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# The use of cortical bone grafts in ossiculoplasty I: Surgical techniques and hearing results

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**Abstract**
Concern about the possible risk of viral infection being transmitted by the use of homografts has renewed interest in cortical bone autografts as an ossicular substitute. Over the last four years I have used cortical bone on a regular basis. Comparison of hearing results obtained using ossicular and cortical bone grafts shows no significant difference between the two groups. Cortical bone appears to be satisfactory material for ossiculoplasty, but long-term studies of outcome are required to confirm this.

**Key words: Ossicular replacement prosthesis, cortical bone; Hearing tests**

## Introduction

The use of cortical bone as an ossicular substitute was first described by Farrior (1960). Results using such grafts were subsequently reported by Bauer (1966), Guildford (1966), Wright (1967), Tos (1974) and Berkowitz *et al.* (1978). Pulec and Sheehy (1973) reported that they had abandoned the use of cortical bone because of problems with resorption. Nonetheless reports of the use of this material continue to appear (Ojala *et al.*, 1983; Vartainen and Karjalainen, 1985).

In a round table discussion in 1969, Hoffman described cortical bone grafts used experimentally in monkeys to be 'engulfed in fibrous tissue', while Zollner described experiments carried out on animals and humans and reported better graft survival in humans. Benitez *et al.* (1971) reported no evidence of resorption of cortical bone grafts which had been in the cat middle ear for up to nine months, while Hildman *et al.* (1969) reported similar remodelling of cortical bone grafts and ossicular grafts in rabbits. Plester and Steinbach (1977) studied the behaviour of various types of graft material in the rabbit middle ear. Cortical bone autografts taken from the femur became smaller and softer over the 12-month period following implantation. However, new bone formation did occur within them and they performed better than homograft bone chips. Osteolysis particularly occurred at sites on the grafts which had been damaged during harvesting.

## Materials and methods

### *Harvesting of grafts*

In order to produce a graft with as much undamaged surface as possible, grafts were taken from the proximal portion of the bony posterior meatal wall, including the spine of Henle. If the patient had undergone a previous mastoidectomy, this was not possible and grafts were obtained from the anterior prominence of the meatal wall or from the edge of the cavity at the base of an endaural incision, if one was being used. This latter approach is technically easier and allows a larger graft to be taken. In cases where there is an overhanging cavity edge, a graft with more than one undrilled surface can be produced. In all cases the graft was outlined with a diamond or cutting burr initially. The process was continued with a cutting burr until the desired thickness of graft and its rough shape had been defined. Its removal was then completed with a Tumarkin labyrinthine gouge. In the early cases the grafts were used with very little further preparation. As time went by and confidence in graft survival grew, more and more extensive modification was used to produce grafts suitable for different purposes.

### *Methods of reconstruction*

In some cases with an intact stapes arch conventional malleus–stapes or drum–stapes assemblies were used (Figure 1 a and b). In one case in which the malleus handle was attenuated and the depth of the middle ear space was too large to allow an assembly of this type, a Schuring Ossicle Cup Prosthesis (Richards Medical Co.) was added to give extra height to the resulting composite prosthesis.

As confidence in using cortical bone grew, the degree of modification of the graft increased, in the hope of improving hearing results. In cases with total loss of the incus a graft with a hole approximately 1 to 1.5 mm in diameter drilled through one end of it was produced. It was found that it was easier to make this hole before the graft was finally separated from the skull. The malleus handle was separated from the tympanic membrane and it was then slid through the hole in the graft. The other end of the graft was then rotated onto the stapes head. Because of the way in which the graft firmly encircles the malleus producing a very

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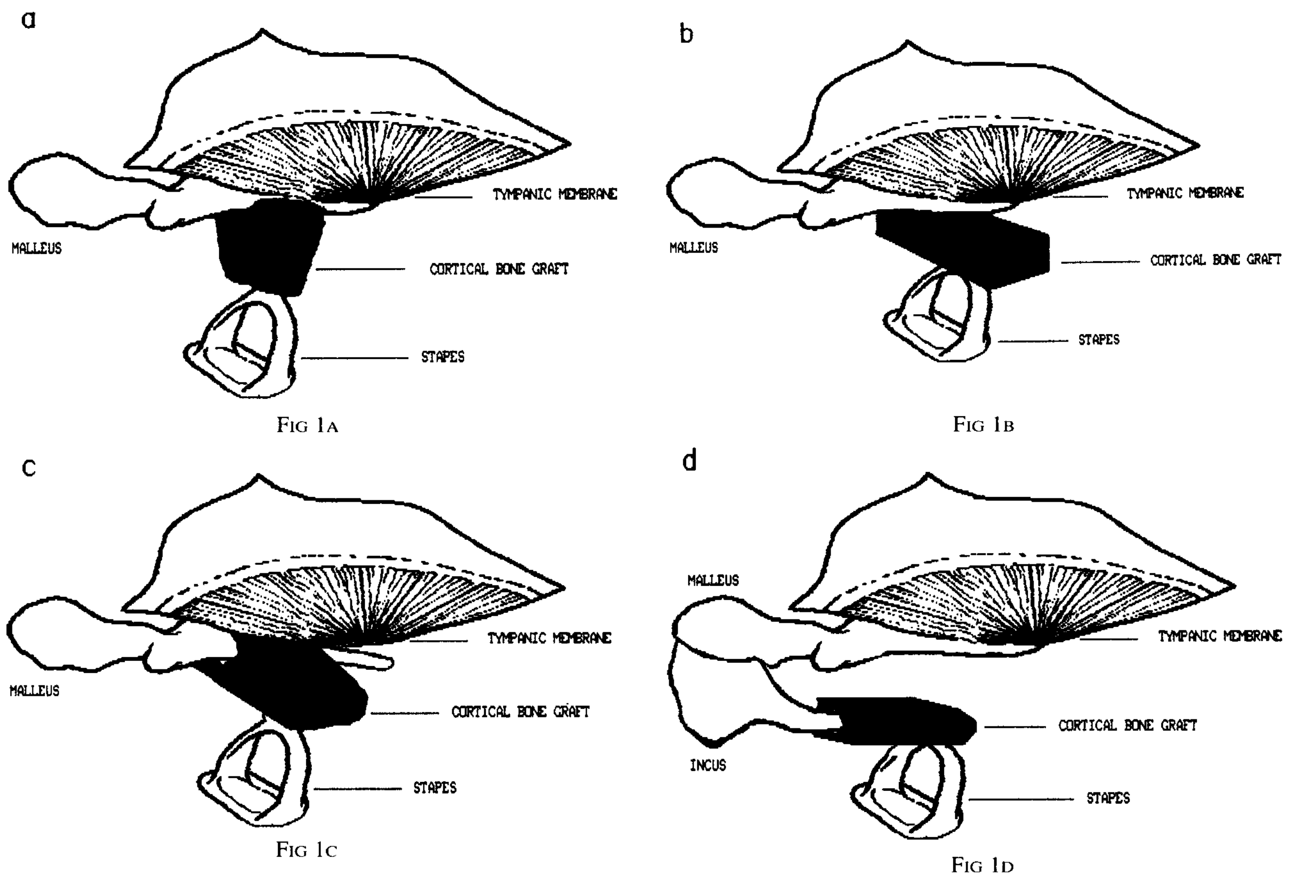


Fig. 1

Surgical techniques for cases with an intact stapes arch: (a) Vertical assembly; (b) Horizontal assembly; (c) 'Jigsaw' assembly; (d) 'Sleeve' assembly.

stable arrangement, it was named the 'Jigsaw' assembly (Figure 1 c). The technique itself was originally used for ossicular grafts by Marquet (1973).

In cases where there was a sufficient length of incus long process present, a graft with a hole drilled down its long axis was used. This hole was then slid over the incus long process and the lower end, which had a hollow drilled in its inferior surface, was rested on the stapes head. This was named the 'Sleeve' assembly (Figure 1 d).

When the stapes superstructure was absent a composite prosthesis employing the Schuring Ossicle Columella Prosthesis (Richard Medical Co.) was used between the footplate and malleus or, if this was not possible, between the footplate and the drum (Figure 2 a). Composite prostheses were created by drilling a hole in the under surface of the graft of sufficient depth to allow stable attachment of the bone graft to the shaft of the prosthesis. The early results using this technique were disappointing and so in subsequent cases a total ossicular replacement graft (TORG) was fashioned from cortical bone (Figure 2 b). These were used as malleus–footplate or drum–footplate assemblies. Alternatively a hole was drilled in the body of the graft so that it would be used in a 'Jigsaw' type of assembly (Figure 2 c).

In one case with a partially absent incus and an absent stapes arch, a graft was fashioned to lie between the incus and the footplate (Figure 2 d). This graft was shaped like an inverted L and had a groove drilled in its superior surface for the incus long process.

During tbe first two years these techniques were only applied in cases where no autograft incus was available. The early experience was so encouraging that it was felt appropriate to use cortical bone in the development of new reconstructive techniques, as described above. The aims were to preserve the incus *in situ* rather than removing it, and to produce more stable and/or more physiological reconstructions.

*Evaluation of hearing results*

Mean pre- and post-operative hearing losses and air–bone gaps were calculated using three frequencies (500, 1000 and 2000 Hz). Post-operative air–bone gaps were calculated using pre-operative bone conduction thresholds. Mean air conduction thresholds for the other ear were calculated using the same three frequencies. The one-year hearing results for patients who have had operations using cortical bone have been compared with those in whom ossicular grafts were used. Each cortical bone graft case was matched with one in which an incus had been used to form pairs with the same pre-operative ossicular defect and mean pre-operative air–bone gaps which differed by no more than 5 dB. The data were examined using the normal probability plot to confirm that they were normally distributed. As this proved to be the case, the results for mean air–bone gaps and mean hearing change were analysed using a *t*-test for paired data. These two parameters were chosen because they are indicators of the technical success of the operation.

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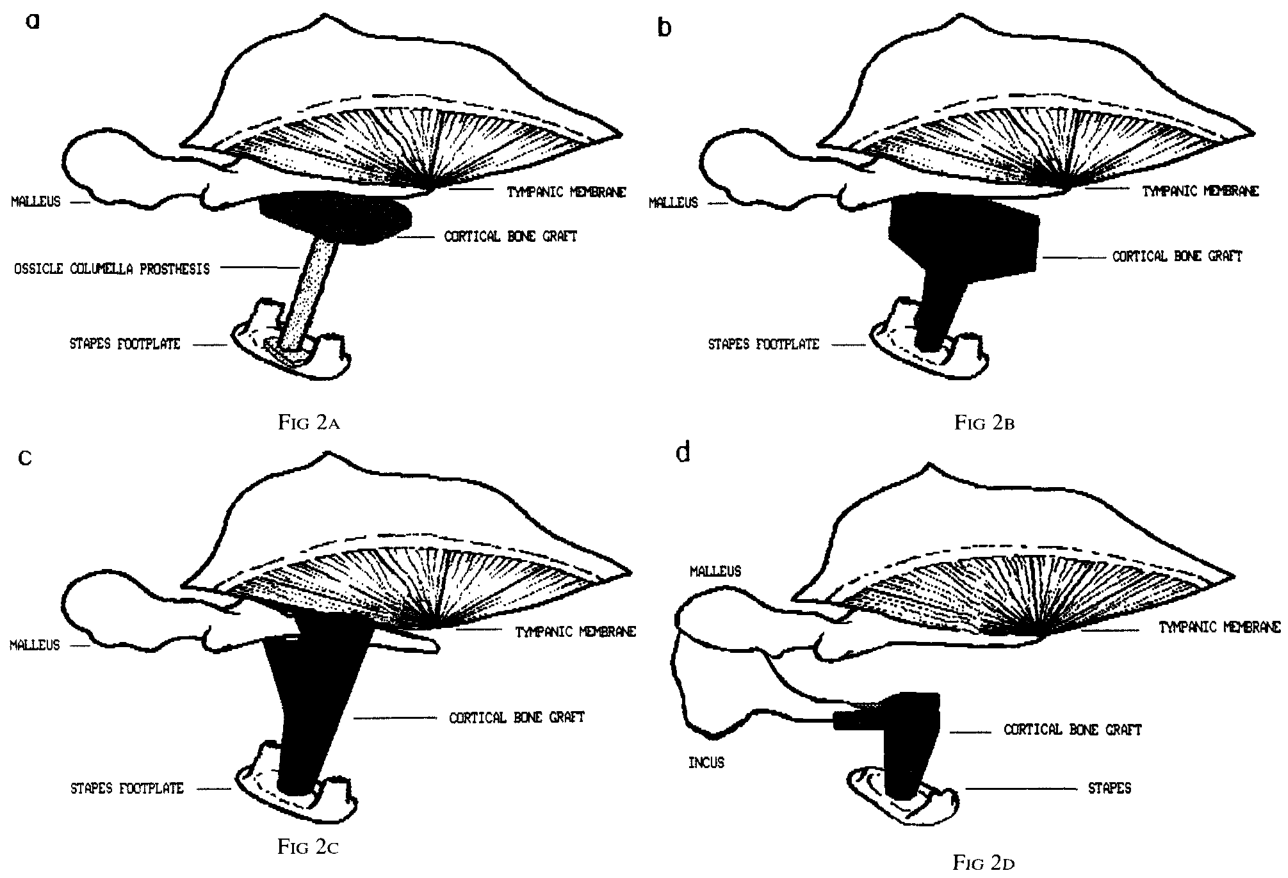


FIG. 2

Surgical techniques for cases with loss of the stapes arch: (a) Composite prosthesis using a cortical bone graft and a Schuring Ossicle Columella Prosthesis (Richards Medical Co.); (b) Cortical bone total ossicular replacement graft (TORG); (c) 'Jigsaw TORG'; (d) Incus–footplate assembly.

## Results

So far 46 operations using cortical bone grafts have been performed. Of these 35 have been followed up for at least one year. The duration of follow-up for the whole group varies between one month and four years. So far no graft has been extruded. The results for the first 35 operations are presented in Figure 3 using the Glasgow Benefit Plot (Browning *et al.*, 1991). Statistical analysis was carried out for 30 matched pairs and no significant differences between the groups were demonstrated. The results for the two groups are summarized in Table I.

## Discussion

The authors' interest in cortical bone as an ossicular substitute was first stimulated by concern about the possibility of viral infection being transmitted by an ossicular homograft. To date the only reports which lend some support to this view concern a case of Creutzfeldt-Jacob disease which occurred following the use of homograft dura (JAMA Update, 1987) and a case of HIV infection following the use of a bone graft (Center for Disease Control, 1988). The current DHSS policy on the use of stored grafts, including bone, states: 'Living donors must be asked to confirm that they are not in any of the high risk groups . . . similarly enquiries should be made in respect of any cadaveric donor' (DHSS, 1987). In practice it is difficult to satisfy these requirements in the context of normal clinical use of homograft ossicles.

TABLE I

SUMMARY OF HEARING RESULTS (dB, ISO) FOR CASES IN WHICH CORTICAL BONE OR OSSICULAR GRAFTS WERE USED ($n$ = 30 MATCHED PAIRS)

| Graft type | 1-year air–bone gaps Mean | SD | 1-year hearing change Mean | SD |
|---|---|---|---|---|
| Cortical bone | 22 | 15.6 | 11 | 16.4 |
| Ossicular grafts | 18 | 14 | 14 | 12.6 |

Cortical bone is a suitable material for ossicular reconstruction for a number of reasons. It is available in the operative field and, although it is not identical to the dense bone of the ossicles, it is similar. When an ossicle is used as a graft, the modification that can be carried out is restricted by its size and shape. In the case of cortical bone, any shape can be produced provided that the degree of modification does not lead to destruction of the graft. This has facilitated the development of a several experimental reconstructive techniques. Cortical bone can be sculpted easily and, provided that it is handled with care, it is not prone to fracture. Berkowitz *et al.* (1978) have described a hollow drill designed to harvest a cylindrical bone graft for use in ossiculoplasty.

The present study indicates that the hearing results for cases in which a cortical bone graft is used are no worse than for those in which an ossicular graft is employed. This finding is in line with those of Ojala *et al.* (1983) who reported better hearing results for cases with cortical bone grafts than for ossicular grafts in a series of 164 ears.

On the basis of the data currently available, autologous

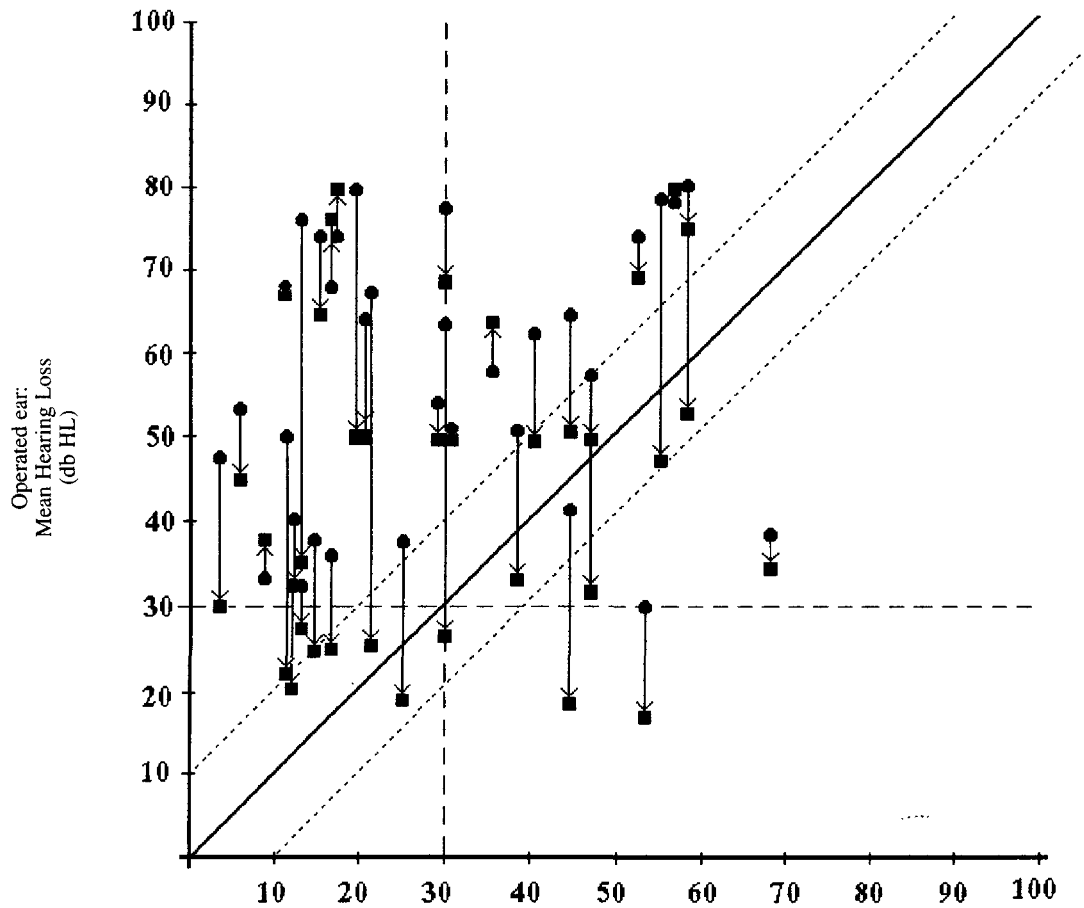


FIG. 3

Hearing results for the 35 cases who have been followed up for more than one year displayed using the Glasgow Benefit Plot.

cortical bone can be considered to be a suitable material for ossicular reconstruction and preferable to homograft ossicles.

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