 29, range, 7–86 days), and the majority (14 cases) arose in an area of localized vascular compromise. Concurrent infection of the area was noted in 1 case. In the remaining patient, infection of the reconstructed ear required washout of the area, followed by formation of a chronically discharging wound. This was eventually addressed with debridement of the wound and closure with a local cutaneous transposition flap. The size of the area of exposed cartilage ranged from 5–200 mm2, with 10 exposures greater than 10 mm2. The majority were located on the antihelix ($n=5$), followed by the tragus ($n=3$), helical rim ($n=3$), concha ($n=2$), and anti-tragus ($n=2$). One of these patients subsequently also developed a second area of exposed cartilage over the anti-helix-conchal junction secondary to wire extrusion and infection 3.5 months following the second stage of reconstruction.

Review of our data suggested that three principal factors dictated management. The presence of infection, location of exposure (area of convexity or concavity), and size of exposed surface. The latter was further sub-divided into areas $<$ and $>$10 mm2. Irrespective of location or surface area, infection prompted conservative debridement of the affected

Figure 1 An 8-year-old patient presented with bilateral microtia as a component of craniofacial microsomia. For reconstruction of the left ear, the cartilage framework was placed within the skin envelope of the microtic ear, using a Firmin type 3a skin approach.

cartilage and washout in theatre, followed by hospital admission for a course of intravenous antibiotics. Once the infection was controlled, subsequent management was as per non-infected exposures, with coverage of cartilage exposure within 48 h. Areas of exposure < 10 mm2 were managed conservatively in all cases. Conservative management consisted of application of antibiotic impregnated ointment and regular clinic visits for wound review. All exposed areas healed within 10–14 weeks.

Larger areas of exposure (> 10 mm2) required surgical management with debridement and cutaneous or fascial flap coverage, depending on *location* relative to the contours of auricle and adjacent tissue mobility. For cartilaginous exposures over convex surfaces with no adjacent skin mobility (helix and anti-helix), a *fascial turnover flap* and skin graft was used for coverage (Firmin, personal communication) (Figures 1–3). For harvest of a random fascial flap, a T incision is made adjacent to the defect, with the short limb of the incision placed along the periphery of the construct. The two resulting scalp flaps are elevated superficial to the superficial mastoid fascia. The dimensions of the fascial flap required for cover are outlined, the fascia incised, and the flap elevated superficial to the deep mastoid

Figure 2 Necrosis of the skin envelope overlying the superior helix was noted on post-operative day 37, with consequent exposure of the underlying cartilage.

Figure 3 (a) Post-operative result 9 days after salvage of the cartilage framework. Debridement of non-viable tissue was followed by cartilage coverage using a turnover, random galeal (mastoid) fascial flap and scalp split thickness skin graft. The flap and skin graft healed satisfactorily.

fascia. An anteriorly based fascial flap is 'turned-over' and inset over the denuded cartilage. The fascia is then covered with a split thickness skin graft harvested from an adjacent area of scalp. Convex surfaces with surrounding skin laxity or areas with the potential recruitment of soft tissue (anti-tragus, tragus) were addressed by either direct closure or local (cutaneous) rotation-advancement flaps.

For large concave surfaces, primarily the concha, if sufficient viable surrounding skin is present, direct closure may be achieved by reliance on the *drawbridge effect*, which occurs when tissue lining a concave surface is mobilized anteriorly. Alternatively, a *tunneled* fascial turnover flap and skin graft may be used (Figures 4–6). In this case, following elevation of the cutaneous scalp flaps overlying the fascial flap, a tunnel is created beneath the cartilaginous framework from the periphery of the construct to the recipient site. The harvested fascial flap is then delivered into the wound and inset in place.

Our algorithm for treatment is outlined in Figure 7. All patients were successfully managed with no adverse sequelae to the final aesthetic outcome (Figures 8 and 9). The areas resurfaced with a fascial flap and skin graft maintained their shape, without evidence of increased thickness of the area. The resulting scar over areas left to heal

Figure 4 A 7-year-old patient with hemi-facial microsomia, presenting with right unilateral lobular microtia.

Figure 5 Twenty-nine days after the first stage, she presented with total necrosis of skin overlying the concha, with cartilage exposure of approximately 2 cm2.

spontaneously remained stable and did not cause any distortion to the shape of the reconstructed ear or other long-term problems. Moreover, cartilaginous exposure and management did not delay timing of the second stage, in any patient.

Discussion

Cartilage exposure following localized skin necrosis is one of the most frequent complications of autologous ear reconstruction,[4] though few authors have specified the precise incidence of cartilage exposure in their patient series. Brent[14] reported 10 cases in his experience with 1200 reconstructions over a 25-year period and described the use of small rotational scalp or fascial flaps for coverage of the cartilage exposure.[14-16] In our series, the incidence of cartilage exposure was approximately 7%. With one exception, all exposures were the result of vascular compromise of the overlying skin envelope, which (in the majority of cases) was noted in the early post-operative period. Appropriate planning of the skin cover for the cartilage framework requires careful appraisal of the microtia remnant. The importance of pre-operative planning is illustrated in Figure 1. For reconstruction of the left ear, a Firmin type 3a skin approach was erroneously utilized. The superior portion of the existing auricle was visibly deficient and the skin envelope of the upper pole was not large enough to accommodate the cartilaginous construct. As a result, skin necrosis and cartilage exposure ensued, necessitating fascial flap coverage. On reflection, a Firmin type 2 transfixion skin approach should have been selected in this case.

A common criticism of the second stage of autologous reconstruction is a loss of definition of the construct. This has led many authors to increase projection of the ear at the first stage of reconstruction by augmenting the posterior wall of the concha with an additional segment of cartilage positioned on the posterior surface of the anti-helix similar to placement of the cartilage block at the second stage of reconstruction.[4,12,17,18] The latter modification potentially obviates the need to further enhance projection with a second stage.[17] However, the inclusion of this cartilage segment depends on a well-vascularized skin envelope with sufficient laxity in the middle third of the ear, as the increased height of the framework can cause increased tension on the

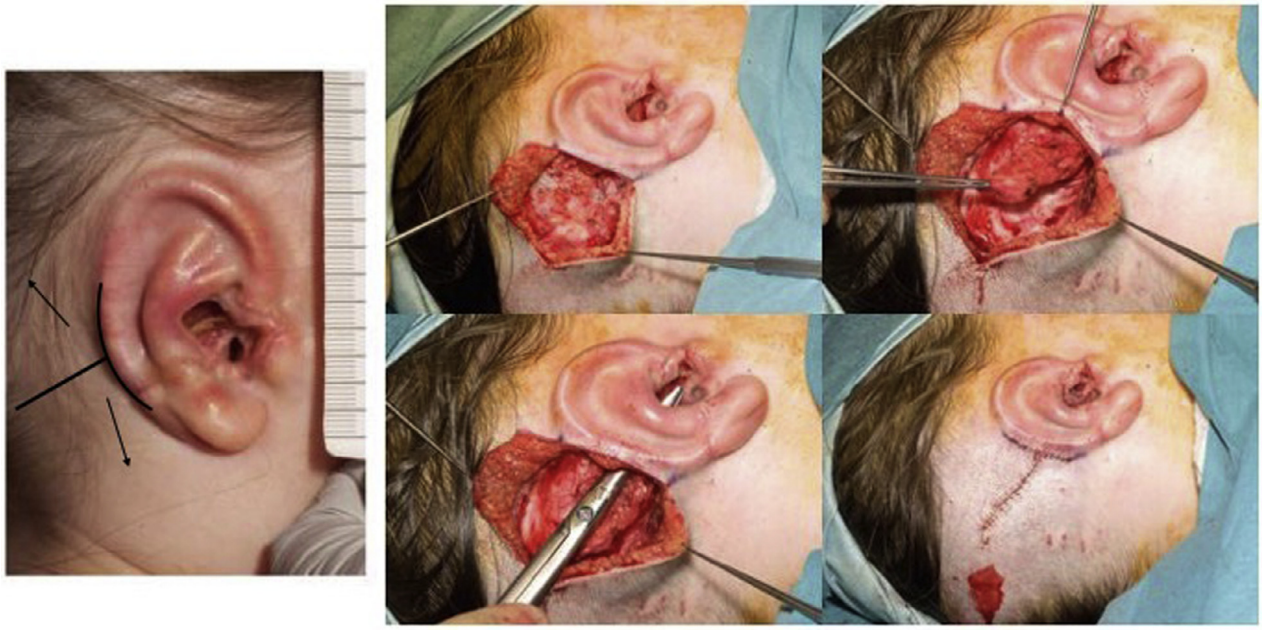

Figure 6 (a) Coverage of exposed cartilage using a random pattern superficial mastoid fascial flap, which was tunneled beneath the cartilaginous ear construct to reach the distal extent of the defect. The fascial flap was then grafted with a split thickness skin graft harvested from the scalp (skin graft donor site shown).

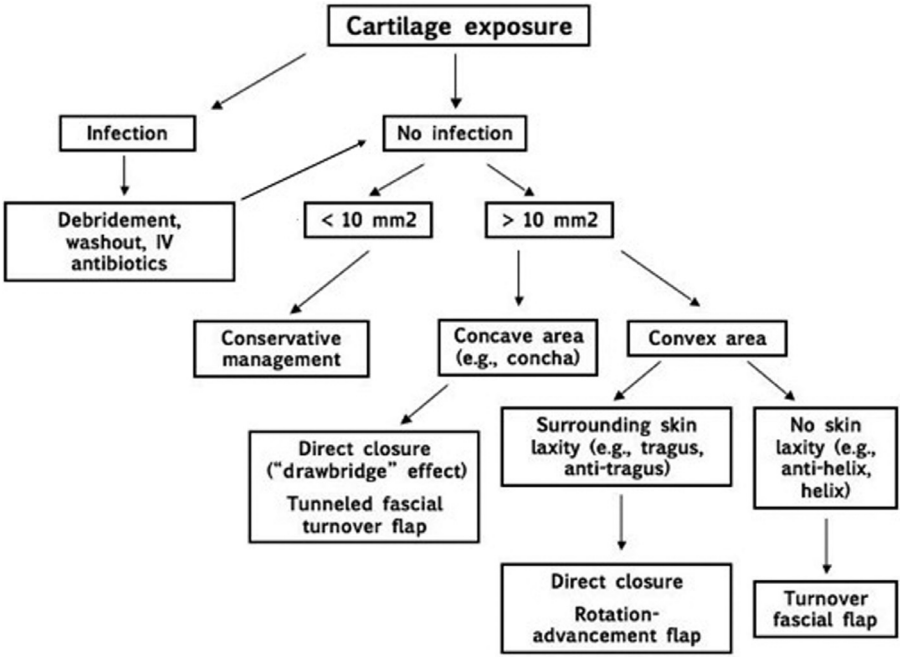

Figure 7 Algorithm for treatment of cartilage exposure.

Figure 8 Long term results following conservative management of small (< 10 mm2) areas of cartilage exposure. Three representative cases are shown with exposure at (a) the conchal bowl, (b) helix, and (c) anti-tragus.

cutaneous cover. This may have been the cause for cartilage exposure in the reconstruction shown in Figure 4 in a patient with hemi-facial microsomia. We believe that the appropriate skin approach was selected (Firmin type 2 skin incision). In this case, additional projection pieces were affixed to the framework in an effort to compensate for the mastoid hypoplasia to increase projection of the construct. However, because of the hypoplastic skin cover in the auricular region, necrosis of the skin in the conchal bowl developed.

Eleven exposures occurred in reconstructions initiated before February 2010. At that point in the senior author's practice, a dressing was applied over the construct at the first stage of reconstruction. This was left in place for 5 days. We hypothesize that the dressing resulted in further vascular compromise of areas of skin with an already tenuous blood supply. As a result, the senior author changed his practice and no dressings were applied for subsequent reconstructions.

Once cartilage exposure occurs, appropriate management is critical in order to prevent resorption of the cartilaginous framework. However, there is no algorithm to guide surgeons on the management of this complication. Firmin[4] proposed local wound care for exposure < 3 mm, unless located on the helix where coverage with a local fascial flap was typically required. For larger exposures, Firmin advised the use of an axial temporoparietal fascial flap.[4] However, most surgeons agree that small areas of skin loss, (defined as < 10 mm), may be managed conservatively.[19] The algorithm we propose incorporates these opinions and is confirmed in our series. We recommend local wound care for all cartilage exposures < 10 mm2, irrespective of location, since (in our series) complete healing was noted in all cases of exposure with this dimension. Once the area of exposure exceeds 10 mm2, operative intervention is warranted, with specific treatment based on the location involved.

Figure 9 The outcome for (a) the patient shown in Figures 1–3 and (b) Figures 4–6, respectively, 4 years following cartilage salvage.

Although there were no cases of skin necrosis in the scapha, treatment of this area would be similar to that of the concha, where a fascial turnover flap can be used. However, for cases of conchal (as well as anti-helix) exposure, we recommend tunneling the fascial flap *beneath* the intermediate framework and overlying cutaneous cover so as to preserve the definition of the unaffected parts of the construct. Exposures in the scapha are not amenable to coverage with a tunneled fascial flap as the flap cannot be guided through the base block of the cartilage construct. Likewise, within the scapha, the skin edges cannot be brought together easily to close the defect directly (the so-called *draw-bridge effect*), as the lesser depth of this contour does not allow for the necessary skin recruitment. Exposures of the tragus and anti-tragus are often amenable to direct closure, either following debridement of non-viable superficial cartilage or after undermining of the adjacent skin. Alternatively, rotation-advancement flaps can be designed on pre- or post-auricular skin. While local cutaneous flaps can be used for coverage of the helix and anti-helix, all cases in our series were managed with turnover fascial flaps.

In 1991, Park described an anatomical cadaver study of the mastoid region, and discussed the use of the mastoid fascia in ear reconstruction.[6] In his study, he noted that the mastoid fascia is composed of two distinct fascial layers, the superficial and deep mastoid fascia, which correspond to the superficial temporal fascia and innominate fascia, respectively. The superficial mastoid fascia is supplied by the posterior auricular artery, the posterior branch of the superficial temporal artery and the occipital artery. Park[6,20] used this fascial flap for single stage microtia reconstruction, where the framework is covered by a skin flap on its anterior surface and fascial flap on its posterior surface, with overlap of the two layers at the anterior helix. The robust vascularity of this fascial layer also ensures viable tissue coverage either for the cartilage block during the second stage of auricular reconstruction[21,22] or for cartilage exposures following localized necrosis of the skin envelope.[23,24] To our knowledge, the only report to explicitly address the management of cartilage exposures described salvaging the cartilage frameworks in two cases of microtia reconstruction by using an anteriorly based superficial mastoid fascial flap.[23] The authors of this study noted that the maximum flap size that can be safely elevated was 6×6 cm. Others have reported that the superficial mastoid fascial layer can be extended as far as 8–10 cm posteriorly and superiorly from the remnant cartilage.[20] In our experience, the extent of fascial flap harvest was 10 cm from the periphery of the framework and 4 cm in width, using the distal extremity of the flap for framework coverage.

Hirase et al.[24] have previously described the use of the deep temporal fascia for post-operative cartilage exposure, when the superficial temporal fascia has already been used for coverage of the cartilage framework in the initial reconstruction. Indeed, the traditional option for secondary cover of exposed cartilage framework has been the temporoparietal fascial flap.[5,25] However, for many surgeons, this fascial flap is used to fashion the post-auricular sulcus at the second stage of reconstruction and remains a critical salvage option in the event of a failed microtia reconstruction, if the soft tissue envelope must be sacrificed. Although the temporoparietal fascial flap was not used to cover cartilage exposures in our case series, it should be included as an option in any algorithm. We recommend using this fascial flap for large cartilage exposures comprising the superior third or more of the auricular surface or for significant exposures which may occur after the second stage of reconstruction, where the anteriorly based superficial mastoid fascia has already been used.

Disclosure

The authors have no commercial associations, financial interest, or other conflict of interest to declare in relation to the content of this article.

Parental consent was obtained for publication of all photos included.

Authorship

1. Sabrina Cugno MD, MSc, FRCS(C), FAAP.

Contribution: Conception and design of study, acquisition of data, analysis/interpretation of data, drafting of manuscript.

2. Neil W. Bulstrode MBBS, MD, FRCS(Plast).

Contribution: Conception and design of study, revision and final approval of manuscript.

References

1. Nagata S. A new method of total reconstruction of the auricle for microtia. *Plast Reconstr Surg* 1993;**92**:187–201.

2. Ishikura N, Kawakami S, Yoshida J, Shimada K. Vascular supply of the subcutaneous pedicle of Nagata's method in microtia reconstruction. *Br Assoc Plast Surg* 2004;**57**:780–4.
3. Firmin F. Ear reconstruction in cases of typical microtia. Personal experience based on 352 microtic ear corrections. *Scand J Plast Reconstr Hand Surg* 1998;**32**:35–47.
4. Firmin F, Marchac A. State of the art autogenous ear reconstruction in cases of microtia. *Adv Otorhinolaryngol* 2010;**68**:25–52.
5. Song Y, Song Y. An improved one-stage total ear reconstruction procedure. *Plast Reconstr Surg* 1983;**71**:615–22.
6. Park C. A single-stage two-flap method of total ear reconstruction. *Plast Reconstr Surg* 1991;**88**:404–12.
7. Nagata S. Modification of the stages in total reconstruction of the auricle: part I. Grafting the three-dimensional costal cartilage framework for lobule-type microtia. *Plast Reconstr Surg* 1994;**93**:221–30.
8. Nagata S. Modification of the stages in total reconstruction of the auricle: part II. Grafting the three-dimensional costal cartilage framework for conchal-type microtia. *Plast Reconstr Surg* 1994;**93**:231–42.
9. Nagata S. Modification of the stages in total reconstruction of the auricle: part III. Grafting the three-dimensional costal cartilage framework for small conchal-type microtia. *Plast Reconstr Surg* 1994;**93**:243–53.
10. Nagata S. Modification of the stages in total reconstruction of the auricle: part IV. Ear elevation for the constructed auricle. *Plast Reconstr Surg* 1994;**93**:254–66.
11. Firmin F. La reconstruction auriculaire en cas de microtie. Principes, methods et classification. *Ann Chir Plast Esthét* 2001;**46**:447–66.
12. Firmin F, Marchac A. Auricular malformations. *Ann Chir Plast Esthet* 2016;**61**(5):420–8.
13. Fattah A, Sebire NJ, Bulstrode NW. Donor site reconstitution for ear reconstruction. *J Plast Reconstr Aesth Surg* 2010;**63**:1459–65.
14. Brent B. Technical advances in ear reconstruction with autogenous rib cartilage grafts: personal experience with 1200 cases. *Plast Reconstr Surg* 1999;**104**:319–34.
15. Brent B. Auricular repair with autogenous rib cartilage grafts: two decades of experience with 600 cases. *Plast Recontr Surg* 1992;**90**:355–74.
16. Brent B, Byrd HS. Secondary ear reconstruction with cartilage grafts covered by axial, random, and free flaps of temporoparietal fascia. *Plast Reconstr Surg* 1983;**72**:141–51.
17. Kasrai L, Snyder-Warwick AK, Fischer DM. Single-stage autologous ear reconstruction for microtia. *Plast Reconstr Surg* 2014;**133**(3):652–62.
18. Brent B. The correction of microtia with autogenous cartilage grafts: i. The classic deformity. *Plast Reconstr Surg* 1980;**66**(1):1–12.
19. Walton RL, Beahm EK. Auricular reconstruction for microtia: part II. Surgical techniques. *Plast Reconstr Surg* 2002;**110**:234–49.
20. Park C. Subfascial expansion and expanded two-flap method for microtia reconstruction. *Plast Reconstr Surg* 2000;**106**:1473–87.
21. Yoshimura K, Asato H, Nakatsuka T, Sugawara Y, Park S. Elevation of a constructed auricle using the anteriorly based mastoid fascial flap. *Br J Plast Surg* 1999;**52**:530–3.
22. Wang Y, Zhuang X, Jiang H, Yang Q, Zhao Y, Han J, Yu D, Zhang Z. The anatomy and application of the postauricular fascia flap in auricular reconstruction for congenital microtia. *J Plast Reconstr Aesthetic Surg* 2008;**61**:S70–6.
23. Oyama A, Sasaki S, William M, Funayama E, Yamamoto Y. Salvage of cartilage framework exposure in microtia reconstruction using a mastoid fascial flap. *J Plast Reconstr Aesthetic Surg* 2008;**61**:5110–13.
24. Hirase Y, Kojima T, Hirakawa M. Secondary ear reconstruction using deep temporal fascia after temporoparietal fascial reconstruction in microtia. *Ann Plast Surg* 1990;**25**:53–7.
25. Kim YS, Yun IS, Chung S. Salvage of ear framework exposure in total auricular reconstruction. *Ann Plast Surg* 2017;**78**:178–83.