Yonsei Medical Journal
Vol. 31, No. 4, 1990

An Experimental Study on Prevention of Postlaminectomy Scar Formation

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In repeat lumbar surgery for failed back syndrome, well organized fibrous scar tissue is often noted, binding together the dura, nerve roots, and paraspinal muscles. An animal experimental study was done to investigate the prevention of scar formation after lumbar laminectomy by using dacron and sodium hyaluronate. The experimental animals consisted of three groups: 1) control group, 2) D group (covering the laminectomy defect with dacron sheet), and 3) H group (covering the laminectomy defect with sodium hyaluronate gel). Animals were sacrificed at varying intervals (3-12 weeks) and the lumbar spines were evaluated with histologic preparations. Scar adhesion to the dura was most significantly suppressed in the D group, followed by the H group and the control group.

Key Words: Cicatrix, laminectomy, prevention, dacron, sodium hyaluronate

Scar formation about the dura mater and nerve roots after lumbar disc surgery is one of the most common troublesome complications and is an important cause of poor results (Benner and Ehni 1978; Buroon 1978; Gill *et al.* 1979; Yong-Hing *et al.* 1980). To date many authors have carried out studies to prevent postlaminectomy scar formation by using various interposing biologic or nonbiologic materials. The nonbiologic materials used in experimental stuides are absorbable gelatine sponge, silastic membrane, polylactic acid membrane, methylmethacrylate, and Kiel bone (LaRocca and Macnab 1974; Barbera *et al. 1978; Mikawa et al.* 1986). The biologic materials used in studies are free fat graft, pedicle fat graft, ligamentum nuchae, and ligamentum flavum (Gill *et al.* 1979; Yong-Hing *et al.* 1980).

In general, the nonbiologic materials that were used as interposing membranes to prevent scar extension into the spinal canal and to prevent scar formation about the dura and nerve roots were found to be ineffective (Yong-Hing *et al.* 1980), contrary to the earlier report by LaRocca and Macnab (1974). The animal experimental studies using biologic materials of free or pedicle fat graft and ligamentum nuchae reported these materials to be effective in the prevention of scar formation (Langenskiold and Kiviluoto 1976; Jacobs *et al.* 1980; Yong-Hing *et al.* 1980). But the disadvantages of the use of the biologic materials were the prolonged operation time and some postoperative wound problems. This multiplicity of procedures available is clear evidence that none is absolutely satisfactory; thus, the search for more satisfactory results continues.

This report presents the results of an experimental study implemented for the purpose of preventing scar formation in rabbits after laminectomy by the use of new biomaterials.

MATERIALS AND METHODS

Forty-five adult white rabbits weighing 2.5-3.0 kg were stuided. Dacron purchased from Meadox Chemicals, Inc. and sodium hyaluronate purchased from Pharmacia were used. After the animals were anesthetized intravenously with phenobarbital, they were placed on the table in the prone position. A midline incision was made posteriorly in the lumbar region and laminectomy of L4 was performed in the usual manner. Bleeding from the paraspinal muscles and epidural vessels was controlled with a bipolar coagulator. The ligamentum flavum and epidural fatty tissue were excised carefully.

Received February 6, 1990
Accepted July 5, 1990
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The animals in the three groups were sacrificed at varying intervals of three, six, and twelve weeks after the operation. The lumbar spines were removed with en bloc excision and were fixed in a formalin solution and decalcified. Horizontal sections of each laminectomized portion of L4 were made and prepared for histologic evaluation by hematoxylin-eosin and Masson's trichrome stainings. The histologic sections were interpreted by ourselves under the quidance of the pathologist in our hospital.

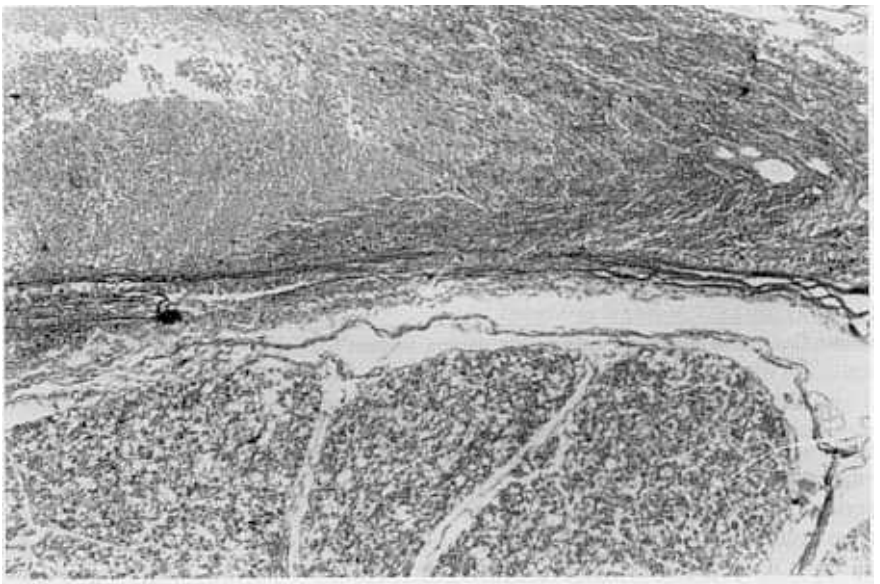

Fig. 1. Three weeks after the operation. Laminectomy membrane can be observed adhering to the dura (H-E stain, ×40).

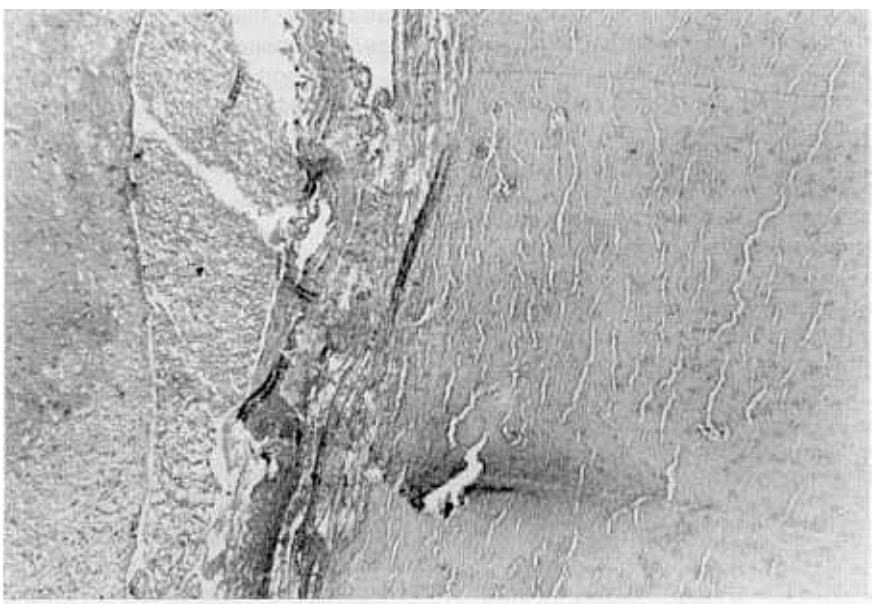

Fig. 2. Twelve weeks after the operation. Thick and hard scar tissue adheres strongly to the dura (H-E stain ×100).

RESULTS

Control Group

Three weeks after the operation, a rather coarse tissue, which could be called laminectomy membrane. was observed adhering to the dura in the control group (Fig. 1). Twelve weeks later, this laminectomy membrane became dense, thick, hard scar tissue adhering strongly to the dura (Fig. 2). The scar con-

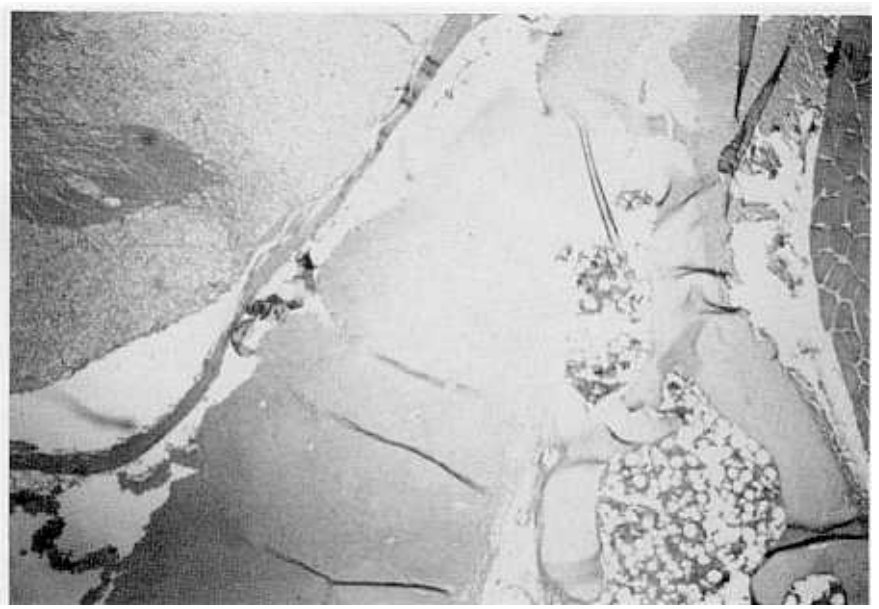

Fig. 3. Twelve weeks after the operation. Scar tissue invades the canal and extends beneath the lamina (H-E stain, ×40).

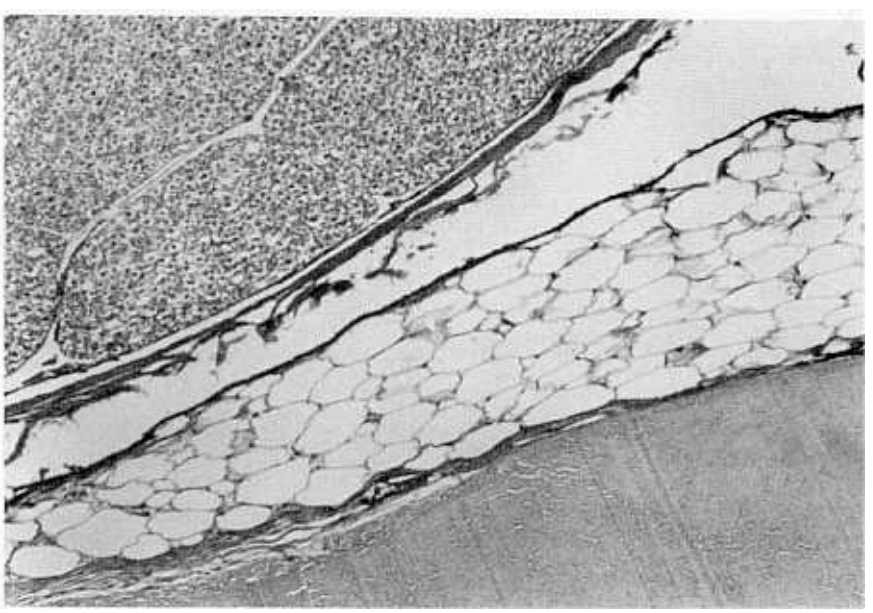

Fig. 4. Twelve weeks after the operation. Epidural fatty tissue serves as an excellent barrier between the scar tissue and the dura (H-E stain, ×100).

sisted of fibrous connective tissue which originated from the bone edges at the laminectomy margins and the posterior paraspinal muscles. Invasion of the scar tissue into the vertebral canal was also noted (Fig. 3). In the case of the animal in which the natural epidural fatty tissue was left during the operation, the dura and nerve roots were not adhered to the scar tissue (Fig. 4).

D Group

Three weeks after the operaton, the dacron sheet

Fig. 5. Three weeks after the operation. The dacron sheet is observed, separating the dura from the scar tissue (H-E stain, ×40).

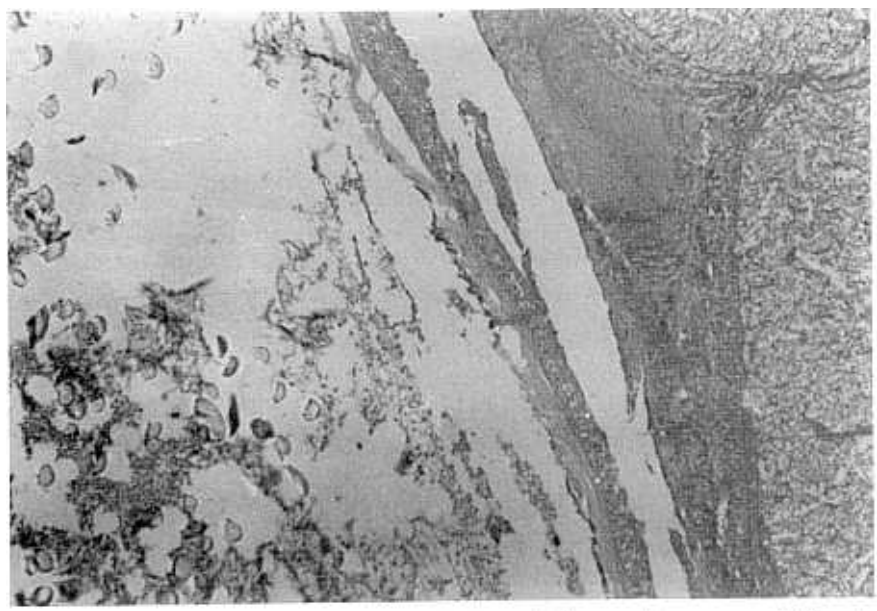

Fig. 6. Twelve weeks after the operation. Mild thickening of the dura and chronic inflammatory cell infiltration are seen (H-E stain, ×100).

was in direct contact with the dura and proliferation of the coarse tissue was observed dorsally (Fig. 5). The connective tissue had not invaded the space between the dacron sheet and the dura twelve weeks after the operation. There were no significant gross inflammatory reactions noted but some chronic inflammatory cells were observed (Fig. 6). The scar tissue was confined posterior to the sheet, protecting the dura and nerve roots from adhering to the scar tissue, and the dacron sheet was found to be structurally un-

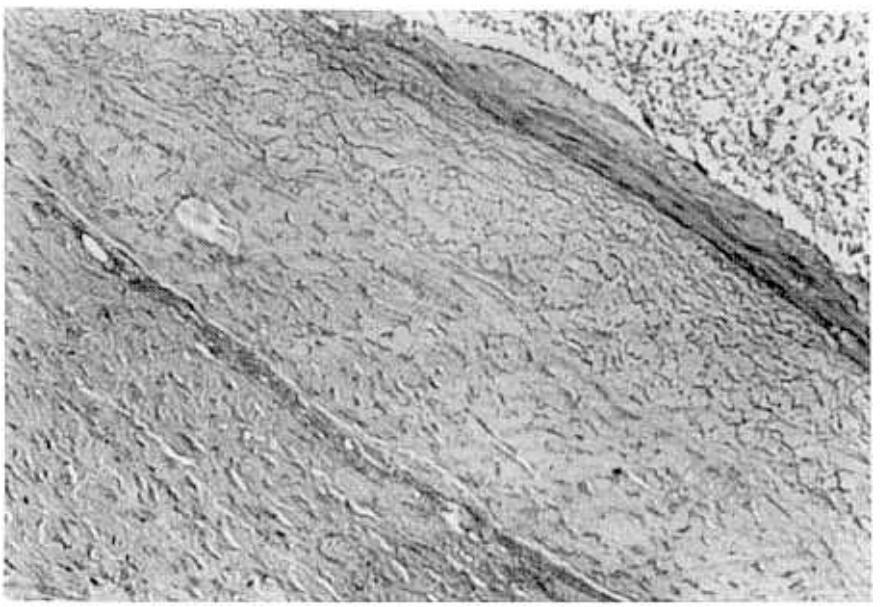

Fig. 7. Three weeks after the operation. Sodium hyaluronate acting as an effective barrier between the scar tissue and the dura (H-E stain, ×200).

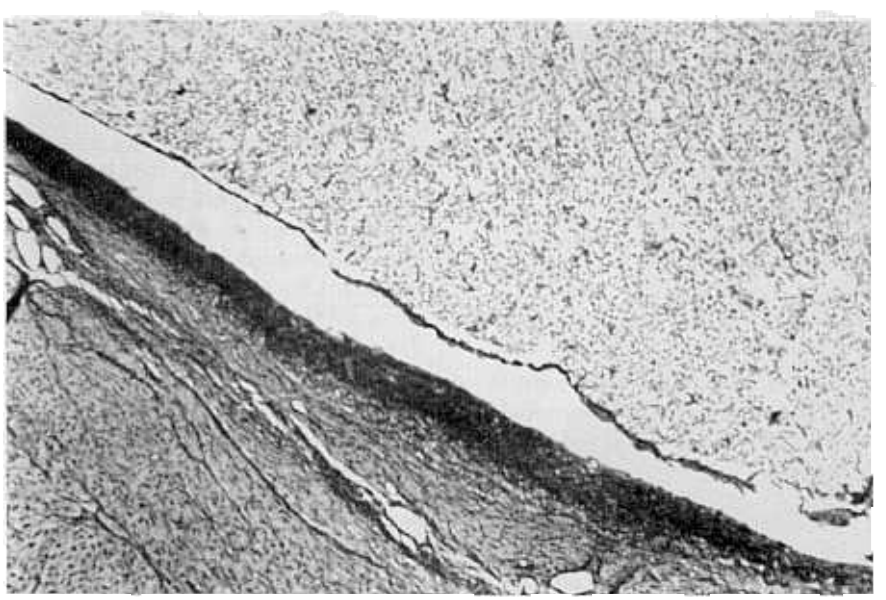

Fig. 8. Six weeks after the operation. Some resorption of sodium hyaluronate is noted (Masson's trichrome, ×100).

changed up to three months.

H Group

Three weeks after the operation, proliferation of the connective tissue dorsal to the sodium hyaluronate layer and mild hypertrophy of the dura were seen (Fig. 7). But after six weeks, absorption of the sodium hyaluronate layer was noted and adhesion of the dura to the scar tissue was also observed (fig. 8). Twelve weeks after the operation, the invading connective

Fig. 9. Twelve weeks after the operation. Sodium hyaluronate barrier is not seen and the scar tissue adheres to the dura (H-E stain, ×100).

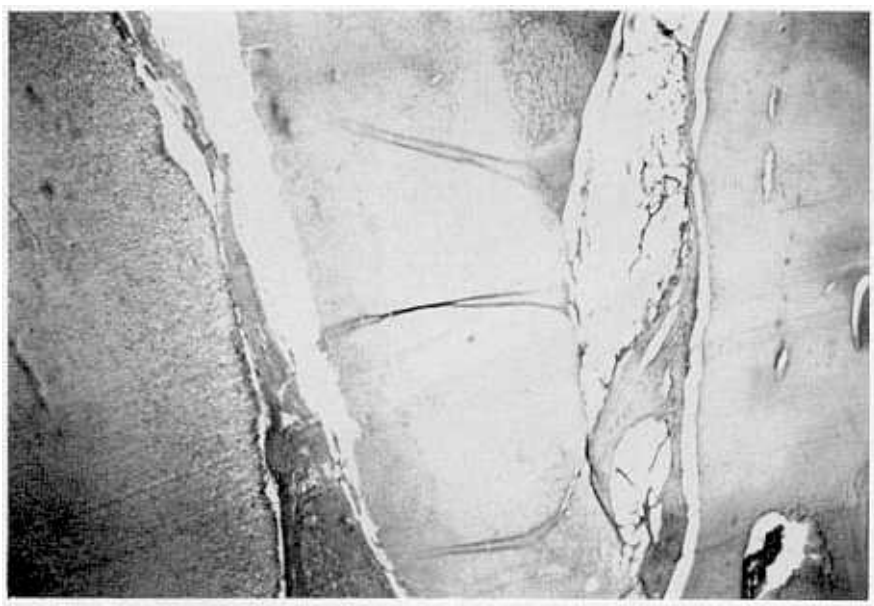

Fig. 10. Twelve weeks after the operation. Extension of the scar tissue into the spinal canal is observed (H-E stain, ×40).

tissue became dense, adhesion to the dura was observed and extension of the scar tissue into the spinal canal was noted (Fig. 9, 10).

These results indicate that scar formation is most significantly suppressed in the D group, followed by the H group and the control group.

DISCUSSION

Reexploration of the dura and nerve roots after previous laminectomy for removal of a disc often reveals the formation of well organized fibrous tissue firmly attached to the dura, at times binding down to the nerve roots to the posterior surface of the disc and the adjacent vertebral body. It is very difficult to divide the scar and the dura and this often results in tearing of the dura. Up to fifteen per cent of postlaminectomy patients have postoperative symptoms related to the scar and adhesion formation.

This laminectomy scar is formed by fibrous connective tissue ingrowth into the surgical hematoma originating from the paraspinal muscles (LaRocca and Macnab 1974). The bone edges of the laminectomy margins also contribute to a limited extent. Invasion of the scar tissue into the spinal canal is suppressed when epidural fatty tissue is present. Even if absent, however, invasion of the scar tissue into the spinal canal is not so marked, but its adhesion to the dura is severe (Jacobs *et al.* 1980). So the concept of prevention of ingrowth of the scar tissue into the spinal canal by interposing a substance between the dura and the paraspinal muscles was originally introduced by LaRocca and Macnab (1974).

Among the nonbiologic materials studied for this purpose, porous materials such as gelatine form, evitane, and collagen fibers probably act as impervious materials for scar extension into the spinal canal. But these porous materials appear to behave as a scaffolding material for fibrous tissue ingrowth (Jacobs *et al.* 1980). The biologic materials such as free fat, pedicle fat, ligamentum nuchae, and ligamentum flavum were found to be a superior mechanical barrier for preventing scar adhesion to the dura (Yong-Hing *et al.* 1976; Gill *et al.* 1984). But these grafting procedures have some technical difficulties and post-operative complications.

Dacron is a fabric commonly used in the field of orthopedic and cardiovascular surgery. It has two-sided, texturized velour pile and enhances tissue encapsulation with a smooth surface. Sodium hyaluronate is a physiologically compatible and noninflammatory material. It is commonly used in cataract surgery due to its high viscoelasticity. It maintains a space for surgical maneuvering and separates synechiae in closed space. Its molecular weight is 1.9-3.9 million.

The membrane form of dacron is a good impervious material for exclusion of hematoma from the spinal canal. This causes no adherence to the neural elements, but sometimes moderate inflammatory reactions are found. We consider this inflammatory reaction as a foreign body reaction, not a phenomenon caused by an infection. The other membranous forms of nonbiologic materials were found to have scar tissue invasion through the gap between the membrane and the laminectomized edges (LaRocca and Macnab 1974). The dacron membrane used in this study did not indicate such problems.

The effectiveness of sodium hyaluronate in preventing postlaminectomy scar formation was recently presented by Weiss *et al.* (1989). We also conducted experiments using sodium hyaluronate at about the same time. In our experiments, sodium hyaluronate was an excellent barrier for invasion of scar into the spinal canal in the early stage. However, in the late stage, this material was absorbed to from an adhesion of the scar tissue to the dura. We think that the differences of results between us and Weiss *et al.* (1989) was caused by the amount of sodium hyaluronate that was implanted or by the different chemical structures.

Another observation confirmed from this study was postoperative narrowing of the spinal canal in the control and H group. The scar tissue occupied the posterior one-third or lateral space of the spinal canal, and resulted in compression of the spinal cord. The massive scar tissue was resting on the neural element. We think that this is a significant factor in postlaminectomy spinal stenosis. However, we could not observe scar induced postoperative narrowing of the spinal canal in the D group. We think that this phenomenon is caused by the slightly stiff character of dacron.

While the fat graft has been reported to be excellent in the prevention of scar formation after laminectomy (Gill *et al.* 1979; Jacobs *et al.* 1980), the dacron sheet provides an effective mechanical barrier between the overlying scar tissue and dural elements and serves to reduce postlaminectomy scar and adhesion formation.

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