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# Porous Polyethylene in Reconstructive Head and Neck Surgery

Alexander Berghaus, MD

● Porous polyethylene is a thermoplastic synthetic with a pore size ranging from about 100  $\mu\text{m}$  to 200  $\mu\text{m}$ . In addition to other materials, it is used for alloplastic replacement of auditory ossicles. Experimental and clinical experience in our department in recent years has shown that porous polyethylene, due to its good formability, tissue tolerance, and stability is suitable for use in reconstruction of other cartilaginous and bony structures. Therefore, it has been used successfully in reconstruction of the outer ear, in repairing defects of the facial skull, and in rebase paralyzied vocal folds. Its use in the inner nose to replace the cartilaginous septum or rebase the mucosa in ozena, however, cannot be recommended. The suitability of the material for alloplastic tracheal replacement is investigated experimentally.

(*Arch Otolaryngol* 1985;111:154-160)

Porous, high-density polyethylene (PHDPE) is a sintered synthetic that is superior to the more brittle ceramic in its elasticity and to porous metals in its chemical resistance. For the sintering procedure, powder of low-pressure polyethylene types with a relatively wide melting range is

used. In this way, it is possible to produce plates and tubular and special profiles, as well as shaped parts, which then can easily be formed by sawing, drilling, milling, planing, cutting, punching, and so on, and also welded and additionally shaped thermoplastically. The density amounts to 0.6 g/cu cm, the porosity, 40%.<sup>1</sup> The pore size ranges from 40 to 150  $\mu\text{m}$  and can reach 200  $\mu\text{m}$  or more (Fig 1). The material can be regarded as being only slightly infection prone.<sup>2</sup>

Although in principle it is possible to use the autoclave for sterilization, we prefer ethylene oxide gas sterilization because of the incipient thermoplastic plasticity at about 110 °C. In the ear, nose, and throat field, porous polyethylene is mainly known for its use in alloplastic replacement of auditory ossicles.<sup>3</sup> Less work has been done in other areas of application. In our clinic, ossicular replacement with porous polyethylene prostheses has been abandoned in favor of the ceramic prostheses. Our experimental and clinical studies with porous polyethylene in recent years have shown that this material, which shows good tissue tolerance and form stability, is suitable for replacement of various bony and cartilaginous structures and for filling certain soft tissue defects.<sup>4,5</sup>

In addition to the tympanoplastic applications already mentioned, experimental and clinical experience also encompasses the following areas: (1) reconstruction of defects in the

facial skull; (2) reconstruction of the external ear; and (3) rebase of vocal folds. The material was also used to rebase the mucosa in ozena and to reconstruct the cartilagenous nasal septum, but cannot be recommended for the inner nose on the basis of our experience. In addition, we are in the experimental stage of working on a tracheal prosthesis composed of porous polyethylene.

## CORRECTION OF FACIAL-SKULL DEFECTS

Various experiments have shown that, in a bony implant bed, there is ingrowth of newly formed bone into the porous polyethylene<sup>6-12</sup> of up to 100% under optimal conditions. In an experimental animal study we performed,<sup>5</sup> in which a comparison was made between porous polyethylene and a combination of Teflon polymer and carbon fibers, we were able to show that, after implantation in skull defects in guinea pigs, PHDPE evis-

Fig 1.—Porous polyethylene of German origin (scanning electron microscope,  $\times 500$ ).



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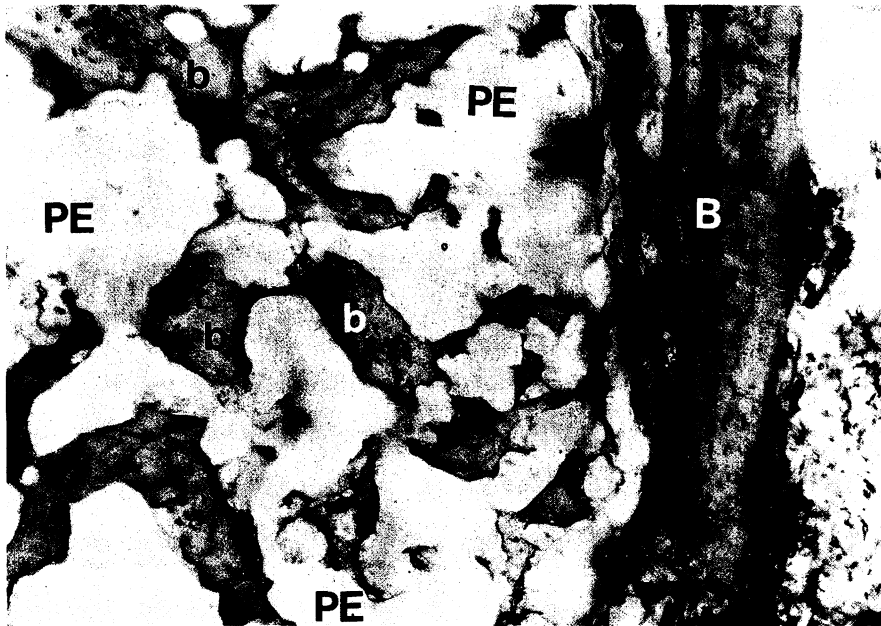


Fig 2.—Bony anchorage of porous polyethylene (PE) six weeks after implantation in calotte of guinea pig. Pores are filled with bone (b). B indicates implant bed (Giemsa stain, X180).

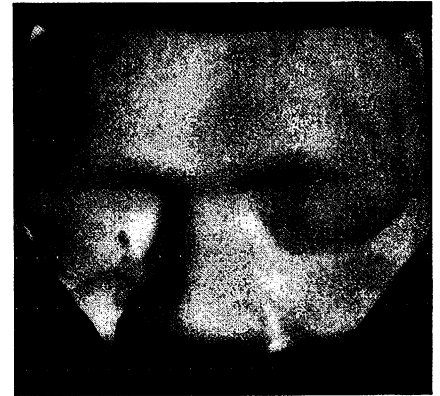


Fig 3.—Porous polyethylene profile plate that is shaped according to correction in plaster model and may be cut to size with scissors as required.



Fig 4.—Left, Incision behind hairline for surgical access to forehead defect. Right, Forehead defect after preparation of scalp. Infundibulum must not be opened.

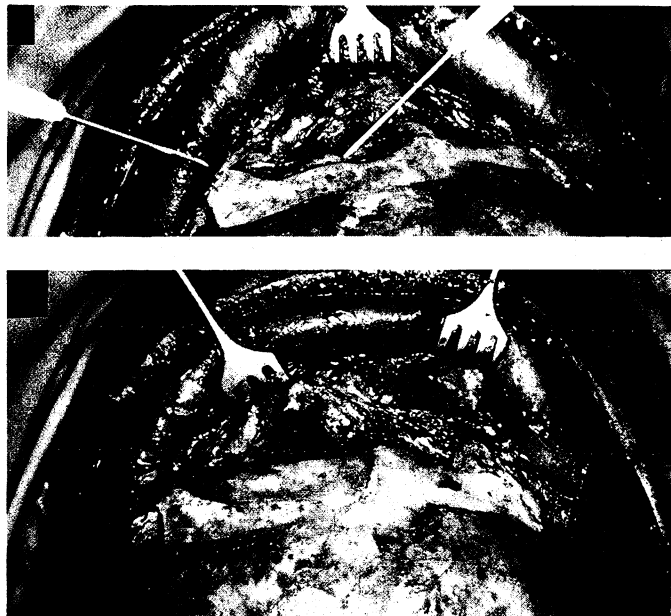


Fig 5.—Top left, Defect of forehead and orbital margin on left in condition following operation of mucocoele due to trauma. Patient did not desire correction of defective eye position. Bottom left, Two years after metopoplasty with porous polyethylene (PE) implant. Top right, Filling of forehead defect with iliac crest bones after preparation of scalp flap. Fixation of bone chips with fibrin glue. Bottom right, Final profiling of forehead with PE plate.



Fig 6.—Left, Roentgenogram of forehead defect depicted in Fig 5. Right, 1 1/2 years postoperatively. Increasing ossification of the cavity.

dences a considerably more stable bony anchorage than the combination of Teflon and carbon fibers and maintains its form and structure (Fig 2).

Consequently, PHDPE offers favorable preconditions for application in the reconstruction of facial-skull defects, particularly since this synthetic is easily formable, not only with

the scalpel but also thermoplastically.

We first applied PHDPE of German origin in 1982 for correction of a forehead defect after a mucocoele operation. The desired profile was formed on a plaster cast, and then a 2-mm thick polyethylene plate of corresponding size was shaped by pressing

it to the plaster model at about 130 °C (Fig 3). After heating, the synthetic can also be formed by "deep drawing" (suction to the model), which may possibly be less damaging to the pores.

Surgical access to the defect is usually created via an arcuate incision behind the hairline (Fig 4). We filled the defect cavity in the patient shown in Fig 5 with fragmented iliac crest bone; the profile plate composed of PHDPE was then implanted above it and fixed with fibrin glue. This permitted a particularly symmetrical and stable reshaping of the forehead with the supraorbital projection, which would not have been possible with bone transplants alone. A year and a half after the operation, roentgenographic examinations of the nasal sinuses showed the expected ossification of the entire preoperatively visualized defect area (Fig 6).

In another case, the defect cavity under the profile plate was not filled with bone but with porous polyethylene (Fig 7). This was accomplished by using a PHDPE block with multiple perforations, which can be easily shaped to the required size intraoper-



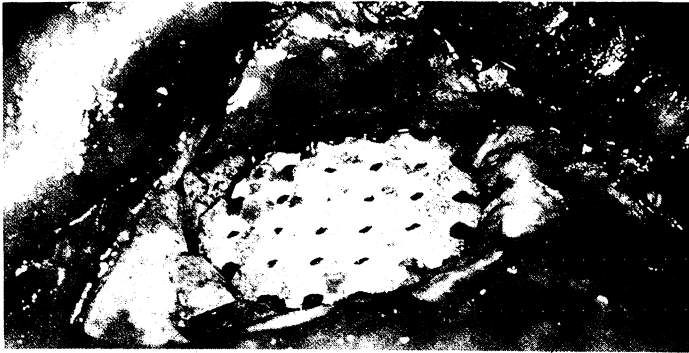


Fig 7.—Forehead defect shown in Fig 4. Top left, Filling of cavity with porous polyethylene block. Bottom left, Coverage with profile plate. Top right, Preoperative condition following osteitis. Bottom right, One year postoperatively. Smooth forehead surface.

actively with the scalpel. The drill holes facilitate ingrowth of connective tissue and bone and reduce the total mass of the synthetic, the pores of which must fill up with the ingrowing bone.

In this patient as well, follow-up roentgenograms a year later gave evidence of an osseous, or at least, a dense fibrous obliteration of the former defect cavity (Fig 8).

The synthetic can also be applied in the described manner when, after a trauma, larger fragments of the frontal bone are missing and the skin has grown directly onto the dura (Fig 9).

#### SURVEY OF RESULTS

To date, four frontal and orbital margin defects have been corrected with porous polyethylene. The defect cavity was filled with autogenic iliac crest bone in one case and with perforated blocks of PHDPE in the three other cases.

Fig 8.—Roentgenogram of defect seen in Figs 4 and 7. Top, Preoperative roentgenogram. Bottom, One year postoperatively.

The postoperative follow-up period extends from three months up to 2½ years. Complications such as infection, suture dehiscence, rejection, skin necrosis, or shifting of the implant have not been observed in any of the cases. A small seroma was tapped once shortly after the operation in only one case. In all cases, the cosmetic result was to the greatest satisfaction of both the patient and the surgeon.

#### RECONSTRUCTION OF THE EXTERNAL EAR

Reconstruction of the external ear not only requires sufficient suitable skin, but also a stable supporting





Fig 9.—Left (top and bottom), Condition following extensive trauma of facial skull. Right eye is blind. Skin of forehead grown onto dura. Top right, Profile plate used for reconstruction. Bottom right, Condition two months after metopoplasty. Correction of nose and defective eye position follow later.



Fig 10.—Shaped porous polyethylene (PE) implant under skin of rat. Adaptation of skin to form provided. Pores of synthetic filled with connective tissue (hematoxylin-eosin,  $\times 4$ ).

structure, which is expected to have the following properties: stability of shape, good tissue tolerance, a low absorption rate and the capacity for relief formation through good skin adaptation.

In a comparative experimental animal study, we tested Teflon felt, polyterephthalate velour, combination of Teflon polymer and carbon fibers, and PHDPE to determine their suitability for this purpose.<sup>4</sup> Subcutaneous

implants of these materials in rats were supposed to make possible the permanent formation of a skin fold. After a ten-month observation period, it became evident that only PHDPE fulfilled the requirements. The other synthetics failed, mainly because the supporting structures, being too soft, were pressed flat by skin tension (Fig 10).

For reconstruction of the external ear, we made a supporting frame of PHDPE and first used it in 1982 in a case where the external ear had been nearly lost due to abscess-forming perichondritis. As a result of the suppuration, the cartilage had disappeared almost completely except for a few rudiments, and only the cutaneous sheath remained (Fig 11, a). After the acute inflammation had subsided, we implanted the polyethylene framework before scarry skin shrinkage had occurred and only had to perform a minor cosmetic correction seven months later. After two

years, the external ear showed a satisfactory relief; the skin adapted well to the implant, as was to be expected from the results of the animal experiments (Fig 11, b and c).

The good formability of PHDPE makes it possible to produce delicate supporting structures adapted to the particular needs of individual cases, the ideal basic form showing no points or edges. For correction of microtia, we prefer the fan-flap technique described by Fox and Edgerton<sup>13</sup> in combination with the suction method by Cronin.<sup>14</sup>

Sénéchal et al<sup>15</sup> also reported the successful application of PHDPE-supporting structures for reconstruction of the external ear, which may obviate removal of autogenous costal cartilage if the results obtained continue to be favorable.

#### SURVEY OF RESULTS

Up to now we have used porous polyethylene four times for the recon-

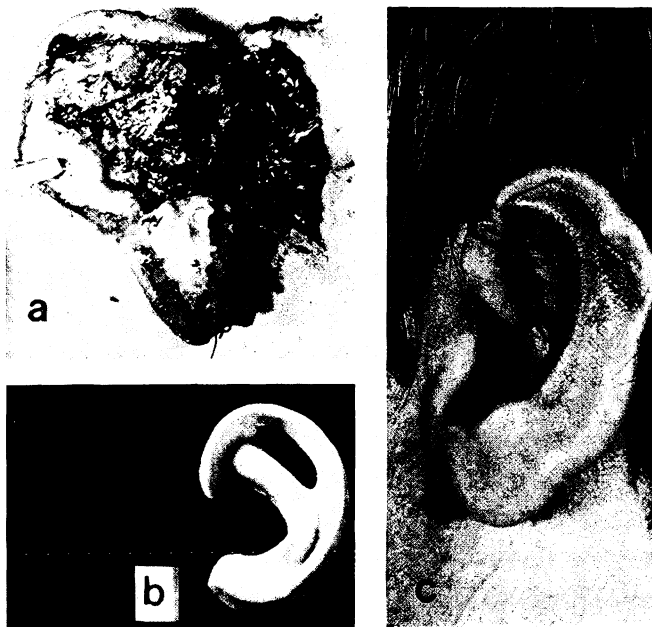


Fig 11.—Letter a shows cutaneous sheath of external ear after abscess-forming perichondritis; b, porous polyethylene framework; and c, condition two years postoperatively. After seven months, a part of implant was resected for cosmetic reasons.

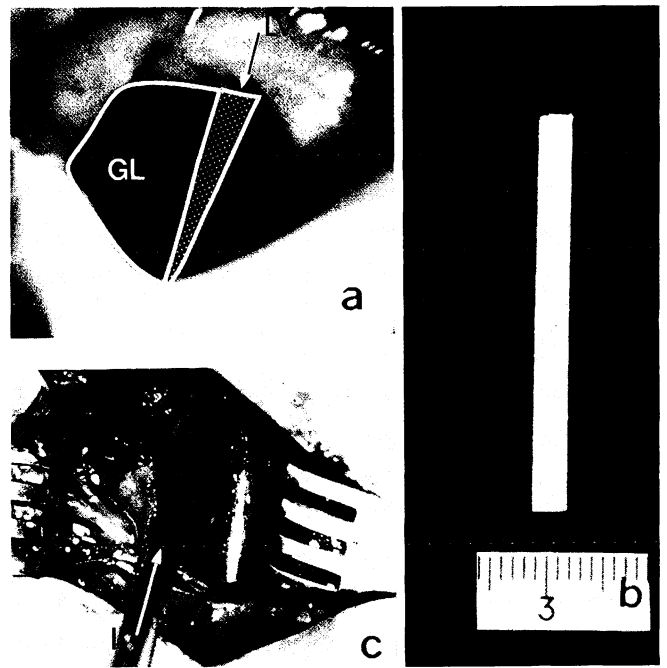


Fig 12.—Missing right vocal cord after cordectomy (a). LV indicates left vocal fold; GL, glottis. Porous polyethylene implant (b). Good view into larynx after thyrotomy with high-frequency jet ventilation (c). Instrument (I) points to prepared tunnel at level of glottis. Scale is given in centimeters.



Fig 13.—Two years after bilateral vocal-cord rebasing with porous polyethylene chips. Top, Respiratory position. Bottom, Phonatory position.

struction of external ears: after an abscess-forming perichondritis in one case; one partial,<sup>4</sup> and two complete reconstructions in microtia. The follow-up period extends from six

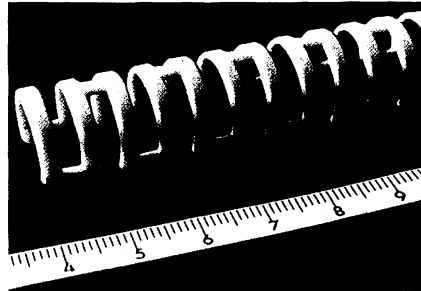


Fig 14.—Our tracheal prosthesis composed of porous polyethylene. Scale is given in inches.

months to 2½ years. In the one case of perichondritis, a small suture dehiscence was corrected shortly after the operation, but there were no further complications, in particular no skin necroses or infections. In a case of a patient with microtia, we still plan a positional correction and the formation of the tragus.

Another case of partial reconstruction of the external ear after tumor excision was a failure because the patient manipulated the wound himself immediately after the operation. This led to infection and wound healing disturbances, and soon forced us to perform an implant removal.

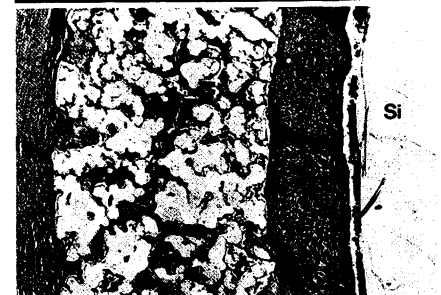
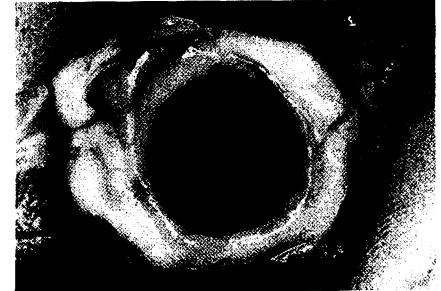


Fig 15.—Tracheal prosthesis after preimplantation in neck muscles of minipig. Lumen was kept open with silicone placeholder. Formation of inner lining. Top, Macroscopic view. Bottom, Histologic examination. Si indicates silicone placeholder (X19).

#### REBASING OF VOCAL FOLDS

Rebasing of vocal folds may be necessary for paresis of the recurrent nerve, marked hypofunctional dys-

phonia, and loss of vocal cord due to cordectomy. After several rather unsuccessful therapeutic attempts with the injection of Teflon and with silicone chips, the rebasing of vocal cords in such cases with rounded chips of porous polyethylene, which can be produced in any desired thickness and length, was introduced in our clinic. The larynx is opened by a thyrotomy for this intervention, and, at the level of the glottis, a tunnel is prepared submucosally where the PE chips are inserted (Fig 12).

### SURVEY OF RESULTS

In eight patients thus treated, including one case of bilateral rebasing, revision was only necessary once because an implant, being too large, was exposed and had to be replaced by a smaller one. Examination of the patients one and two years postoperatively showed that rebasing of vocal folds with porous polyethylene chips yielded clearly better results in connection with vocal function than injections, because the vocal cord and laryngeal mucosa fit well on the

smooth porous polyethylene surface—like the skin on the supporting frame structures for the external ear—and thus a smooth vocal cord edge develops<sup>16</sup> (Fig 13).

The good results obtained with this material could justify the performance of thyrotomy, which doubtlessly constitutes a principle disadvantage of the method. It caused no complications for any of our patients, nor were any of them bothered by the fine scar on the neck. The follow-up period extended from three to four years in seven patients and six months in one patient. Only in one case did the operation not result in an improvement of the vocal function.

### COMMENT

Several attempts at treating ozena by rebasing the lining of the main nasal cavity with PHDPE chips must be regarded as failures, just as the septum reconstruction that was also carried out with such chips, because all these implants were rejected from the nasal cavity after four weeks to one year postoperatively. We there-

fore prefer the transplantation of autogenous or conserved cartilage in the inner nose.

At the moment, we are working on an alloplastic tracheal replacement made of porous polyethylene in animals. The first results are encouraging,<sup>17</sup> however, a final assessment is not yet possible.

According to the demonstrated experiences with porous polyethylene, it seems as if this material offers a further auxiliary, beyond all known forms of application, for reconstructive measures in the head and neck area. As always when dealing with alloplastic materials, a prerequisite for successful results is, in addition to a carefully established indication, as complete as possible a coverage of the implant with healthy host tissue.

Fibrin glue was provided as "Tisseel" by the Immuno AG, Vienna. Porous polyethylene was supplied as "RCH 1000 porös" by the Ruhrchemie AG, Oberhausen, West Germany.

Heinz Rösler assisted with the experimental work, and Joanne Weirovski, PhD, helped translate and prepare the manuscript.

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