Long-term histological fate of cartilage in ossicular reconstruction

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The surgical reconstruction of the ossicular chain continues to be a challenge to the otologist. Many different techniques of ossicular reconstruction have been reported in the literature over the last 2 decades. There is hardly any issue of a journal without reference to either a new material or a new method of reconstruction of the ossicular chain.

The purpose of this paper is to present the long-term histological cartilaginous changes after ossicular reconstruction. The use of cartilage in reconstructive middle ear surgery was introduced in the early 1960’s (Utech, 1959). We have used cartilage for ossicular reconstruction from 1963 until 1970. Since then we have used it infrequently as a result of the very disappointing results.

Material

Fifty-two cartilages which were implanted into the middle-ear to re-establish the sound pressure transfer mechanism were studied histologically. In 44 cases a second operation was necessary because of failure to maintain the hearing, and in 8 cases because of recurrence of the disease. Table I shows the time interval between the grafting of the cartilage in the middle ear and the time of its removal. There were three main ways in which the reconstruction was done:

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<th>TIME INTERVAL BETWEEN GRAFTING OF THE CARTILAGE AND ITS REMOVAL</th>
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1. As a columella between the mobile footplate and the fascia.
2. In the form of an L, with one limb on the footplate and the other under the fascia.
3. Between the long process of incus and the head of the stapes.

Of the 52 cartilages examined, 39 were autologous tragal cartilage grafts and 13 were homologous nasal cartilage grafts.

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Twenty-nine of the patients had cholesteatomas and 23 had chronic middle-ear disease with a persistent perforation. Most of these patients had an air-bone gap of between 30 and 60 db. In 41 cases the post-operative gap was closed, and in the remainder the gap was 15 to 20 db.

Results

Forty-six of the 52 cartilage grafts had gross macroscopic defects. 

Shape: Out of 32 columellas 25 had become irregular in appearance, 3 had completely disappeared and 5 had maintained their original shape. The cases in which it had completely disappeared were cases with recurrent cholesteatomas. The L-shaped cartilages also showed marked changes. In 7 cases the vertical limb of the L had an irregular appearance and did not have contact with the footplate. The horizontal limb in contact with the tympanic membrane had maintained its shape. Out of 4 cases in which a piece of cartilage was inserted between the partially eroded long process of the incus and the head of the stapes, the long process was further necrosed and the cartilage was replaced by a single fibrous band. Thirty-eight cartilages had become spongy. Only nine cartilage implants, in which the horizontal limb of the L was in contact with the fascia, were not completely softened.

Microscopic appearance

Most of the cartilages which were removed were covered by normal mucosa. There was no evidence of any inflammatory reaction. Vascular proliferation was only occasionally seen. The most important findings were as follows:

Chondrocytes: The appearance as well as the number of cells had changed. The paired character had become single. The border of the cells were poorly defined. The nucleus was pyknotic in some and absent in others. Some contained only ghost cells. The rows of chondrocytes had become irregular. These rows occupied only parts of the cartilage, alternating with clear zones which had only a ground substance. In other words the cartilage had become grossly hypocellular (Fig. 1).

Fibrosis: In many specimens the cartilage was replaced by fibrous tissue. In some there was collagen without fibroblasts, but in others a fibrous band could be seen adjacent to the surface of the cartilage (Fig. 2). In 6 specimens, there was vascular proliferation with absence of chondrocytes and subepithelial fibrosis directly under the fascia (Fig. 3). In 4 specimens, however, there was no evidence of any chondrocytes. On haematoxylin-eosin staining there were many areas which appeared necrotic. But on PAS-alcian blue or toludin blue staining, neutral and acid mucopolysacharide could be demonstrated, thus confirming some metabolic activity.

Resorption: In some specimens there were lacunae which indicated a
resorptive process; on the border of these lacunae, cells which could be called ‘chondroclasts’ could be identified. In some specimens, fracture lines could be seen (Fig. 4). In two specimens the most interesting finding was the demonstration of blood vessels surrounded by lamellar bone (Fig. 5) occurring in the centre of two cartilages which had been in the middle ear for 12 and 15 years respectively.
Photomicrograph of the implanted cartilage directly under the tympanic membrane. Note the subepithelial fibrosis (H and E ×160).

Photomicrograph showing resorption at the surface. Note darkly-stained cells on the border which could be called 'chondroclasts' (H and E ×160).
FIG. 5
Photomicrograph of the cartilage which lay in the middle ear for 13 years. Note formation of lamellar bone (H and E ×160).

Discussion

The aim of ossicular reconstruction in tympanoplasty is to obtain a permanent restoration of hearing. In recent times some of the advocates of the use of cartilage in ossicular reconstruction have started to have doubts about the use of this material (Smyth et al., 1975). It is very tempting to use cartilage, because it is readily available from the surgical field. It can be easily shaped and when fresh it has good elasticity for sound conduction. In 31 out of 52 cases the deterioration in hearing occurred between 3 and 7 years after surgery. In most of these cases the cartilage was used as a columella, and all of them were softened. Some authors advised the use of wire to stabilize the cartilage. Smyth and Kerr (1967) and Jansen (1968) feel that the cartilage prevents the extrusion of the wire. The rationale of the use of this combination raises certain questions. If the cartilage is strong enough, why should there be a wire? For if it is placed under favourable conditions the wire should not be extruded and if the wire is to extrude the cartilage will hardly be able to prevent it.

It is extremely important for an implant to stay in place and retain the same permanent characteristics e.g. shape and consistency, because only then is it possible for the functional result to be maintained. When only cartilage is used as a columella, there is a chance that it will be nourished from the two points which are in contact: first, from the footplate; and secondly, either a remnant of the tympanic membrane or the implanted fascia which itself has rather poor nourishment. These two points are not sufficient for the nutrition of the piece of cartilage which is without
perichondrium. The nourishment of cartilage is by diffusion, with the help of the perichondrium. We feel it is extremely important for the viability of cartilage that the perichondrium on at least one side is intact. Salén (1968) mentions, in his article, that Loeb (1926) and Peer (1939) found that cartilage with adherent perichondrium could be transplanted from one site to another. Animal experiments (Gibson et al., 1959) also showed that cartilage with perichondrium can survive for a long time. Minami (1976) found that cartilage remained unchanged when it was inserted subcutaneously in cats.

The irregular arrangement of single chondrocytes and adjacent empty spaces is one of the early changes that is observed. Smyth and Kerr (1970) also observed 'empty' chondrocytes in their experiments. Jansen (1968) found only a few living chondrocytes in one of his specimens. Shea and Glasscock (1967) reported that some of the lacunae did not have nuclei.

Our findings concerning the L-shaped implanted cartilage are of great interest. In some cases the L was broken at the angle with the vertical limb becoming non-viable. The horizontal limb that was in contact with the remnant of the tympanic membrane or with the fascia retained some degree of cartilaginous architecture. This was mainly because this limb of the cartilage could obtain nourishment from the surface. The vertical limb could only be nourished from the surface. In an otherwise satisfactorily healed middle-ear.

If we take a look at the revascularization of cartilage and compare it with ossicular grafts we find a great difference in the basic structure of these two materials, e.g. in case of the incus there are vascular channels which run from the periphery to the centre (Fig. 6). Thus the proliferation of the vessels can occur directly through these channels. This is clearly seen by areas of new bone formation around the vessels in cases of implanted ossicles. In contrast, cartilage has no blood vessels and has to depend on diffusion from the surface for its nourishment or metabolism.

The greatest advantage of the cartilage graft was thought to be its very low metabolic rate. In spite of this it does need some nutrition. It could be said that for a period of time it has a capacity of its own to survive. Smyth and Kerr (1970) found connective tissue on the surface of the cartilage with some fracture lines. In some of our specimens it was evident that the centre of the cartilage was viable, while the periphery showed connective tissue and areas of necrosis (Fig. 7). This finding is difficult to interpret because the nutrition should come from the periphery, so the expected necrosis should be in the centre. Possibly the low metabolic rate in the central part of the cartilage where there is minimal activity results in the cartilage remaining viable for a longer time. The greater activity in the periphery might lead to early proliferation of blood vessels and resorption, with the presence of cells similar to osteoclasts. This again is comparable to implanted bone chips where one finds new bone formation in the centre and resorption and lacunae with osteoclasts at the periphery. The
replacement of cartilage by bone which occurred in two cases further strengthens this hypothesis. Therefore it can be said that there is a gradual replacement of cartilage with fibrous tissue and deeper proliferation of blood vessels leading to lamellar bone around blood vessels. Minami (1976) also found infiltration of connective tissue and calcification in
animals when the cartilage was placed in the bulla. Thus one can say that
cartilage will remain viable for only a certain length of time but will
eventually show changes in its character and function.

We have used cartilage with perichondrium to reconstruct both the
lateral attic wall and the tympanic membrane. Here the situation is
completely different. The revascularization in case of a reconstructed
lateral attic wall is from the lateral borders of the perichondrium as well as
from the tympano-meatal flap. The revascularized perichondrium in turn
can nourish the cartilage by diffusion and this can then remain permanently
viable. On 6 occasions we had to remove the lateral attic wall
reconstructed with a cartilage-perichondrial graft due to recurrent
cholesteatoma. The cartilage appeared normal even after 13 years. The
condition is somewhat similar in cases of reconstruction of the tympanic
membrane. The blood supply to the graft is from the adjacent
tympano-meatal flaps.

The above findings clearly demonstrate that the main cause of
deterioration of hearing was the alteration in the shape and structure of the
cartilage. It has been reported that, though the cartilage becomes non-
viable, it remains functional. It is very difficult to say how long it will
remain functional. In our series the average time was found to be 3 years.

The difference that was found between homologous and autologous
cartilage was that the Cialit-preserved cartilage had completely lost its
architecture and consistency. This is absolutely contrary to what happens
with Cialit-preserved ossicles. Maybe fresh homologous cartilage will
behave differently.

We conclude that the cartilage graft as a sound-conducting structure
remains functional for a limited period of time. It is almost impossible to
predict for how long. We had a case in which the cartilage had to be
removed after 8 months, and in others it remained functional for 15 years.
Cartilage used for reconstruction of the lateral attic wall or tympanic
membrane remains functional and viable for a very long time. We can say,
finally, that it was worth a try but looking at the present results the use of
cartilage for ossicular reconstruction should be limited to a few well
selected situations.

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