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# PROCESSED CORTICAL BONE FOR INTERNAL FIXATION IN LUMBOSACRAL ARTHRODESIS

## *An Application of the Distraction-Impaction Principle to Increase the Intervertebral Canal and Disc Spaces*

*By*

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Surgeons everywhere value the works of the distinguished professors of orthopaedics, *Gunnar Wiberg & Sten Friberg,* on the subject of low back pain. *Wiberg* (16, 29–32) described the nerve supply of the intervertebral discs and results of laminectomy for lumbar protrusions, and *Friberg* (11–14) analyzed the pathogenesis and surgical treatment of congenital and acquired defects of the lumbosacral spine. These two investigators have dealt with all the important questions that are under intensive investigation in orthopaedic clinics everywhere in the world. The following three questions are of great interest at this time when many patients are appearing with degenerative joint disease and large bone defects following laminectomy. Is it possible to restore the intervertebral canal and disc spaces and produce arthrodesis at the same time? Assuming an arthrodesis relieves pain, what is the surgical procedure that will succeed in the highest percentage of patients? Can internal fixation be obtained by mortised implants of bone?

A new material has recently been introduced for spinal fusions. This is designed to provide guaranteed sterility, minimal antigenicity, unlimited period of storage, and ready availability. In previous investigations, such material was described as collapatite, a derivative of bone,

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consisting of collagen with its apatite mineral, to be used as a substitute for metal for internal fixation of fractures. The surgical procedure in which processed bone is used is similar to that advocated by *Friberg* on the basis of the end-result study by *Unander-Scharin* (1950); this consists of iliac autografts between spinous processes, intervertebral arches and joints, except that an implant in the form of an "H" block is added for internal fixation. The block is not a substitute for warm, viable, autogenous graft, but serves as a physical-chemical-mechanical scaffold.

## METHODS AND CASE MATERIAL

The method of processing of homogenous or heterogenous cortical bone to retain the collagen and apatite and exclude as much as possible of the extrafibrillar and intracellular protein, described in a previous report (26, 27), was employed in the first 10 cases. Bovine heterogenous bone (*Boplant, Squibb*), prepared by new and improved methods by procedure of Dingwall and his associates, was implanted in the succeeding 18 cases. This processed bone is now under investigation in all kinds of experimental animals and orthopaedic cases (*Anderson et al.* 1962, *Bassett et al.* 1962).

Twenty-eight patients with severe low back pain caused by degenerative disc and joint disease, or spondylolithesis, were treated, either *per primam* or as a secondary procedure following removal of the nucleus pulposus by surgical fusion of the posterior elements of the lumbosacral region. In general, the method consisted of:

1) midline dorsal incision, for decortication or "fish-scaling" of the lamina as in a classical Hibbs fusion;
2) lifting of the dorsal cortex of the facets;
3) matchstick autogenous grafts into 1.5 mm. transarticular drill holes through the center of the facets while the spine is in acute flexion;
4) carving a groove in the base of the spinous processes including the lamina of the first sacral vertebra;
4) transfer of fresh autogenous bone from the crest of the ilium by extending the dissection lateralward along the lumbosacral fascia through the same incision;
6) placement of a carpet of strips and a thin "H-shaped plate" of iliac bone between the lamina of the lower lumbar vertebra and the sacrum;
7) implantation of a block of processed cortical bone (*Boplant*) mortised as close as possible to the base of the spinous processes with the spine in flexion and with the aid of lamina spreading forceps to produce maximum distraction or separation of posterior elements of the vertebra;
8) early ambulation in a firm corset.

To avoid weakening and possible fracture of the spinous processes, the notches are prepared as close to the base as possible and only the minimum amount of bone is removed with a small rongeur. When the thick block (0.8 cm.) of processed cortical bone is placed above the thin block (0.15 cm.) of fresh autogenous bone, there

TABLE 1

*Summary of 28 patients with internal fixation with blocks of processed bone for arthrodesis of the lower lumbar spine.*

| Name | Age | Diagnosis | Date of operation | Sites of arthrodesis | Current status |
|---|---|---|---|---|---|
| A.F.H. | 26 | Old laminotomy | 2.17.59 | $L_5$–$S_1$ | Pain free |
| J.K. | 33 | Spondylolisthesis | 4.14.59 | $L_4$–$L_5$–$S_1$ | Pain free |
| V.R. | 69 | Spondylolisthesis, spondylosis, scoliosis | 5.25.59 | $L_3$–$L_4$ | Unimproved |
| G.R. | 40 | Old laminotomy | 5.18.59 | $L_4$–$L_5$–$S_1$ | Improved |
| C.L. | 43 | Laminotomy arthrodesis *per primam* | 9.22.59 | $L_4$-$L_5$–$S_1$ | Pain free |
| A.K. | 40 | Old laminotomy | 11. 1.59 | $L_4$–$L_5$–$S_1$ | Improved |
| L.N. | 36 | Old bilateral laminectomy | 11.17.59 | $L_4$–$L_5$–$S_1$ | Improved |
| D.A. | 50 | Old laminotomy, spondylosis | 12.16.59 | $L_4$–$L_5$–$S_1$ | Improved |
| J.McG. | 50 | Spondylolisthesis | 2. 1.60 | $L_4$–$L_5$–$S_1$ | Unimproved, wound infect. |
| B.B. | 62 | Old laminectomy | 2. 2.60 | $L_3$–$L_4$–$S_1$ | Pain free |
| J.F.R. | 45 | Old laminectomy | 2. 4.60 | $L_4$–$L_5$–$S_1$ | Pain free |
| H.W. | 28 | Laminotomy and arthrodesis *per primam* | 3.29.60 | $L_4$–$L_5$–$S_1$ | Pain free |
| H.B. | 49 | Old laminectomy and arthrodesis $L_5$–$S_1$ | 5.31.60 | $L_4$–$L_5$ | Unimproved |
| B.B. | 48 | Old laminotomy | 5.10.60 | $L_4$–$L_5$–$S_1$ | Unimproved |
| F.E. | 40 | Laminotomy *per primam* spondylosis | 6.30.60 | $L_4$–$L_5$–$S_1$ | Unimproved |
| D.McC. | 44 | Laminotomy and arthrodesis *per primam* | 9. 7.60 | $L_4$–$L_5$–$S_1$ | Pain free |
| R.H. | 33 | Laminotomy and arthrodesis *per primam* | 11.28.60 | $L_5$–$S_1$ | Pain free |
| T.C. | 29 | Laminotomy and arthrodesis *per primam* | 12. 8.60 | $L_4$–$L_5$–$S_1$ | Pain free |
| E.M. | 37 | Laminotomy and arthrodesis *per primam* | 2.16.61 | $L_4$–$L_5$–$S_1$ | Pain free |
| L.P. | 37 | Old laminotomy, $L_4$ | 5. 2.61 | $L_4$–$L_5$–$S_1$ | Improved but not pain free |
| M.A. | 53 | Laminotomy and arthrodesis *per primam* | 5.18.60 | $L_5$–$S_1$ | Pain free |
| C.S. | 41 | Laminotomy and arthrodesis *per primam* | 6.26.61 | $L_4$–$L_5$–$S_1$ | Too recent to evaluate |
| V.W. | 25 | Laminotomy and arthrodesis *per primam* | | $L_4$–$L_5$–$S_1$ | Too recent to evaluate |

TABLE 1 (cont.)

| Name | Age | Diagnosis | Date of operation | Sites of arthrodesis | Current status |
|---|---|---|---|---|---|
| J.F. | 46 | Laminotomy and arthrodesis *per primam* | 8.28.61 | $L_4$–$L_5$–$S_1$ | Too recent to evaluate |
| T.B. | 15 | Spondylolisthesis, $L_5$ | 11.10.61 | $L_4$–$L_5$–$S_1$ | Too recent to evaluate |
| J.L. | 34 | Laminotomy and arthrodesis *per primam* | 1.11.62 | $L_5$–$S_1$ | Too recent to evaluate |
| C.B. | 42 | Laminotomy and arthrodesis *per primam* | 2. 8.62 | $L_4$–$L_5$–$S_1$ | Too recent to evaluate |
| R.F. | 36 | Laminotomy and arthrodesis *per primam* | 2. 9.62 | $L_5$–$S_1$ | Too recent to evaluate |

TABLE 2

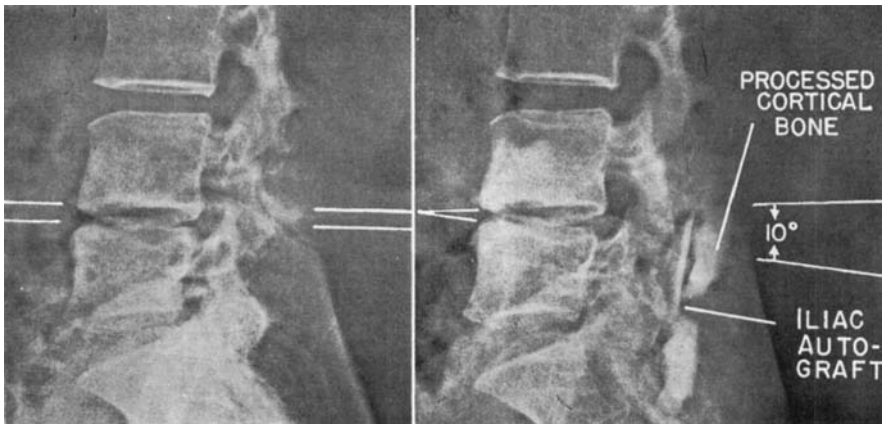
*Summary of 28 lumbosacral fusion operations.*

| Diagnosis | No. | No. pain free | No. Improved | No. Unimproved | % Failure |
|---|---|---|---|---|---|
| Spondylolisthesis | 4 | 2 | 1 | 1 | 25 |
| Old laminectomy | 4 | 2 | 0 | 2 | 50 |
| Old laminotomy | 6 | 1 | 4 | 1 | 16 |
| Laminotomy and fusion *per primam* | 7 | 6 | 0 | 1 | 14 |
| Laminotomy and fusion *per primam* (too recent to evaluate) | 7 | – | – | – | |

appears to be excellent, although probably not absolute, internal fixation. When the spinous process of the first sacral vertebra is underdeveloped or absent, as in patients with spondylolisthesis, a prong or groove is sculptured out of the lamina of the second sacral vertebra to engage the blocks.

## RESULTS

Table 2 summarizes the short-term results in 28 consecutive patients presenting both complicated and uncomplicated problems. The number of cases is too small and dissimilar to evaluate the treatment but the effects of the method are interesting. The blocks sustained the spaces of the posterior portion of the disc and the intervertebral canal. An increase of as much as one millimeter may occur without any demon-




*a.* *b.*

*Fig. 1a.* Lateral view radiograph of the lumbosacral spine of C.L., a 43 year old woman, with degenerative joint and 4th lumbar intervertebral disc disease. Note the circumferential bony lip at the attachment of the annulus fibrosis and the anterior longitudinal ligament.

*Fig. 1b.* Radiograph of the case shown in Fig. 1a, illustrating the placement of the autogenous iliac bone and processed bone blocks, and the enlargement of the intervertebral canal and the posterior intervertebral disc space, 2 weeks after the operation. The angle of elevation in the vertebral body is from 0° to approximately 10°.

strable change in the radiographs. In some cases, it is clearly visible that the block can spread open or increase the posterior space of the intervertebral disc as well as enlarge the intervertebral canal, and at the same time produce a solid, painless arthrodesis of the spine between the fourth lumbar vertebra and the sacrum (Figs. 1 A to F). The fifth lumbar space generally is unchanged but in patients in which the joints are freely movable, spreading occurs at the fourth lumbar interspace. The disc spaces and the joints of the first, second, and third lumbar vertebra do not appear to respond or decrease in thickness.

The radiographic appearance of the blocks of processed bone observed at various intervals from 1 to 3 years after the operation is the same as that of autogenous or homogenous *cortical* bone. Where the implant becomes incorporated in new bone, the sharp corners of the block become round and irregular in outline (Fig. 1 F).

The early results of the operation show an interesting trend in the following direction. Patients with spondylolithesis or recovering from old laminectomy operations may or may not obtain relief of backache.

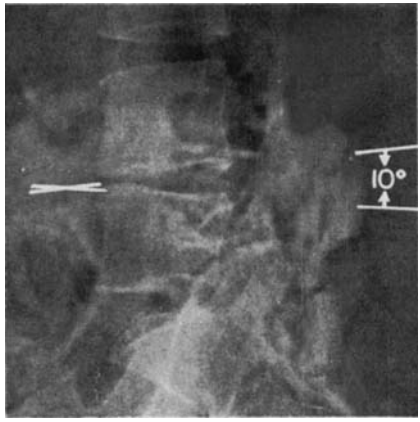



*Fig. 1c.*
Radiograph of the same case as shown in Figs. 1a and 1b showing sustained distraction and fusion of the posterior elements of the lumbosacral spine, two and one-half years after operation.

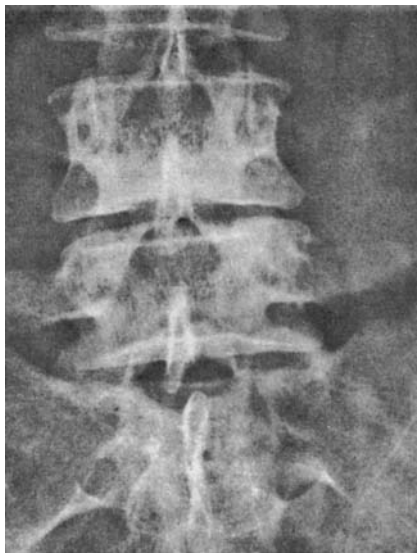


*Fig. 1d.*
Radiograph in the anteroposterior view of the case shown in Figs. 1a to 1c. The 4th lumbar intervertebral disc space is markedly less than that of the 3rd and there is a bony lip on the right superior rim of the 5th lumbar vertebral body.

Patients with laminotomies, particularly those having an arthrodesis *per primam,* or at the time of excision of an intervertebral disc, have a relatively good outlook for either cure or improvement. *Bosworth* (1948) emphasized the fact that the percentages of solid fusion were high in the single interspace fifth lumbar operations and relatively low in procedures that include the fourth lumbar interspace. In the series listed in Table 1, in which 23 of the 28 cases extended from fourth lumbar vertebra to the sacrum, the early results were 14 to 16% symptomatically unimproved patients. It is necessary to perform 5-year follow-up examinations to compare these early results with end-results statistics reported in the literature (3, 7, 17, 21). Some patients with a pseudarthrosis will be relieved of symptoms while others may not. In the patients that are unimproved, it has been assumed the re-exploration is the only positive way to demonstrate that a pseudarthrosis does or does not exist (*Bosworth* 1948). One case (J. McG.), a man with an unexplained postoperative wound infection, required reopera-

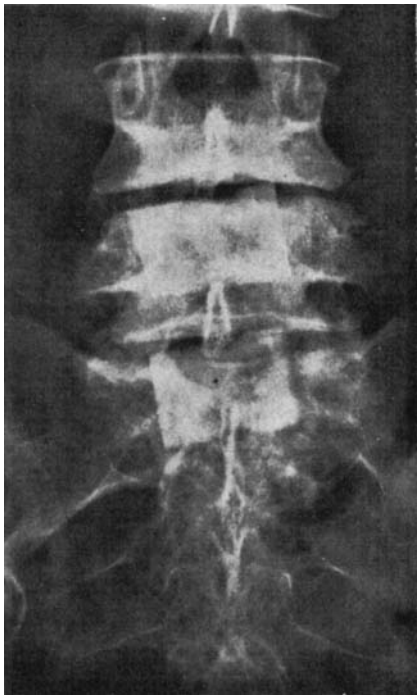


*Fig. 1e.*
Postoperative radiograph of the blocks of processed bone or collapatite (*Boplant*, Squibb) between the 4th and 5th lumbar spinous processes, shown in Fig. 1b.

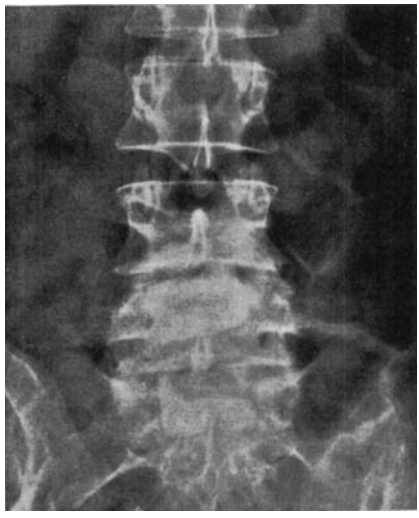


*Fig. 1f.*
Radiograph of the case shown in Figs. 1a to 1e, two and one-half years after operation. Note the resorption of the corners of the block between the 4th and 5th lumbar vertebra. The processed bone is resorbed more slowly than underlying autogenous bone grafts that are seen in Fig. 1b. Note the obliteration of the intervertebral joints.

tion; the processed bone blocks were unfused and enveloped in inflammatory fibrous connective tissue. The implants were removed; an intertransverse process arthrodesis will be attempted at some future date.

## DISCUSSION

The capacity of an implant to produce arthrodesis is determined by several factors. The first and most important is the osteogenetic activity of the host bed (*Urist et al.* 1953, 1958, 1960). The second is fresh autogenous cancellous bone with the capacity to produce an outgrowth of osteogenetic cells (*Abbott et al.* 1947); (*Urist & McLean* 1952). The third is the adverse effect of donor tissues that evoke immune responses from the host. The literature on the third factor with specific refe-

rence to bone has appeared for the most part in recent years (*Burwell & Gowland* 1962). *Billingham, Brent,* and *Medewar* 1956, and *Medewar* 1959, proposed that antigens appeared in two forms: H-antigens, which are relatively stable amino acid complexes and provoke the formation of humoral or serum antibodies, and T-antigens, which are relatively labile DNA protein complexes and evoke the production of cell bound antibodies. Transplantation immunity is mediated by antibodies produced by T-antigens and carried by lymphoid cells ( *Medewar* 1959). The chief source of T-antigen from homogenous iliac cancellous bone is the DNA of the chromosomes of the nucleated cells of the red bone marrow (*Burwell & Gowland* 1962). Quantitatively there is much less antigen in cortical bone (*Weinberg et al.* 1959) after it has been scraped free of periosteum and marrow. The osteocytes buried in the interior of cortical bone retain their nucleoprotein and are protected from contact with antibody-bearing lymphoid cells.

*Homogenous or Heterogenous Processed Bone.* The removal of the non-collagenous, especially nucleoprotein from homogenous or heterogenous bone, may be assumed to quantitatively reduce the capacity of the donor tissue to evoke immune responses. In 1934, when very little was know about tissue antigen, in order to produce a readily available source of bone, *Orell* processed calf bone by defatting in acetone and extracting proteins, including collagen with salt solutions and warm potassium hydroxide, and named it *Os Purem.* In 1952, *Orell* abandoned *Os Purem* because of its "slow osteogenetic activity", preferred a granulate of whole bone frozen at -190° and recommended that the latter be used in combination with metal or cortical bone for fixation.

*Local, Physiologic and Technical Factors.* Autogenous bone grafts in liberal quantity are absolutely essential for a strong arthrodesis, but local factors such as immobilization and contact compression with the host bed are very important. While stored homogenous and heterogenous bone often succeed in fusions of the dorsal spine in children, failure has been reported in a high percentage of cases in the low back in adults. After growth ceases, even a fresh autogenous bone graft sometimes develops a pseudarthrosis. *Barr* (1959) observed that: "There is an obvious need for better techniques of fusion; the incidence of pseudarthrosis is much too high". Technical factors explain the appearance of a pseudarthrosis in some cases. In most instances a combination of the following factors are probably involved:

a) insufficient attention to the work of "fish-scaling" of the lamina;

b) too much necrotic or missing bone in the host bed to produce osteogenesis;
c) insufficient immobilization or failure to provide contact compression between the donor tissue and the host bed;
d) insufficient osteogenetic tissue or autogenous bone, or supply of the proliferating cells that, in an adult individual, is essential for all operations to bridge a bone defect.

T-antigens produced in the course of resorption of the donor cells can lead to envelopment of the tissue in the lymphoid cells that carry cell bound antibodies, and cause rejection of homogenous or heterogenous bone.

*Immobilization, Impaction, and Distraction.* The lumbosacral region requires a plaster bed including both hips to produce total immobilization. To avoid prolonged periods in bed, internal fixation in the form of interfacet screws or paraspinous process plates have been advocated by some surgeons but rejected by others who observed late complications such as necrosis and dissolution of bone tissue, or foreign body problems in instances of pseudarthrosis. Immobilization by means of bone impacted between the spinous processes was described by *Gibson* (1931), *Bosworth* (1942), *Breck & Basom* (1942), first with autogenous tibial cortex and then with iliac bone; removal of cortical bone from the tibia caused too many fractures, and some of the grafts behaved like sequestra. Nevertheless, *Leikkenen* (1959) reported the use of double grafts, tibial plus iliac bone, but he implanted the strips along side the spinous process. The distracting block method aims to restore or enlarge the nerve and disc spaces during the period of fusion of the posterior elements and, at the same time, provides immobilization by impaction.

*Biopsy.* There was one wound infection, reoperation, and recovery of the implant for microscopic study. The processed bone was encased in fibrous scar on all sides and contained no ingrowth of new bone from the host. In a previous study, in which pegs were used for internal fixation of a fracture of the hip, it was noted that the interstices of the processed bone were invaded by osteogenetic tissue, and attached to the host bone through the deposition of cement substance (*Urist* 1960).

*Osteogenesis.* Further improvement in the statistics of spinal fusion may depend upon new progress in basic research on the physiologic mechanisms of osteogenesis. At the present time, autogenous bone can

be considered a graft in the sense that cells survive transplantation, but it is misleading to describe preserved bone as a graft. The success of preserved bone, especially after it is processed by extraction, depends entirely upon the osteogenetic power of the cells in the host bed.


## SUMMARY

1. Processed homogenous or heterogenous cortical bone was successfully employed in the form of an H-block, in combination with iliac autogenous, for internal fixation and spreading of the posterior vertebral arches for arthrodesis of the lumbosacral spine.

2. In some patients with freely movable intervertebral joints, the two layered implant of autogenous iliac and processed cortical bone can enlarge the intervertebral disc and canal spaces and at the same time provide internal fixation for an arthrodesis operation.

3. Processed cortical bone, either homogenous or heterogenous, is a well tolerated relatively inert material that is superior to metal, when it becomes incorporated in the host skeleton.

## RESUME

1. Du tissu osseux périostique homogène et hétérogène a été employé avec succès sous la forme d'un bloc en H pour la fixation interne et l'extension des arcs vertébraux postérieurs dans l'arthrodèse de la colonne lombaire et sacrale.

2. Le bloc en H était un complément à une opération de fusion interfacettaire, interlaminaire et interspinale avec de l'os iliaque autogène.

3. Les deux couches implantées, os iliaque autogène et tissu osseux périostique, peuvent simultanément élargir le disque intervertébral et l'espace du canal et assurer la fixation interne de l'arthrodèse.

4. Le tissu osseux périostique, homogène et hétérogène, est une substance relativement inerte bien tolérée qui est supérieure au métal puisqu'il peut être incorporé au squelette de l'hôte.

## ZUSAMMENFASSUNG

**1. Bearbeiteter homogener und heterogener kortikaler Knochen wurde in der Form eines H-Blocks zur inneren Fixation und Spreizung der hinteren Wirbelbogen zwecks Arthrodesis der lumbosakralen Wirbelsäule mit Erfolg angewendet.**

Der H-Block war eine Hinzufügung zu einer interfacetären, interlaminären, interspinosen Verschmelzungsoperation mit autogenem Knochen vom os ileum.

3 Das doppeltgeschichtete Implantat aus autogenem iliakalem und bearbeitetem kortikalem Knochen kann gleichzeitig die Zwischenwirbelscheibe und den Wirbelkanal erweitern und auch eine innere Fixation für eine Arthrodesis liefern.

4. Bearbeiteter kortikaler, homogener oder heterogener Knochen ist ein gut verträgliches, verhältnismässig neutrales Material, das insofern Metallen überlegen ist als es in das Skelett des Empfängers einverleibt werden kann.

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