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Surgical Concepts for Reconstruction of the Auricle

History and Current State of the Art

Alexander Berghaus, MD, Frank Toplak, MD

We compiled and evaluated the world literature on auricular reconstruction, for a total of over 400 publications, more than 200 authors, and over 3,300 reported cases. We found that partial reconstructions were already performed as early as 600 BC; total reconstructions were still considered impracticable in 1830. But since 1891, more than 40 different cartilaginous, osseous, and alloplastic frame materials have been described. Only eight of these were still being applied in the last decade, with autogenous costal cartilage and silicone as the leading substances. Results of the operation can be improved by special surgical manipulations, e.g., the "fan-flap" technique. Taking into consideration the complication rate, the number of individual interventions, and the stability of the results, we devised a special point system that makes possible a limited assessment of the different surgical techniques.

The two major problems in reconstruction of the auricle are as old as the history of this operation, and they have so far lost nothing of their importance. These problems are—as stated by Eduard Zeis1 as early as 1838—the provision of a suitable supporting frame and its coverage by skin. As an optimal solution has not yet been found, the search continues for the best frame material and the most suitable surgical technique. As this is a relatively rare operation, the experience gained with it is mainly described in scattered individual representations, thus making it difficult to obtain a comprehensive overview.

We compiled all published reports dealing with reconstruction of the auricle in an attempt to provide an overview of all known implants, transplants, and surgical techniques that have been used. In addition, we tried to establish objective criteria for weighing the pros and cons of different surgical techniques on the basis of information given in the literature; we did this by recording all complications mentioned in the cases reported and by simultaneously listing all individual operations necessary for correction. Finally, we wanted to answer the question of whether the preference of a certain material or surgical technique can be derived from the available literature.

The completeness of the literature collection was not limited by the number of sources (>400) or their age; reliable reports on complete auricular reconstructions date from the second half of the 19th century at the earliest, a time from which it is still relatively easy to obtain references. On the other hand, it would have involved a disproportionate amount of effort to procure or translate some studies, mainly from East Bloc countries or east Asia. Approximately ten publications were thus excluded.

The thoroughly compiled sources date from pre-Christian times2 (600 BC in India) to 1984. As the search for literature was not regionally restricted, we cannot claim our study to be complete; the investigation is, however, continuously under way. We registered 205 authors, 404 publications, 3,346 cases of reconstructed auricles, and 42 different types of frame materials. From the mass of data and findings, only some individual aspects can be mentioned herein. It is interesting from the historical point of view that even famous surgeons, such as Dieffenbach,3 Nelaton and Ombre-
danne, and Fritz and Reich considered total reconstruction of an auricle to be impractical for a long time—until the end of the 19th century—whereas partial reconstructions are reported to have already been carried out in ancient India and Alexandria and, later, Italy.

Apart from the merely theoretical proposal for the reconstruction of an auricle without a supporting frame, never carried out by von Szymanowski, who gave the first description in 1870 (Fig 1), and the inappropriate attempt to improve this technique by subcutaneous injections of petroleum jelly (Vaseline) by von Hacker in 1901, we found that the first reports on total surgical reconstruction of an auricle were the following. Kuhnt, and his assistant, Schanz, in Jena, Germany, in 1890, used the ipsilateral auricular cartilage rudiment (Fig 2). Randall, in Philadelphia in 1893, used a frame of fresh rabbit cartilage (Fig 3). Körte, in 1905 at the municipal hospital Am Urban in Berlin, used (inspired by König from Altona, Germany) a “wedge-shaped part of full thickness” from the healthy ear, which would be called “composite graft” today, together with the mastoid skin of the affected side and a free skin transplant for the operation. Lexer and Eitner are among the dozen of Körte’s followers who have adopted this technique. The last reports on it were presented by Gabka in 1972, Gorney et al in 1971, and Gorney, who carried out a systematic analysis of the applicable parts of the nonaffected ear (Fig 4).

FRAME MATERIALS

Although isolated attempts have been made again and again to reconstruct an auricle without a supporting frame, eg, Beck in 1925, De River in 1927, and, most recently, Sarig et al in 1982, attention was focused on the search for optimal supporting material during the following half century. At the same time, the demands for aesthetic results continued to grow. Later, in 1944, Suraci suggested the following seven criteria that must be met in reconstruction of the auricle: (1) correct size, (2) appearance identical to that of the contralateral ear, (3) identical ear-head angles, (4) identical levels of the ears, (5) durability of the results in terms of size and shape, (6) selection of adequate supporting and soft tissue for precise molding, and (7) the color of the skin has to correspond to that of the contralateral ear.

Autogenous costal cartilage, which later became the most widely applied material, was used very early. In 1908, Schmieden at the Royal Surgical University Clinic, Berlin, used this material to form an ear under the abdominal skin and then moved it to the defect area using a “plastic migrating pedicle flap” (Fig 5). According to our investigations, Giliies, in 1920, was the first to recon-
struct an auricle with autogenous costal cartilage in Anglo-American countries.

Of a total of more than 40 surgical techniques distinguishable by the material used for the supporting structure (Table 1), some are mentioned here briefly as follows: autogenous tibial bone, iliac bone, mastoid bone, autogenous nasoseptal cartilage, maternal auricular cartilage, allogenous conserved auricular cartilage, autogenous diced cartilage, allogenous costal cartilage, ox cartilage, calf cartilage, and allogenous meniscus. In addition to allogenous meniscus, Pitanguy, in 1958, also used autogenous meniscus. The above-mentioned materials have also been combined with each other and with other materials. In view of the disadvantages for the patient that result from taking autogenous material, eg, additional surgical areas and risk of bending or resorption, scientists have always tried to find uncomplicated materials for implantation that are easily obtained without interventions in the patient and well tolerated at the same time. As Tanzer stated in 1963, the ideal supporting framework consists of anorganic material that can be preoperatively formed, then sterilized and applied. This resulted in the use of ivory, for example (Fig 7), and in the early search for a suitable alloplastic material on the other hand. Thus, the observed resorption, even of autogenous costal cartilage, caused Ombredanne and others to use acrylic material and later polyethylene instead of autogenous material (Table 2). The following alloplastic materials have been used: caoutchouc, tantalum wire, acrylic glass, x-ray film, polyamid, silicone, and porous polyethylene. We were able to differentiate 42 cartilaginous, osseous, alloplastic, and combined frame materials; the classification provides for a subdivision into autogenous, allogenous, and xenogenous types based on origin, since different behavior in the implant bed can be assumed in each case. It was problematic to classify the use of the microtic auricular cartilage rudiment (always autogenous). Some surgeons reject the use of this cartilage, others consider its use valuable, and a third group does not mention it when describing the intervention. Finally, its specification as an independent material combined with others always appeared useful in cases in which the author emphasized the processing of this rudiment in a particular manner as an operative principle.

**RECONSTRUCTION PROCEDURES**

According to the information we compiled, only eight of more than 40 separate procedures were still being applied internationally within the last ten years. They are (in the order of the number of cases reported in the literature) as follows: autogenous costal cartilage, silicone, allogenous diced cartilage, allogenous costal cartilage, autogenous cartilage combinations, autogenous mastoid bone, allogenous auricular cartilage, and porous polyethylene.

**Autogenous Costal Cartilage**

Although the general view is that autogenous cartilage cannot be regarded as an optimal implant material in some respects, it has been applied far more frequently than seven other frame materials in the last ten years. While the development of additional risks (eg, pleural ruptures or thoracic deformities) and scars are obvious disadvantages, numerous surgeons disregard or underestimate the danger of partial or complete resorption of autogenous costal cartilage. Incomplete data in the publications render it impossible to determine the
Fig 5.—Auricular reconstruction with autogenous costal cartilage and "plastic migrating pedicle flap" in 1908 (from Schmieden).

precise percentage of resorption related to the total number of ears (1,592) with autogenous costal cartilage as the implant material. It is nevertheless noteworthy that 13 (19%) of 69 authors report on "resorption" in their group of patients (Table 3). This number is increased by an additional 14 authors, if—as appears justifiable—the "spreading" and "shrinking" of the new auricle that they describe is interpreted as resorption. If these are included, as many as 39% (27/67) of all surgeons with published results on autogenous costal cartilage as the supporting structure would have observed this unfortunate complication. One can only speculate as to how many of the remaining authors observed a resorption but did not report it. Other not uncommon phenomena are skin necroses and frame protrusions, which were described by 20 (29%) of the 69 authors. Thus, unproblematic healing cannot be taken for granted with costal cartilage, even though it is an autogenous material.

Silicone

The possibility of complications is even greater with silicone frames, which have more recently been ranging second in their frequency of application (we found reports of over 679 ears reconstructed with this material). Of 15 authors, 12 (80%) had to remove the silicone frames for various reasons. Nine (60%) of the authors observed spontaneous skin perforations, and seven (47%) an infection (compared with 9% [6/69] with autogenous costal cartilage); again it was not possible to determine the percentages in relation to the total number of ears that were operated on (Table 3).

Other Materials

The other six current frame materials are used much less often, judging from the literature references that mention them. The materials listed under items 3 through 8 in Table 4, taken together, were used in operations on about 400 ears.

The application of allogeneous costal cartilage and "plastic migrating pedicle flap" in 1908 (from Schmieden).
cartilage has so far been reported by 15 authors (as with silicone) but only once in the last ten years (in 1980). On closer consideration, however, this material cannot be recommended, because resorption has been observed with striking frequency (by some authors in as many as 100% of all cases).

It is surprising that comparatively fewer resorptions were described with diced allogeneous costal cartilage, which was implanted by Limberg in 1961 and others with a "cartilage injection." Of the three Russian authors concerned, Yarchuk mentions an "absorption" in 33 of 100 cases, but Limberg (41 cases) and Aleksandrov (one case) apparently did not observe this complication.

Allogeneous conserved auricular cartilage was reported to be used as frame material in 1983 by Campbell but in only one patient whose long-term course is not known. It is interesting, however, that Kruchinskii had previously (1973) reported only one frame removal over a period of four years in 32 ears constructed of this material. As early as 1940, Kirkham also assessed the allogeneous auricular-cartilage frame quite favorably.

**ATTEMPT AT A NUMERICAL ASSESSMENT**

Is it now possible to somehow objectively compare the results of all the authors considered? This project certainly involves some problems, for example, the nonuniform nomenclature in specifying complications and the frequent lack of data in the publications. Nevertheless, we have attempted to assign a mathematically determined point value to each of the different reports, taking into consideration the objectively positive and objectively negative aspects of the surgical procedures. Based on the briefly and appropriately formulated demands made by Sanvenero-Rosselli to achieve "the best result within the shortest period of time with as few interventions as possible," a long postoperative observation period with maintenance of the surgical results is assessed as positive by our calculation procedure. The following phenomena, on the other hand, appear to be negative: many separate surgical sessions, additional operating areas outside the ear region, and, of course, the postoperative complications, comprising early and late complications. For example, it is possible that an early postoperative suppuration may at first heal without loss of the entire ear but that, years later, the same ear may nevertheless end up as a failure through rejection of the implant or shrinking of the cartilage.

<table>
<thead>
<tr>
<th>Surgeon</th>
<th>Year</th>
<th>Frame Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gillies</td>
<td>1920</td>
<td>Autogenous costal cartilage</td>
</tr>
<tr>
<td>Pierce</td>
<td>1937</td>
<td>Autogenous bone</td>
</tr>
<tr>
<td></td>
<td>1937</td>
<td>Allogeneous auricular cartilage</td>
</tr>
<tr>
<td></td>
<td>1951</td>
<td>Xenogenous cartilage</td>
</tr>
<tr>
<td>Ombredanne</td>
<td>1944</td>
<td>Autogenous costal cartilage</td>
</tr>
<tr>
<td></td>
<td>1951</td>
<td>Acrylics</td>
</tr>
<tr>
<td></td>
<td>1958</td>
<td>Polyethylene</td>
</tr>
<tr>
<td>Backdahl</td>
<td>1939</td>
<td>Allogeneous auricular cartilage</td>
</tr>
<tr>
<td></td>
<td>1946</td>
<td>Rustproof steel wire</td>
</tr>
<tr>
<td></td>
<td>1948</td>
<td>X-ray film</td>
</tr>
<tr>
<td></td>
<td>1949</td>
<td>Autogenous costal cartilage</td>
</tr>
<tr>
<td></td>
<td>1950</td>
<td>Xenogenous cartilage</td>
</tr>
</tbody>
</table>
tions (eg, resorption), which can signify the failure of the operation, is entered into the calculation undivided. If authors did not mention in later publications the development of complications in previously reported cases, we assumed that the long-term results were good.

The mode of calculation used for the point value that we determined for the individual procedures is illustrated in the examples of authors A and B in Table 5. The individual points are totaled after assessment. A value around 0 speaks favorably for the surgical technique, while increasingly negative values—particularly around —100—are considered unfavorable. In principle, our calculating methods are also conceivable, eg, forming a quotient, but the relations should remain the same. It becomes clear anyhow that this assessment can only be carried out if the results are published by the authors with sufficient transparency. The gaps found in the reports that we assessed are in part considerable. Of current interest is the evaluation of techniques of the last ten years, as shown in Table 5.

**Influence of Surgical Technique on Results**

Apart from the implanted material, the surgical technique can also exert an influence on the long-term result; it is possible to demonstrate this impressively by using as an example the “fan-flap” technique (the term alludes to the fan shape of the fascia...
flap). This procedure, which, in its essential aspects, had already been described and applied by Herrmann and Zühlke in 1964 as "perichondrization" of the supporting frame, became generally well known in the modified form published independently by Fox and Edgerton in 1976. The procedure is based on the principle that coverage with pericranium provides an implant or transplant with a vital protective coat, which not only prevents infections and necroses but also permits a frame thus coated to be covered with a free-skin transplant in one session (Fig 10). Brent and Byrd developed the fan-flap technique in detail in 1983 by utilizing the healthy contralateral temporal fascia as a free flap and connecting it, such as in burn injuries, to the affected side by microvascular anastomosis. Although Dufoumont and others in 1958, had already utilized the temporal vessels covered with a skin transplant for reconstruction of the auricle, the vessels only served as a protection for the helix margin of the implant. The enthusiasm recognizable in the reports of those authors who apply the fan-flap technique can be objectively explained by our assessment system. If the point values are compared when the same frame material is used with and without application of the fan-flap technique, a marked improvement of the results obtained with autogenous costal cartilage and silicone can be achieved by the use of a covering composed of temporal fascia (Table 4, items 9 and 10). However, this hope must be expressed with caution, particularly for autogenous costal cartilage, since reports by only two authors with 44 fan-flap operations could be evaluated. The calculation for silicone frames is more reliable, because this technique was reported by four authors with 250 cases, which can better be compared with 12 authors and 412 cases without application of the fan flap. Ohmori and Sekiguchi, who have had experience with both methods, have observed only very few frame protrusions since they started using temporal fascia. For their results, we calculated a point value of -14.6 from the publication in 1974 reporting 116 cases without application of the temporal fascia; later, in 1984, Ohmori and Sekiguchi achieved a mean value of +0.6 with 156 reconstructed ears using the fan-flap technique. This observation is also supported by our experience with the fan-flap technique in combination with a frame of porous polyethylene, although our cases are limited in relation to the number of cases discussed herein.

The fact that our assessment system shows no improvement for alloplastic frames and the fact that our assessment system shows no improvement for alloplastic frames compared to autogenous costal cartilage with the fan-flap technique is most probably due to the strong resorptive tendency of the material rather than to the technique. If the feared frame protrusions do not again occur with alloplastic implants, application of the fan-flap technique would for the first time render a modern synthetic material clearly superior to the cartilage frame.

Assessment of Our Results

The great advantage of an alloplastic frame compared to that of autogenous costal cartilage lies—above all, for the patient—in the fact that it obviates the removal of autogenous cartilage, which has its own surgical risks and scars. Due to the high failure rate (especially without the fan flap) and the known risk of infection associated with silicone

### Table 4.—Assessment of Current Auricular Reconstruction Procedures in the Literature

<table>
<thead>
<tr>
<th>Frame Material</th>
<th>Publication Period</th>
<th>Total No. of Authors (Assessed)</th>
<th>Total No. of Cases (Assessed)</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Autogenous costal cartilage</td>
<td>1908-1983</td>
<td>69 (32)</td>
<td>1,590 (1,238)</td>
<td>-22.0</td>
</tr>
<tr>
<td>2. Silicone</td>
<td>1966-1984</td>
<td>15 (12)</td>
<td>679 (412)</td>
<td>-46.3</td>
</tr>
<tr>
<td>3. Allogenic costal cartilage</td>
<td>1956-1975</td>
<td>3 (2)</td>
<td>142 (141)</td>
<td>-10.5</td>
</tr>
<tr>
<td>4. Allogenic costal cartilage</td>
<td>1939-1980</td>
<td>15 (10)</td>
<td>104 (86)</td>
<td>-64.0</td>
</tr>
<tr>
<td>5. Autogenous cartilage</td>
<td>1963-1983</td>
<td>5 (3)</td>
<td>77 (72)</td>
<td>0</td>
</tr>
<tr>
<td>6. Autogenous bone</td>
<td>1937-1983</td>
<td>3 (2)</td>
<td>51 (51)</td>
<td>-52.5</td>
</tr>
<tr>
<td>7. Allogenic auricular cartilage</td>
<td>1940-1983</td>
<td>4 (2)</td>
<td>40 (34)</td>
<td>-4.8</td>
</tr>
<tr>
<td>8. Porous polyethylene</td>
<td>1981-1984</td>
<td>2 (2)</td>
<td>5 (5)</td>
<td>-0.8</td>
</tr>
<tr>
<td>9. Autogenous costal cartilage</td>
<td>1958</td>
<td>2 (2)</td>
<td>44 (44)</td>
<td>-0.6</td>
</tr>
<tr>
<td>10. Silicone</td>
<td>1984</td>
<td>4 (4)</td>
<td>250 (250)</td>
<td>+1.7</td>
</tr>
<tr>
<td>11. Allogenic costal cartilage</td>
<td>1958</td>
<td>1 (1)</td>
<td>8 (6)</td>
<td>-101.0</td>
</tr>
<tr>
<td>12. Porous polyethylene</td>
<td>1983</td>
<td>1 (1)</td>
<td>2 (2)</td>
<td>-2.5</td>
</tr>
</tbody>
</table>

*Items 9 through 12 included the application of the "fan-flap" technique; all appeared in the literature after 1976.

**Parenthetical values indicate the number of authors and cases that we evaluated on the basis of sufficient data, using our point system.

### Table 5.—Two Assessment Examples

<table>
<thead>
<tr>
<th>Assessment Criteria</th>
<th>Author A: Autogenous Costal Cartilage</th>
<th>Author B: Silicone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation period of years</td>
<td>+8.0</td>
<td>+5.0</td>
</tr>
<tr>
<td>Operation sessions</td>
<td>-4.0</td>
<td>-4.0</td>
</tr>
<tr>
<td>Operating areas outside the ear region</td>
<td>-3.0</td>
<td>-1.0</td>
</tr>
<tr>
<td>Percentage of early complications</td>
<td>-16.0</td>
<td>-5.6</td>
</tr>
<tr>
<td>Percentage of late complications</td>
<td>-95.0</td>
<td>-9.0</td>
</tr>
<tr>
<td>Total Points</td>
<td>-110.0</td>
<td>-14.6</td>
</tr>
</tbody>
</table>
frames, however, silicone did not seem optimal. In searching for a tissue-compatible and stable alloplastic frame with low susceptibility to infection, Berghaus et al., in comparative animal experiments with four materials, found porous high-density polyethylene to be particularly suitable (Fig 11).

Since report of these experiments in 1983, Berghaus (unpublished data, August 1983), has used this easily pliable material to develop rounded implants in which the synthetic mass is reduced to a minimum (Fig 12). As already shown by preliminary experimental studies, the adaptation of the skin to the frame is very good and increases continually with time, so that a marked relief formation is achieved. The implants permit a total auricular reconstruction and can also be cut down to achieve a partial one.

Important for the stability of the result is coverage with a fan flap, which we prepare as described by Brent and Byrd and supplement by a postoperative suction drainage according to Cronin. Skin coverage is performed with a thick split-skin flap.

We first used a still rather crudely formed porous high-density polyethylene frame in 1982 in a case of auricular cartilage loss due to abscess-
forming perichondritis. The result has remained satisfactory as of this writing (Fig 13).

The further developed, more delicate frames have so far been used five times for total auricular reconstructions (Figs 14 and 15). Postoperative skin shrinkage with small suture dehiscences and protruding synthetic material had made early corrections necessary in two early cases in which the implants were slightly shortened and again covered with small compound or split-skin transplants.

It is noteworthy that no appreciable complications occurred in a postoperative observation period of between six months and three years. A point value of 2.5 was calculated for our own results.

CONCLUSION

Due to the great number of procedures reported, it is impossible to discuss in detail the various types of incisions and flap techniques. In addition to roll and distant flaps, bilobate as well as transposition-rotation flaps have been applied, and, above all, split-skin and compound flaps from diverse donor sites have been used. Besides the fan flap discussed herein, particular mention should be made of the “Easier inlay”7 and the “scapel roll.”7

Other special procedures were the “valise-handle technique” of “tunnel procedure” of Tanzer7 and the “skin expansion” and “expansile framework” performed temporarily by Brent,7 who after 1976 preferred a modified framework from that used by Tanzer. This is probably today’s most used type of autogenous rib cartilage framework for auricular reconstruction.

The numerical assessment system that we have suggested for better comparison of the various procedures can only function properly when the data in the publications are always complete and up to date, which means that the system is dependent on ideal conditions. Since these are never given, the calculations for an overview can only be of an orienting character. On the other hand, since each surgeon’s own current data are always accessible, we believe that our point system may be a valuable aid for the individual surgeon in assessing his or her total results.

Joanne Weirowski, PhD, helped translate and prepare the manuscript.

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