Influence of Polydioxanone Foil on Growing Septal Cartilage After Surgery in an Animal Model

New Aspects of Cartilage Healing and Regeneration (Preliminary Results)

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Objective: To determine whether late complications after septoplasty in growing septal cartilage in children can be prevented by the use of a resorbable polydioxanone (PDS) foil in combination with the cartilage.

Design: Animal study with 45 young rabbits, operated on at the nasal septum. Four typical septoplasty procedures were carried out, including elevation of the mucoperichondrium, cartilage excision, and reimplantation of crushed and noncrushed cartilage; for each of the procedures, resorbable PDS foil was used in half of the animals. Observation time ranged from 2 weeks to 5 months, to observe the healing process until complete outgrowth of the septum and complete resorption of the foil were achieved.

Setting: Ear, Nose, and Throat Department at University of Pécs, Pécs, Hungary.

Main Outcome Measure: Histomorphologic findings on specimens of septum stained with hematoxylin-eosin and periodic acid–Schiff stains.

Results: Depending on the surgical procedure, there were various degrees of differences between the groups with and without PDS. After elevation of the mucoperichondrium, there were almost no differences between the 2 groups. After cartilage resection, reimplantation, and crushing, however, there was a remarkable difference between groups. In the group without PDS, septal deviations and poorly regenerated cartilage were observed, but in the group with PDS no significant deviation after complete regeneration of septal cartilage was observed.

Conclusions: The resorbable PDS foil prevented a secondary deviation in the surgically treated growing septal cartilage in young rabbits. Use of this foil could reduce late complications such as septal deviations and possibly prevent growth inhibition in the growing nasal septum after septoplasty.

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The most typical surgical steps during septoplasty are the elevation and repositioning of the mucoperichondrium, excision of the cartilage, and reimplantation of crushed and noncrushed septal cartilage. The resulting surgical trauma is well tolerated in adults. However, in growing septal cartilage it often leads to severe late complications, such as growth inhibition of the nose and maxilla and recurrent deviations of the septum. These deformities occur because the regenerated cartilage, which is formed during the healing process, is different from the original septal cartilage. Histologically the regenerated cartilage shows smaller chondrocytes without any columnar arrangement, which is typical of original septal cartilage. In addition, an overlap and deviation of cartilage fragments due to the interlocked stresses often occurs during the healing process.

Our clinical experiences with septal reconstruction with the use of polydioxanone (PDS) foil in adults as well as our observation of experiments with the PDS foil in connection with ear cartilage in rabbits suggested that the PDS foil successfully prevents postoperative sequelae such as dislocation of the reimplanted cartilage fragments and recurrent deviation caused by overlapping of the cartilage borders.

To answer the question of whether the same effect can be expected if growing septal cartilage is supported by the PDS foil, an experimental and histologic study was performed with growing New Zealand white rabbits used as a model.

Methods

Eight groups of 5 New Zealand white female rabbits were used in this experimental study. The animals were operated on under general anesthesia with ketamine hydrochloride, 100 mg/kg intramuscularly. The nasal septum was approached via the nasal dorsum. The operation field was infiltrated with 1 mL of 1% lidocaine hydrochloride with epinephrine 1:100000. After a vertical skin incision, the na-
The nasal bones were separated in the sutura internasalis (Figure 1A). The bones were spread out to a distance of 5 mm, without further trauma (Figure 1B). This technical modification of the approach allows the integrity of the mucoperichondrium on both sides to be preserved, which prevents local infections and makes any nasal packing unnecessary.

The mucoperichondrium was separated from the dorsal border of the septal cartilage and elevated on both sides over the middle third of the septum. In group 1A, the mucoperichondrium was simply elevated and repositioned; in group 1B, a 15 × 15-mm square of PDS foil (Ethicon, Norderstedt, Germany) was inserted under the mucoperichondrium on the left side.

For the other groups, the following cartilage work was performed after a subperichondrial tunnel was created on both sides: In group 2A, a 10 × 10-mm piece of cartilage of the middle third was resected (after elevation of the mucoperichondrium) without reimplantation and the mucoperichondrium was repositioned. In group 2B, the resulting cartilage defect was covered with a 15 × 15-mm PDS foil on the left side without special fixation.

In group 3, a 10 × 10-mm piece of cartilage was resected, trimmed to the size of the defect (which became smaller because of the interlocked stresses) to achieve an end-to-end connection, and reimplemented (group 3A) or sutured onto a PDS foil (15 × 15 mm) and reimplemented together (group 3B).

In the last 2 groups, the resected piece of cartilage was crushed and shortened before reimplantation without (group 4A) and with (group 4B) PDS foil.

The animals were killed 2, 4, 10, 16, and 25 weeks after surgery. For histologic examinations, the septa were resected in a block with parts of the bony palate and the nasal bones and fixed in 5% formaldehyde. The specimens were cut horizontally to make sure that the area operated on was included completely, cut in serial 4-µm sections, and stained with hematoxylin-eosin and periodic acid–Schiff. By light microscopic examination, we wanted to investigate the following questions concerning the healing process: Is the PDS foil a scaffold for regenerated cartilage? Is the PDS foil able to prevent overlapping of cartilage fragments? Is there an effect on the histologic properties of the newly formed cartilage?

**RESULTS**

In group 1 there were no significant differences in histologic reactions between the animals with and without PDS. After 2, 4, and 10 weeks, the foil did not show microscopic resorption, and the surrounding tissue reaction was similar to that in the animals without PDS.

After 16 weeks in the animals without PDS, there were no further histologic reactions to observe. The mucoperichondrium was of normal thickness and the cartilage was histologically unchanged. In group 1B, the PDS foil was already partially resorbed, with persisting fragments of PDS surrounded by a thin layer of fibrous tissue without inflammatory reaction. The cartilage was unchanged as well. After 25 weeks, the PDS foil was completely resorbed. Beneath the normal cartilage, only very thin remnants of scar tissue, practically without thickening of the septum, were observed.

In group 2, the essential difference between the 2 subgroups was that, after resection of septal cartilage, in group 2A the 2 layers of mucoperichondrium were in direct contact, but in group 2B the mucoperichondrium was separated by the PDS. After 2 and 4 weeks there were no notable differences in histologic reactions of remaining cartilage and surrounding tissue. In both subgroups, proliferative reactions between the mucoperichondrium blades occurred, with a growing tendency for cell differentiation into chondroblasts. After 10 weeks, in both sub-
groups regenerated cartilage occurred, but the chondrocytes were smaller and without a columnar arrangement. In later specimens, an obvious morphologic alteration between the subgroups was found: without PDS the newly formed cartilage often developed secondary deviations, which was remarkably reduced with PDS. 

In group 3A, 4 weeks after surgery the reimplanted cartilage grafts often showed an overlap in the area of the cut edges, although this area was firmly covered by the mucoperichondrium on both sides. The beginning cartilage regeneration caused development of new deviation. In group 3B the PDS foil stabilized the free graft and prevented overlapping.

In group 4, the most significant morphologic and histologic differences were found. The early results of the 2 subgroups after 2 and 4 weeks were again quite similar, but after 10, 16, and 25 weeks the differences were increasing: in group 4A, without PDS, in the area of the reimplanted crushed cartilage, the regenerated cartilage caused various degrees of deviations (Figure 4A). In areas where the crushed cartilage was resorbed, new bone formation occurred (Figure 4B). In group 4B, with PDS, the crushed cartilage healed almost without a trace (Figure 5).

**COMMENT**

Elevation of the mucoperichondrium, excision, reimplantation, and crushing of cartilage are standard procedures in septoplasty. The consequence of these procedures for septal surgery in children has been investigated in previous studies.

In this recent research project, the effect of the use of resorbable PDS foil was studied in the above-mentioned standard septoplasty procedures, because this material seems to meet most of the criteria for ideal implants for guided tissue regeneration.

The elevation of the mucoperichondrium does not induce significant histologic reactions and has no effect on the growth of the septal cartilage. The PDS foil inserted on one side of the cartilage causes no significant change in these reactions, and after 25 weeks, after complete resorption of the foil, almost no fibrous scar tissue was found, so there was no thickening of the septum.

After elevation of the mucoperichondrium in combination with cartilage resection, regeneration occurs and forms a bridge between the anterior and posterior fragments of the original cartilage. Even after 25 weeks, however, this newly formed cartilage remains histologically different from the original cartilage, with smaller chon-
drocytes and without any columnar arrangement. This type of cartilage has a tendency to bend, causing secondary septal deviations. The insertion of PDS foil after cartilage resection that covers the area of the cartilage defect seems to provide a sort of guide for the regenerated cartilage. This helps to substantially decrease the early secondary deviation of the newly formed cartilage. It even seems to have an effect on the histologic appearance of this regenerated cartilage, because in some specimens we could find no difference between the original and regenerated cartilage.

After resection and reimplantation of the original septal cartilage as a free graft, there is always a tendency toward overlapping and angulation between the original septal cartilage and the graft.2 The cut edges stay covered with fibrous tissue, thus representing a permanent weak point of the septum. The specimen with PDS foil showed that the foil works as scaffolding material and prevents early secondary deviations. In some specimens even the cut edges could not be identified after 25 weeks, as an entire plate of septal cartilage had developed. After complete resorption of the foil, almost no scar tissue was left.

After implantation of crushed cartilage grafts, the connection between the graft and the original cartilage is always better, as we know from former studies.5,10 Secondary deviations, however, occur as a result of bending of the cartilage graft itself. This bending can be reduced significantly by combining the crushed cartilage with a PDS foil, which supports the graft as a guide.

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REFERENCES