

From the Department of Orthopaedic Surgery, The Permanente Medical Group and the Kaiser Foundation Hospital, San Francisco, California.

PROCESSED HETEROGENOUS BONE IMPLANTS (BOPLANT, SQUIBB) AS GRAFTS IN SPINAL SURGERY^{1, 2}

By

PAUL H. HARMON

With the advent of fully compatible non-immunogenic prepared heterogenous bone (Boplant, Squibb³), several different applications have been made in osseous (orthopaedic) surgery. The use of this type bone in human surgery was undertaken only after basic (chemical and immunologic) studies had been completed, and it had been demonstrated that this type bone derivative was easily vascularized and was biologically compatible. These studies were carried out both in an ectopic site (2) (anterior chamber of the rat eye) and in an orthoptic area (3, 4) (long bones of animals). In the bone grafting experiments, comparisons were made between autogenous bone and the prepared heterogenous bone, for capacity to become vascularized and to unite in long bone defects. Such comparisons of the behaviour of Boplant in the host osseous area of another species in the crucial test for a prospective bone grafting material. The orthoptic experiments demonstrated: (1) The initial incorporation of both types of bone was similar; and, (2) After six months, the heterografts were more thoroughly remodelled than the autografts as judged by gross, radiographic, histologic and microradiographic criteria. The large marrow-vascular spaces of the prepared bone derived from young calves were more favorable to

¹ Aided by Research Grants from the Kaiser Foundation and from the Squibb Institute for Medical Research.

² Read at the Ninth Congress of the Pan-Pacific Surgical Association, Honolulu, Hawaii, November 6, 1963.

³ Generous quantities of the prepared protein and fat-extracted lyophilized Boplant were furnished by James A. Dingwall, M.D. of the Squibb Institute for Medical Research.

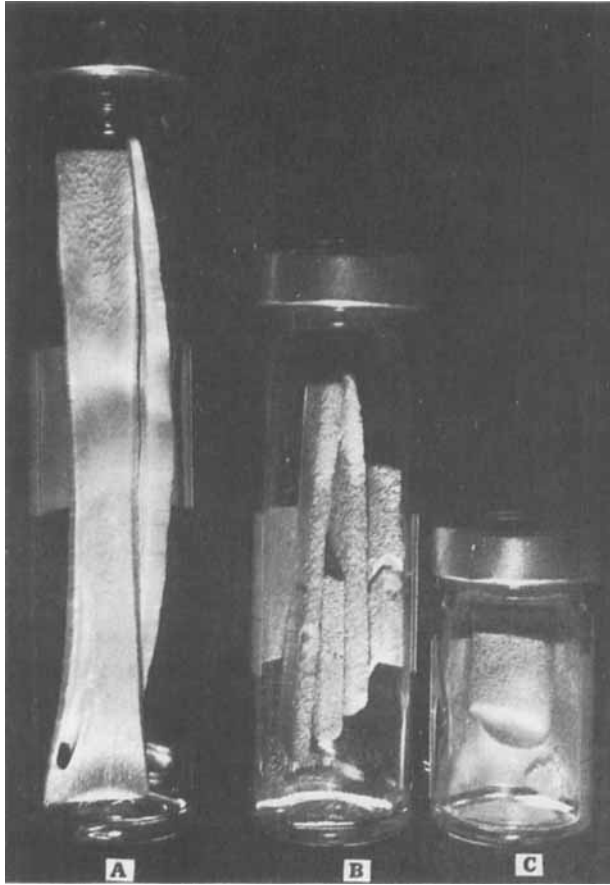


Fig. 1 a.

Appearance of Boplast cortical and cancellous grafts in the sterile lyophilized state. Saline is added to the sterile bottles six to twelve hours prior to proposed use.

(A) Cortical strips; (B) Cancellous strips; and (C) Cortico-cancellous plugs.

osseous substitution than even some types of autogenous bone. With these clear-cut experimental findings, it seemed appropriate to challenge the clinical dictum that "there is nothing like the patients' own bone".

Detailed and comparative studies of this type heterologous bone in human spinal surgery were then undertaken by this author. The recipient sites for bone grafts in this type surgery are particularly advantageous because of: (1) marked osseous vascularity; (2) excellent wide surface contact; and (3) a deep somatic site, well surrounded by

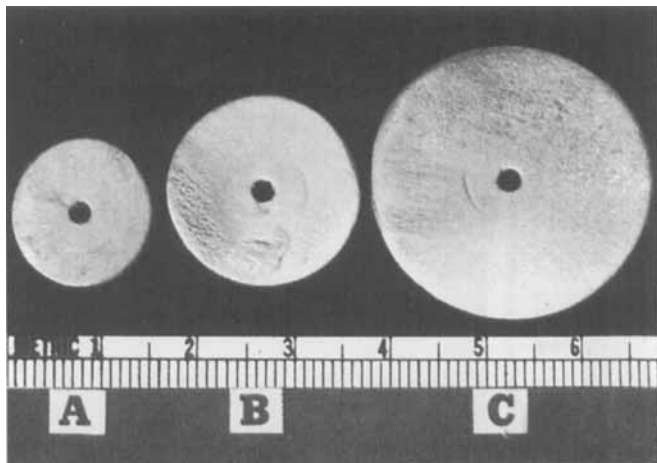


Fig. 1 b.

Three sizes of cortico-cancellous plugs (A) One-half inch diameter; (B) Three-fourths inch diameter; and (C) One and one-eighth inch diameter.

vascular soft tissues. Operative technique will not be discussed in this paper except as brief descriptive references to orient the reader to the different type applications when the anatomy and roentgen findings are being discussed. Those interested in the detailed operative technique are referred to appropriate publications (6, 8, 10). Fig. 1 illustrates the types and shapes of bone (Boplant) utilized in these studies.

It should be noted here that spinal stabilization by bone grafting operations upon the vertebral bodies themselves is a phase of surgery that has been perfected and practiced upon a wide scale only in recent years (Cervical spine, *Cloward* (5) and *Robinson et al.* (12); Lower lumbar spine, *Harmon* (6-11)). This type surgery has been applied to the unrelieved acute, chronic, and recurrent intervertebral disc syndromes of both areas and their complications: chronic vertebral arthrosis and the spinal instability of chronic, long-standing intervertebral disc degeneration. Adequate and usually full relief of symptoms can even be expected in about ninety per cent of patients who have not been able to secure relief from non-operative treatments or from other types of operations. They are the procedures of choice for certain painful spinal conditions following trauma and for salvage in failures from previous excisional disc operations and/or spinal fusions. Documentation of these statements is available in the articles of the bibliography.

There are many positive advantages to an anterior vertebral fusion:

(1) non-weakening of the posterior spinal structures; (2) avoidance of contact with neural elements; and, (3) the important practical fact that this is a systematic and extensible surgical procedure, the practical results of which equal or exceed those of any other type operation in either the cervical or the lumbar area. This is equally true in primary operations, best demonstrated in the first operation of an "uncomplicated single level" case¹ of persistently symptomatic lumbar discopathy. There is immediate relief of both lumbago and radicular symptoms in most cases without complicating paresthesias from nerve root stimulation. The morbidity, hospitalization period, and over-all disability² is about the same from the primary anterior excision-fusion procedure as from a posterior excisional operation. Patients who have had both procedures, without exception, state that the anterior operation is "easier", *providing a second field is not opened for the removal of an autogenous bone graft.*

The need for a substitute for autogenous bone grafts does not have to be argued. Use of bone from another source is impressive to patients and surgeons alike, who both remember cases with excellent, pain-free function at the definitive operative site with pain and disability at the graft donor site. When another bone grafting operation sometimes needs to be performed, many patients can no longer spare bone from the usual donor sites or are unwilling to do so.

The first operation performed by the author with a Boplant heterograft was an anterior lumbar interbody fusion (May 1, 1958). Although the method of preparation of this particular heterograft was somewhat inferior to that now in use, the "take" was prompt and satisfactory. The resultant spinal stabilization relieved the patient of his complaints. In the interim and up to six months prior to the preparation of this report, the following numbers and types of surgical operations have been performed:

- (1) Anterior interbody lumbar fusions utilizing only cortical grafts of Boplant for the intervertebral defect created by osteotome excision of the intervertebral disc and portions of the cortical osseous vertebral plates (16 cases).

¹ An "uncomplicated single level case of lumbar discopathy" refers to a primary operation on a patient with a corresponding extent of lumbar disc pathology.

² Excepting that the back of the worker in heavy industry must be protected from stress until fusion is rather far advanced (four to six months).

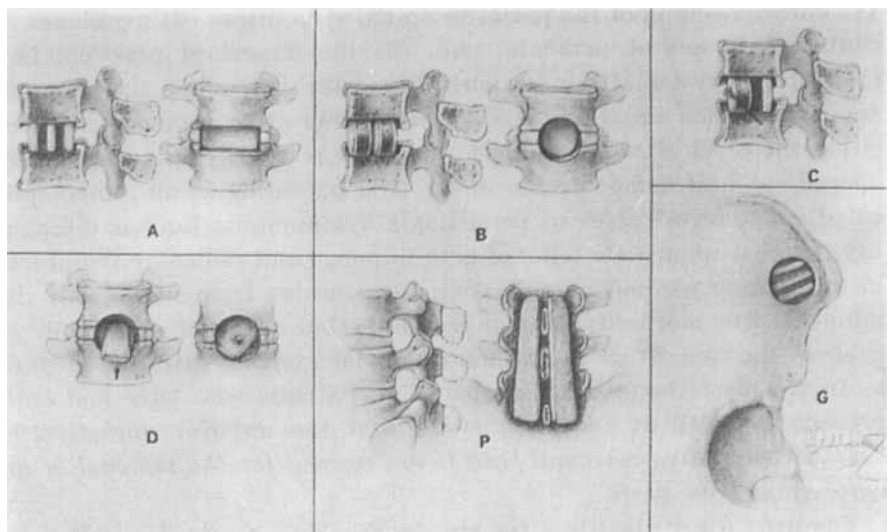


Fig. 2.

Some technical variations of applying intervertebral bone grafts and various applications of Bopplant in spinal osseous surgery. (A) Intervertebral "sandwich" grafting with alternate layers of cortical and cancellous bone following disc removal and excision of portions of the cortical osseous plates. (B) "Coin" grafting with circles of full-thickness iliac grafts. (C) Combining "sandwich" and "coin" grafting with semifixation of the ventral graft with a metallic screw. The latter is indicated when the ventral graft cannot be countersunk or when it is slightly loose. (D) Intervertebral grafting with multidirectional pieces of cortical bone. (P) Use of strips of cancellous Bopplant as onlays to augment the osseous fusion mass in posterior lumbar fusions. (G) Cancellous strips used to fill the circular iliac defect created by removal of fullthickness grafts.

- (2) Anterior lumbar fusions performed by "sandwich grafting" with alternate layers of cortical and cancellous Bopplant (103 cases).
- (3) Anterior lumbar interbody fusions, posterior portion of the grafting performed with cortical and/or cancellous grafts of Bopplant, with the anterior portion of the interbody grafts made with a full-thickness autogenous iliac "coin" graft (18 cases).
- (4) Same type operation as (3) supplemented with grafts of cancellous Bopplant in the lateral "wings" of the interbody grafted area (31 cases), (see also Fig. 2).
- (5) "Plug" grafting with Bopplant in anterior cervical interbody fusions (Cloward operative technique (5)), (40 cases).
- (6) Cancellous Bopplant replacement into iliac defects of patients created by the removal of full-thickness grafts (12 cases).

- (7) Utilization of cancellous slabs of Boplant to supplement autogenous iliac chips in posterior fusions in the lower lumbar area (15 cases).

Some comparisons will be made to similar operations where only autogenous bone was used. The simultaneous use of two types of grafts, heterogenous and autogenous, in some cases had the double purpose of testing the reactions of host graft recipient site to the presence of both types of grafts and the clinical effect of only removing a modest amount of bone from the ilium for one of the grafts. Thereby, the discomfort of the patient at the donor site was minimized. The further question of the presence of a small or modest amount of autogenous iliac bone having a favorable influence on transformation and consolidation of the whole grafted bed is important.

The largest number of operations has been the anterior lower lumbar fusions (categories 1 to 4 inclusive). The second most frequently performed operation was the anterior cervical interbody fusion (category 5). The post-operative observation of patients who have had the first type operation has been five years or more in category 1 and six months to three years in categories 3 and 4. The cervical interbody plug fusions have been observed from six months to three years (75 per cent more than eight months). By eight months, the final end-result of cervical interbody fusions is well patterned. By twelve months a reliable similar opinion is available about the lumbar interbody fusions. Some additional roentgen changes occur in the grafted area in the cervical spine for the next four months and in the lumbar area for the next eighteen months or even longer in some few cases (see Figs. 3-6).

Methods of Study and Evaluation of Results.

Detailed and objective conclusions as to the practicability of using Boplant for spinal fusions is obtained from the following types of inquiry: (1) A comparative study of the post-operative course and the end-results from autogenous grafting as compared with cases in which Boplant has been used, by observation on: (a) instability symptoms (pain and lumbar muscle spasm), (b) serial roentgen changes that might bring out desirable or undesirable features of either type graft, (c) pseudarthrosis (fusion failures), and (d) time required to obtain a clinically adequate fusion so the patient can safely discard external spinal support; (2) Statements from the patients (sometimes of ques-

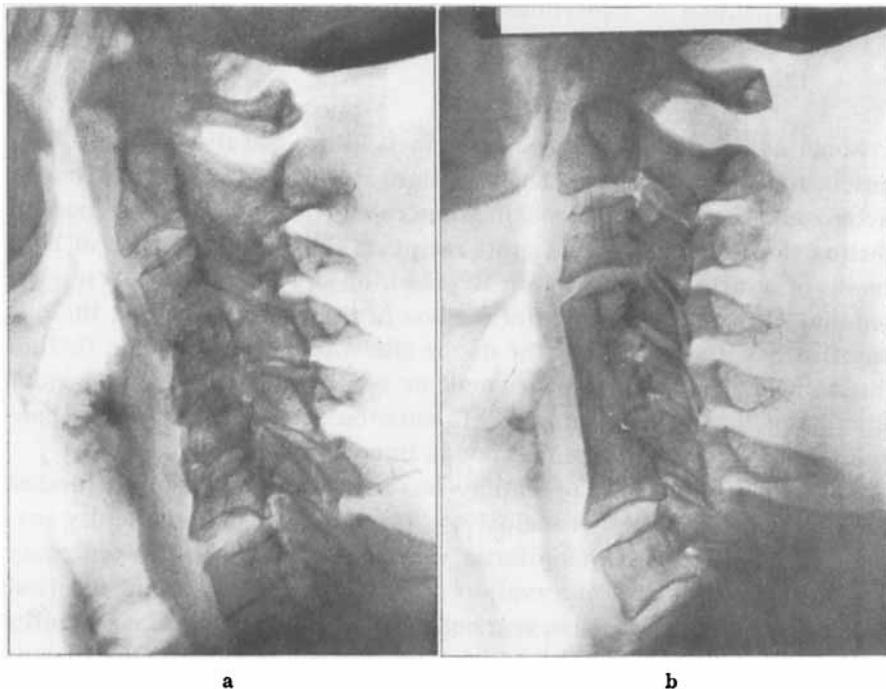


Fig. 3.

(a) Three level (C-3, C-4, C-5, C-6) anterior cervical fusion seven months post-operative, utilizing Boplast plug grafts. Union is present, but the grafts have not as yet reached uniform density compared with the recipient bed; (b) Two level (C-4, C-5, C-6) anterior cervical fusion twenty-two months post-operative. Autogenous full-thickness iliac graft at C-4, 5 and Boplast cortico-cancellous plug at C-5, 6. Full maturation and consolidation of grafts and recipient bed.

tionable objective value) about the relief from preoperative symptoms. In speedy relief from symptoms, the obvious advantage conferred on patients in not opening a site for the donation of an autogenous graft must, of course, be kept in mind.

Objective opinions as to the speed and completeness of incorporation of bone grafts have to be made in large measure from roentgenograms. This is a somewhat unsatisfactory tool due to the lag, often as long as several weeks, in the accumulation of sufficient calcifying density to effect roentgenographic shadows as compared to the actual biological process as revealed by microscopy or by microradiography. But, allowances can be made for this. In rendering an opinion about the presence and quality of osseous union, there are some fundamental differences in the roentgenograms (and also in the biology) of the assimilation of

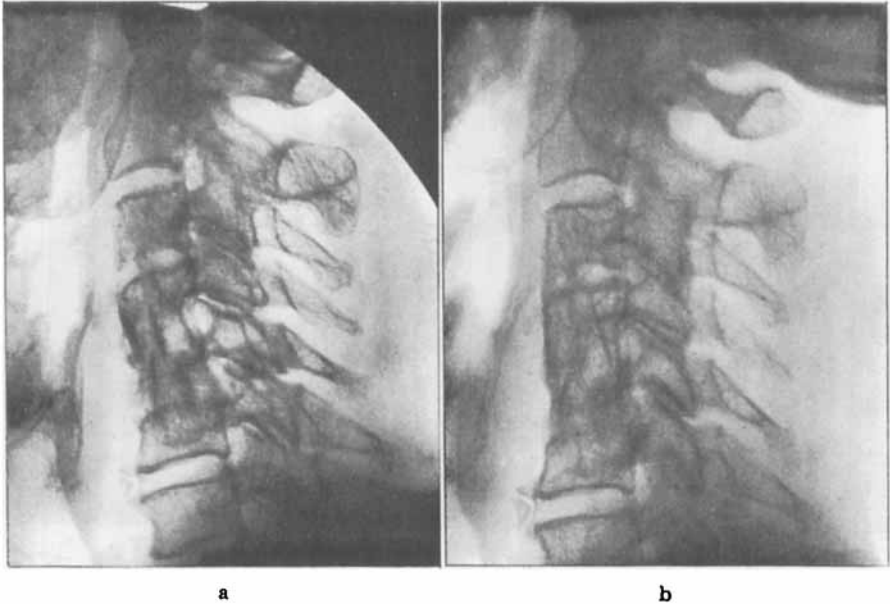


Fig. 4.

Illustrating stages of incorporation of Boplast grafts in a two level cervical (C-4, C-5, C-6) fusion (a) three months post-operative demonstrating preservation of the cortical graft shadows and (b) twenty months, full incorporation of grafts and solid fusion.

autogenous cortical bone to that of Boplast cortical pieces. There are also some relatively minor but distinctive differences in incorporation of cancellous plugs of the two types. Requirements for structural support in the cervical interbody fusions dependent upon changes in the cancellous plugs, thin cortex on one side, are slight as compared to the important weightbearing capabilities of cortical bone in the lumbar spine. Therefore, the necessity of using some cortical bone in the lower lumbar spinal fusions.

There are some serious technical difficulties in the roentgenography of the lumbar and the lumbosacral areas due to thickness of the part and to overlying shadows of neighbouring bone, especially the ilium and sacrum. To minimize these technical difficulties, the roentgenologist¹ who has made the films for these graft transformation studies has employed short focal-spot magnification technique.

In the interpretation of roentgen films, it is helpful to distinguish

¹ *Martin S. Abel, M. D.*

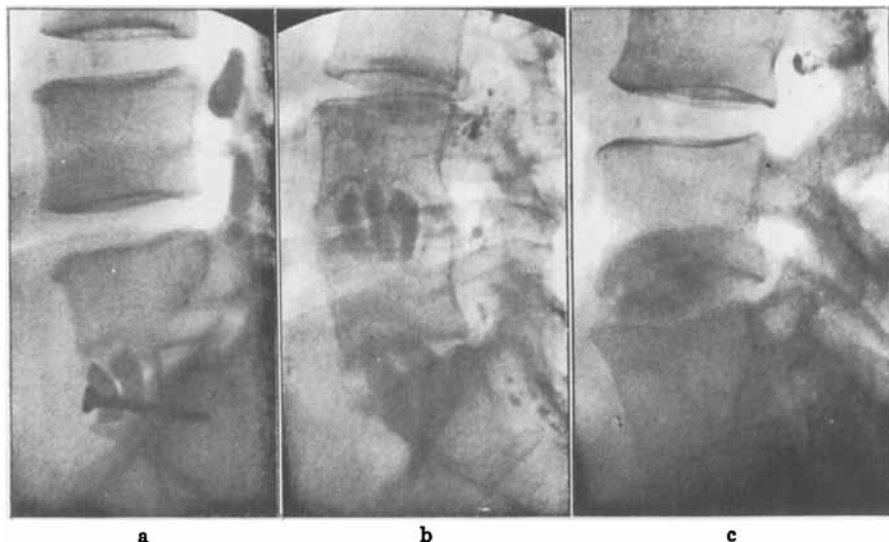


Fig. 5.

Clear illustration of three stages of transformation-incorporation of cortical grafts of Boplant in the lumbar spine. (a) Stage I—discrete outline of grafts shortly after insertion; (b) Stage II—graft “halo” well-demonstrated at lumbar-four with a slightly more advanced stage (early Stage III) union with more disappearance of the “halo” at lumbar-five; (c) Later Stage III graft assimilation-union with density of graft and recipient bed approximating one another.

several progressive stages of “take” of the cortical grafts (1) in the prepared intervertebral sites of the lower lumbar spine (see Figs. 3 to 6 inclusive).

- I. *Haziness at the margins* of the cortical bone grafts best visualized in the lateral views.
- II. *“Halo” formation* about the graft. The halo is a vascular non-ossified or lightly ossified non-inflammatory osteoid with progressive capabilities of strong union to the host. The roentgen appearances of this stage have heretofore been confused with fibrosis about the graft, a late stage of graft rejection. These are distinguished by the time and sequence. The “graft halo” appears at about eight weeks and persists for a similar period or slightly longer (up to twelve or sixteen weeks).
- III. *Stage of trabeculation*. At first this appears as an interlocking of shadows of graft and vertebra, with the border of each difficult to discern. Early trabeculation later becomes quite definite

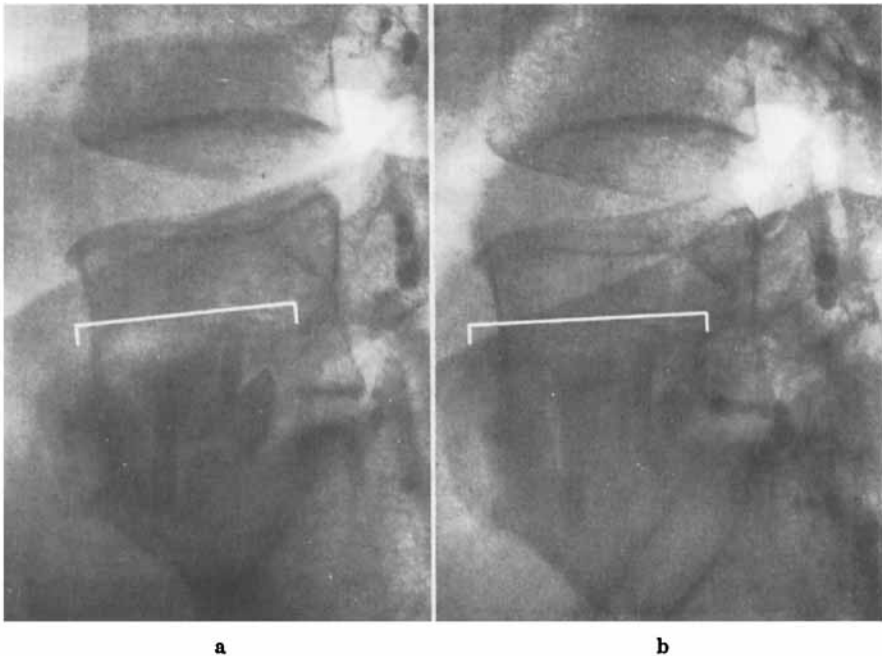


Fig. 6.

Lateral roentgenograms of stages of cortical Bopant assimilation after (a) six months and (b) nine months in a 42-year-old male patient, grafter at lumbar-five. The two posterior grafts in (a) demonstrate the perigraft "halo" described as Stage II (Page 106). A slightly more advanced stage of graft union-assimilation of Stage III, the "halo" having now disappeared except from the most posterior graft. The bracket indicates the depth of the intervertebral graft recipient bed.

and discrete in roentgenograms as progressively heavier shadows.

- IV. *Final maturation* is a complete blending of graft and recipient bed. Cortical grafts, irrespective of their origin, never completely lose their identity. Traces of this type bone, often a considerable portion of such cortical grafts, persist indefinitely as dense shadows in roentgenograms. Such "ghosts" of cortical bone have unnecessarily worried some observers, but there is no evidence, symptomatic or otherwise, that such bone is undesirable. This dense bone is not a dead sequestrum, but is a failure of remodeling of all the dense and thick trabeculae of the cortical grafts.

The details of this process of maturation can be evaluated exactly only from microscopic preparations. Roentgenograms of the intact pa-

tient contain too many irrelevant shadows. Later, reference will be made to correlation of symptoms with the above stages of graft alterations (see Page 110).

TABLE 1
Boplant Intervertebral Grafts Compared to Two Types of Autogenous Bone.
(Lower Two Lumbar Levels.)

	Boplant-sandwich† grafts		Autogenous iliac coin grafts		Autogenous tibial sandwich grafts	
	L-5	L-4	L-5	L-4	L-5	L-4
Number of Cases	31	15	51	15	54	10
Percentage	52	53	37	20	19	50
Incidence of Postoperative Lumbago						
Return to work	3	2.5	3	3	2.5	2.5
(Median) Months						
Time (months) for Stage III Graft Assimilation	4.5	4	—*	—*	8	6

* Impossible to estimate substitution-incorporation of cancellous grafts.

† Additional cases to bring the number to that stated in category 2 (103 cases) are persons grafted at both L-5 and L-4. These are *not* (for the purposes of comparison) "simple" cases and are not considered in this comparative tabulation.

RESULTS FROM THE OPERATIONS

(A) Anterior Lumbar Interbody Fusions.

Some comparative clinical data is summarized in Table 1. Illustrations of some of the methods of intervertebral bone grafting are shown in Fig. 2. As a control-background to the results of Table 1, a considerable number of lumbar interbody fusions with (a) autogenous tibial "sandwich" grafts, 221 cases; and (b) autogenous iliac full-thickness "coin" grafts, 105 cases; (total, 326 cases), have been performed. The results with the autogenous grafts are uniformly longer term results than those from Boplant and are two to three year or longer results. The *five to six year results, 221 cases autogenous tibial "sandwich grafts"*, are 62 per cent *excellent*¹ and 29 per cent *good*¹; *two to three*

¹ "Excellent" results are patients whose symptoms are fully relieved and who are physically active without restriction and without any painful recurrences. "Good" results are a highly acceptable outcome with patients physically active but who may have some very minor non-disabling pains at irregular intervals, *e.g.* with weather change. An average follow-up of 97 per cent of the operations was obtained. Relief refers to freedom from *both* low back pain and radicular pains.

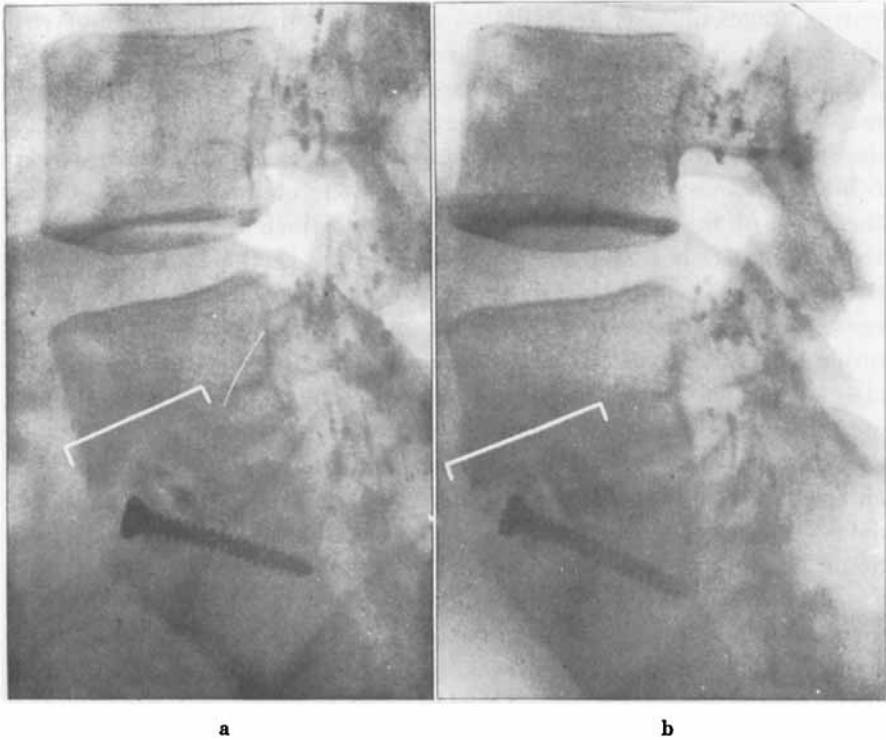


Fig. 7.

Lateral roentgenograms of similar stages of cortical Bopland graft assimilation after (a) three months and (b) after six months in a 29-year-old female patient grafted at lumbar-five. The graft "halo" (Stage II) is wide and well-demonstrated in (a). In the additional three months, this has disappeared and (b) shows well-advanced Stage III (interlocking of graft and recipient bed trabeculations) union. Younger persons with active osseous metabolism transform and assimilate grafts in this area with greater speed.

year results, 105 cases, autogenous full-thickness iliac "coin" grafts were 73 per cent excellent and 16 per cent good; average highly acceptable results, both type autogenous grafts, 90 per cent.

Comparisons of the above results from autogenous anterior intervertebral grafting in the lumbar area with the cases of Table 1, shows a favorable graft assimilation-union time in the cases in which the prepared heterogenous bone (Bopland) was used. The clinical results were equally good with both types of grafts. There was a greater incidence of post-operative lumbago in the first month with cortical pieces of the prepared bone. More important for comparative purposes is data com-

paring stages of graft assimilation as revealed in roentgenograms with the clinical data available in 99 cases (or 73¹ per cent of cases of categories 1 to 3 inclusive). The roentgen data was derived from exposures made by short focal-spot technique with magnification at three, six, and nine months post-operatively and in some cases one and two years following operation. Estimations of the stage of union were made on the basis of the four stages previously described. Reaching Stage IV from Stage III is a step as prolonged in time as the total of the first three stages. Nevertheless, most post-operative and nocturnal lumbago ceases in the latter part of Stage II, and sufficiently advanced clinical union exists at this time to allow normal activities short of stress exercising and heavy work or sport. Only minimal or intermittent support of the back required. Some careful patients need no bracing.

Although there was a greater incidence of low back pain (nocturnal and otherwise) associated with sandwich grafting with Boplant, the dates of return to work and grade of assimilation of grafts through Stage III were favourable to Boplant. A further analysis of cases (*e.g.* Fig. 7) in which screw fixation of grafts to one vertebral body was performed showed that post-operative and nocturnal low back pain could be largely abolished by this means. Final amalgamation-assimilation of grafts was accelerated with Boplant as compared with autogenous tibial grafts, possibly because of wider osteoid seams and marrow spaces of cortical Boplant. Aside from these few differences, there was no radical difference in behaviour of the groups as a whole with the different type grafts studied. The cases of category 4 (cancellous Boplant in the "wings" lateral to a large transvertebral drill hole filled with cortical Boplant) demonstrated further accelerated time of union and corresponding less post-operative lumbago (see also results of Table 2).

While the groups of Table 2 are not strictly comparable (except for the sandwich grafting technique, see Fig. 2) either as to numbers or technique, it is observed even with the small numbers of cases involved that there was no radical difference between any of the groups (see also Table 1). This demonstrates comparability in the post-operative status and results with grafts of the two origins. There were spectacular cases with short hospital stay and complete and permanent relief of symptoms in both groups. The factors of near-ideal fitting of graft to vertebrae, the absence of severe arthrosis (11), and a one-level operation

¹ The smaller number of cases available for this comparison is due to the elimination of cases that did not fit into a uniform technique relative to graft position, thickness, and estimated surface contact of grafts.

were the important factors in both groups that conditioned a favourable course and results. Further detailed study of the steps of the heterogenous graft transformation correlated with age groups (decades) revealed no differences until the patients were 60 years of age or beyond.

TABLE 2
Results from Lower Lumbar Spondylodesis.

	Boplast (Squibb)			Autogenous grafts (contr.)	
	Sandwich† grafts (categ. 2)	Cortical and one auto-coin graft (categ. 3)	Cortical and can- cellous Boplast- lateral (categ. 4)	Sandwich* grafts (controls)	Autoge- nous full thickness coin grafts (controls)
Number of Cases	103	18	31	221	105
Results* (Percentage)					
Excellent	59	67	77	62	73
Good	34	32	19	29	20
Fair	5	1	3	4	5
Poor	2	0	0	5	2

* Descriptive terms are previously defined (Footnote, Page 108). Relief refers to freedom from *both* low back pain and radicular pains.

† For length of follow-up observation see Pages 108-109. Most of the control patients, prior operations with autogenous grafts, were observed one to two years longer than those grafted with Boplast.

In no case was there suggestion of any inflammatory response to the use of the heterogenous grafts as the post-operative temperature curves and local reactions were the same, and leukocyte counts and red cell sedimentation rates were normal in both groups. There were no instances of pyogenic infection in any of the cases considered in this report and no neurological complications.

RESULTS FROM THE OPERATIONS

(B) *Anterior Cervical Interbody Fusions.*

Cortical cancellous Boplast plugs (see Fig. 1) were used in the basic Cloward intervertebral drilling technique in cervical interbody fusions on 40 patients. There was no technical difficulty in placing the plugs, and the follow-up rate was 100 per cent. These operations were performed at one level in five cases, at two levels in 27 cases, and at three levels in eight cases. The post-operative observation period has

been one to two and a half years (80 per cent, more than a year and a half). The results were: excellent, 32 cases (80 per cent); good, six cases (15 per cent); and fair, two (5 per cent). These operations were all performed for cervical arthrosis. (Three illustrative cases are shown in Figs. 3 and 4.)

As compared with full-thickness autogenous iliac plugs, the cancellous portion of the Boplant plugs is somewhat friable. Therefore, grafts at two or more levels need support by a rigid brace extended to the upper half of the thorax, front and back, for approximately 12 weeks, and in some instances up to 16 weeks. Neglect of this complete precaution in one case resulted in minimum cervical kyphus of 10 degrees, but this was asymptomatic. The result in some control cases (70 patients, autogenous iliac grafts) was 95 per cent excellent and good.

RESULTS FROM THE OPERATIONS

(C) Iliac Defects Produced by Trephine Graft Excisions Filled with Boplant and the Adjuvant Use of Cancellous Boplant Slices in Posterior Chip Type Spinal Fusions.

The first mentioned application (iliac defects) was in 12 cases. No incompatibilities were observed and roentgen follow-up in all instances for more than one year periods failed to show any evidence of sequestration of the bone. No surface inflammatory reactions were observed. The second application (onlay in posterior spinal fusions) was in 15 cases. The slices of cancellous Boplant (thickness, 3 to 4 mm.) were onlayed to a bleeding bed of minced autogenous bone.

CONCLUSIONS

1. The prepared heterogenous lyophilized bone (Boplant, Squibb) has been applied in several forms as grafts for anterior spondylodesis, for posterior spinal fusions, and for other auxiliary applications, *e.g.* to fill iliac defects from removal of full-thickness circular grafts. The results in all have equaled those obtained with autogenous grafts.

2. Several technical variations of applying Boplant and autogenous grafts alone or in combinations are described: (a) "Plug" grafting for cervical spondylodesis by the Cloward technique has been without technical failures (no pseudarthrosis) in the hands of the author; (b) Spondylodesis in the lower lumbar area requires maximum sized grafts with adequate cortical bone to withstand the stresses of this area.

3. Relief of most or all symptoms in difficult and intractable cases of chronic and/or recurrent discogenic syndromes complicated by arthritis in these two areas in patients in whom non-operative treatments have failed has been obtained in 90 per cent in the lower lumbar spine and in 95 per cent in the cervical spine.

4. Moderate friability and the larger marrow spaces of the cancellous portions of the prepared bone require external supportive precautions (bracing) in the post-operative period. Two or three cortical surfaces are required for intervertebral support in the lumbar region.

5. There is some clinical and radiological evidence that the grafts of the prepared bone (Boplast, Squibb) are incorporated with the host recipient bed with speed and completeness equal to, and in some cases exceeding, that of autogenous bone.

6. Detailed radiological studies (short focal-spot magnification technique) of the stages of graft conversion-incorporation are described. These indicate full and adequate osseous union sufficient to *discard bracing in the cervical region by two or three months* and to permit *reasonable physical activity without bracing* for patients whose lumbar spine has been grafted by three to four months.

7. Fusion failures (pseudarthrosis) from anterior spondylodesis in the lumbar area have been less with the prepared bone (one per cent) than with autogenous bone (five per cent).

8. Boplast is a satisfactory type of bone satisfying all requirements for bone grafting in the human spine under spine under the conditions of use described in this report. The omission of a graft donor site is gratifying to both patients and surgeon.

ADDENDUM

During the 18 months elapsing between evaluation of the cases of this report and the present time, the author has used cortico-cancellous plugs of Boplast for anterior cervical fusions in 20 additional cases. Various cortical and cortico-cancellous combinations of Boplast with or without a single circle graft of full-thickness iliac autogenous bone have been used as grafts in 172 additional anterior lumbar fusions. Tight fitting grafts with peripheral obliquely inserted plugs of cortical Boplast have achieved better immediate graft immobilization and an almost ideal convalescence, free of low back pains. The clinical course of these cases has been even more favourable than those reported in the article.

SUMMARY

Boplant, (PHB, Squibb) a completely compatible protein and fat extracted lyophilized bone (cortical and/or cancellous) has been used in human surgery for anterior interbody fusions: lumbar, 137 cases; cervical, 40 cases; replace iliac defects made by removal of full thickness grafts, 12 cases; to supplement posterior lower lumbar chip fusions, 15 cases. The follow-up has been over two years, and some cases have been followed twice this period, all to a stable end-result. The post-operative course, rate and result of union was compared to 221 cases of autogenous tibial "sandwich" grafts, to 105 cases of autogenous iliac "coin" grafts both lumbar and anterior interbody fusions, and to 70 cases of anterior cervical fusion with autogenous iliac "coin" grafts. Rate of union and the negligible incidence of non-union in the lumbar area slightly favoured the prepared heterologous bone (PHB) and were no different in the cervical area. There was no evidence of biologic incompatibility and no infections or inflammatory reactions. The results indicated that Boplant was quite satisfactory for the type operations on the human spine as described. The roentgen stages of osseous reunion are described.

RESUME

Boplant (PHB, Squibb) un extrait de protéine et de graisse d'os lyophile (cortical et/ou spongieux) complètement compatible a été utilisé en chirurgie humaine pour fusion antérieure des vertèbres: lombaires 137 cas, cervicales 40 cas, remplacement de déficiences iliaques par l'enlèvement de greffes de pleine épaisseur 12 cas, comme supplément pour la fusion postérieure d'éclats de vertèbres sacrées 15 cas. La période d'observation a été de plus de deux ans et quelques cas ont été observés deux fois cette période, afin d'établir un résultat final. Le cours post-opératoire et le résultat de la soudure ont été comparés à 221 cas de greffes « sandwich » d'os tibial autogène, à 105 cas de greffes cunéiformes iliaques autogènes de fusions antérieures des vertèbres lombaires et à 70 cas de fusion antérieure des vertèbres cervicales avec greffes cunéiformes iliaques autogènes. Le pourcentage de la soudure et l'incidence négligeable de la non-soudure dans la région lombaire est légèrement plus favorable avec l'os hétérologue préparé (PHB) et ne présentait aucune différence dans la région cervicale. Il n'y avait pas, semble-t-il d'incompatibilité biologique, pas d'infection ou de réactions inflammatoires. Les résultats indiquent que Boplant a été

entièrement satisfaisant pour les opérations de la colonne vertébrale du type décrit; les étapes radiologiques de la soudure osseuse son décrits.

ZUSAMMENFASSUNG

Boplant (PHB, Squibb), ein vollständig verträgliches Protein und fettextrahierter, lyophilierter Knochen (Rinden und/oder Markknochen) wurden unter chirurgischen Eingriffen am Menschen zur vorderen Fusion von Wirbelkörpern verwendet: Lendenwirbel – 137 Fälle, Halswirbel – 40 Fälle, Auffüllung von iliakalen Defekten, die nach Entfernung von die ganze Knochendicke umfassenden Transplantaten entstanden waren – 12 Fälle, zur Ergänzung einer rückwärtigen Spähenchenfusion der unteren Lendenwirbelsäule – 15 Fälle. Die Beobachtungszeit ist über zwei Jahre gewesen und einige Fälle sind doppelt so lange, alle bis zu einem stabilen Endergebnis, beobachtet worden. Der postoperative Verlauf, die Häufigkeit und das Ergebnis der Vereinigung wurde mit 221 Fällen von autogenen „Sandwich“ Spähen, mit 105 Fällen von autogenen iliakalen „coin“ (Münzen) Spähen für beide Lendenwirbel – und vordere Zwischenwirbelvereinigung, und mit 70 Fällen von vorderer cervikaler Fusion mit autogenen iliakalen „coin“ Spähen verglichen. Die Häufigkeit der Vereinigung und das seltene Vorkommen von Nichtvereinigung in der Lendengegend sprach etwas zu Gunsten des präparierten, heterologen Knochens (PHB) und zeigte keinen Unterschied in der Cervikalregion. Keinerlei Zeichen von biologischer Unverträglichkeit und keine Infektionen oder entzündliche Reaktionen wurden beobachtet. Die Ergebnisse zeigten an, dass Boplant für die beschriebenen Operationsarten an der menschlichen Wirbelsäule vollständig zufriedenstellend war. Die Röntgenstadien der knöchernen Vereinigung werden beschrieben.

REFERENCES

1. *Abel, M. S., Harmon, P. H. & Dingwall, J. A.*: Processed Heterogenous Bone for Anterior Interbody Spinal Fusions in the Cervical and Lumbar Regions, a Brochure Accompanying a Scientific Exhibit at the 30th Annual Meeting of the American Academy of Orthopaedic Surgeons, 1963.
2. *Anderson, K. J., Dingwall, J. A., Schmidt, J., Lecocq, L. & Clawson, D. K.*: Effect of Particle Size of Heterogenous Bone Transplant and Host Tissue: Histological Study. *J. Bone Jt Surg.* 43-A: 996–1004, 1961.
3. *Anderson, K. J., Karges, D. E., Dingwall, J. A. & Jowsey, J.*: Experimental Evaluation of Processed Heterologous Bone Transplants. *Clinical Orthop.* 29: 230–246, 1963.

4. *Bassett, C. A. L. & Creighton, D. K., Jr.*: A Comparison of Host Response to Cortical Autografts and Processed Calf Autografts. *J. Bone Jt Surg.* 44-A: 842-854, 1962.
5. *Cloward, R. B.*: Lesions of the Intervertebral Disks and Their Treatment by Interbody Fusion Methods. *Clinical Orthop.* 27: 51-77, 1963.
6. *Harmon, P. H.*: Anterior Extraperitoneal Lumbar Disk Excision and Vertebral Body Fusion. 1. A Study of Long-Term Results. 2. Operative Technique, Including Observations upon Variations in the Left Common Iliac Veins and their Connections. *Clinical Orthop.* 16: 169-198, 1961.
7. *Harmon, P. H.*: The Saline Injection Test for Lumbar Disc Degeneration. *Ann. Surg.* 156: 767-775, 1962.
8. *Harmon, P. H.*: Anterior Excision and Vertebral Body Fusion Operation for the Intervertebral Disc Syndromes of the Lower Lumbar Spine: Two to Four Year Results in 244 Cases. *Clinical Orthop.* 26: 107-127, 1963.
9. *Harmon, P. H. & Abel, M. S.*: Correlation of Multiple Objective Diagnostic Methods in Lower Lumbar Disc Disease. *Clinical Orthop.* 28: 132-151, 1963.
10. *Harmon, P. H.*: Surgical Technique for Anterior Interbody Fusion: Special Reference to Avoiding Complications. *Clinical Orthop.* In press.
11. *Harmon, P. H.*: Indications for Spinal Fusion in Lumbar Discopathy, Instability and Arthrosis. 1. Anatomic and Functional Pathology and Review of Literature. 2. Results from Various Types of Operations on the Lumbar Spine in the Presence of Spinal Arthrosis. *Clinical Orthop.* 34: 73-107, 1964.
12. *Robinson, R. A., Walker, A. E., Ferlic, D. C. & Wiecking, D. K.*: The Results of Anterior Interbody Fusion of the Cervical Spine. *J. Bone Jt Surg.* 44-A: 1569-1587, 1962.