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AN EXPERIMENTAL STUDY OF THE IMMEDIATE LOAD BEARING CAPACITY OF SOME COMMONLY USED ILIAC BONE GRAFTS

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Orthopaedic and other reconstructive surgeons employ different configurations of bone grafts to provide a stabilizing function in fusions of the cervical and lumbar spines. Knowledge of the relative strength of the different types of bone grafts is of interest to the surgeon. The authors are not aware of any investigations of the load bearing capacity of the different popular configurations of bone grafts.

Three commonly used grafts are investigated in this study: (a) the horseshoe-type employed by Smith (1958), Robinson (1955), and Southwick (1961); (b) the dowel-type employed by Cloward (1958, 1965); and, (c) a modification of the strut-type employed by Bailey & Badgley (1960). A brief review of the mechanical use of these grafts (Figure 1) will show that in the immediate postoperative period the strength and stability of the surgical construction is largely dependent on the capacity of these bone grafts to withstand vertical compressive loads. It has been noted that some mechanical designs of anterior bone grafting tend to collapse (Kebish & Keggi 1967) or may be unstable (Simmons & Bhalla 1969). A study of the load bearing capacity of entire constructs is planned. This preliminary study is presented to give information about the relative strengths of these different grafts and the range of forces that they can withstand. It was decided to examine the load bearing capacities of these various grafts under controlled experimental conditions which would provide useful information and allow meaningful comparisons among them.

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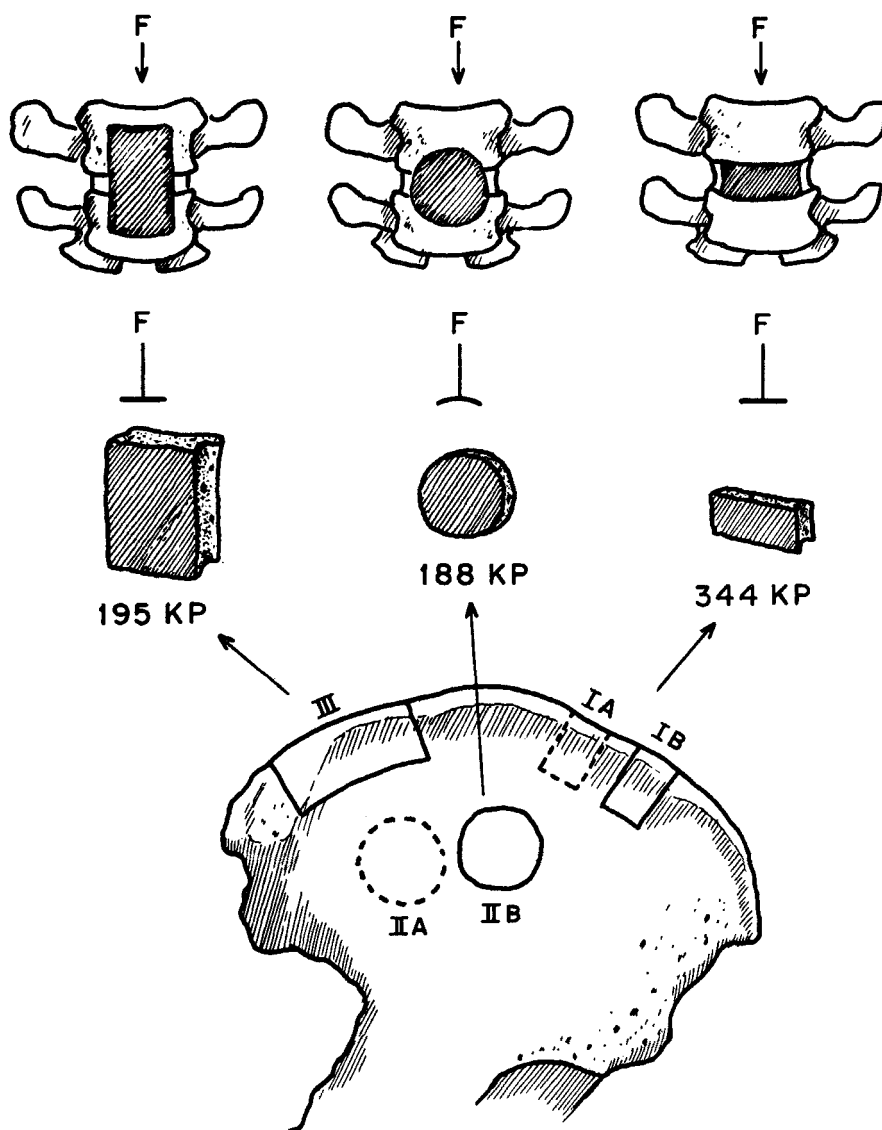


Figure 1. Diagram of approximate location from which grafts were taken, the manner in which they were loaded, and their characteristic location in the fusion.

The figures are the average of the failure points for the three general types.

MATERIAL

The grafts were taken at autopsy from ten subjects, five males and five females, with an age range from thirty-three to eighty-five years. None of the ten subjects had diseases known to affect bone.

Preparation of Material

During autopsy either the right or the left ilium of the subject was removed and stored at minus twenty-five° C. There is evidence that freeze storing does not affect the physical properties of bone (Evans 1957, Sedlin & Hirsch 1966). At the time of testing, the grafts were prepared as described below. The horseshoe-type graft, hereafter to be referred to as *type Ia* or *Ib*, was prepared as follows. With a double blade oscillating saw, set with seven to ten millimeters between the blades, two *type I* grafts were cut, as shown in Figure 1. These grafts were all in

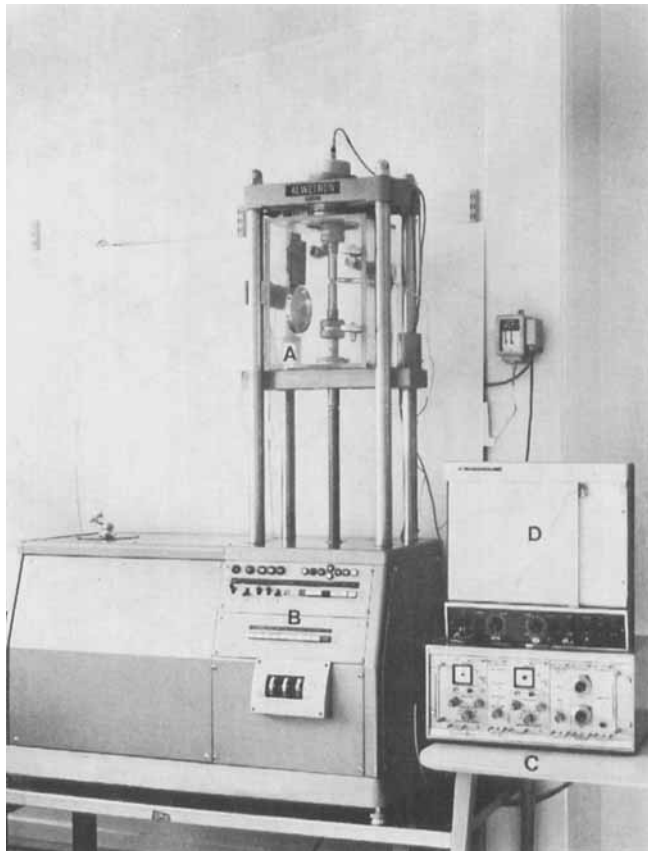


Figure 2. Photograph of experimental apparatus shows: (A) testing chamber, (B) Alwetron test machine, (C) amplifiers, and (D) x-y recorder.

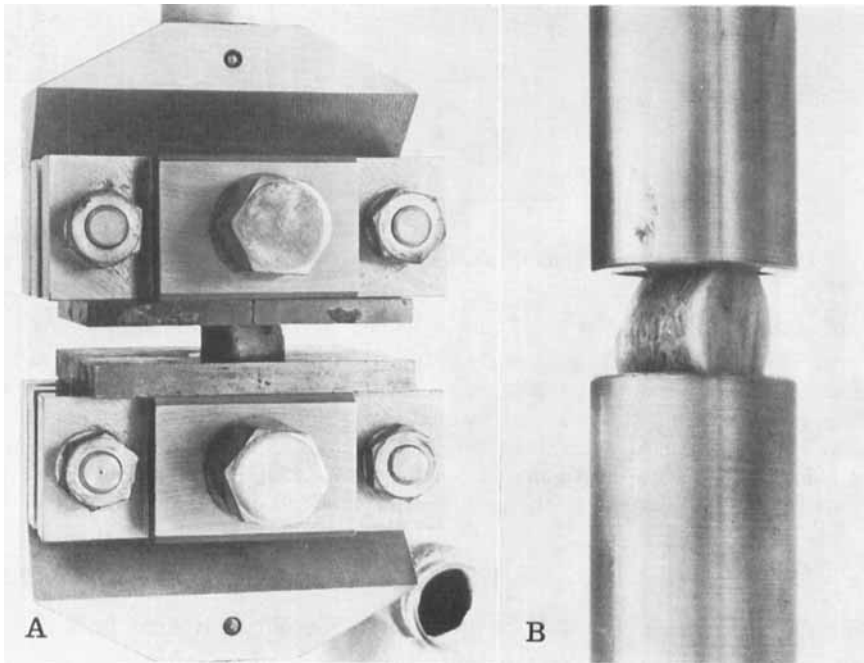


Figure 3. (a) Photograph of the clamps and plates employed to load types I and III. (b) Special cylinders employed to load type II.

the range of nineteen to twenty-five millimeters on their long axis. *I a* was taken anterior to *I b*. The grafts were placed in Ringers lactate solution at room temperature.

The dowel grafts which are designated *II a* and *II b* were taken in the following manner. An oscillating Cloward dowel saw with a sixteen millimeter inside diameter was employed to take two grafts from the ilium in the area indicated in Figure 1. In this case also, *II a* was taken slightly anterior to *II b* and the two pieces of bone were placed in Ringers solution at room temperature.

The strut graft, called *type III*, was taken with the two blades of the oscillating saw twenty to twenty-two millimeters apart (Figure 1). Its size in the axis that corresponds to the long axis of *type I* is also nineteen to twenty-five millimeters. This graft was also placed in Ringers solution at room temperature.

Experimental Apparatus

The experimental apparatus included a T-2000 Alwetron testing machine, an amplifier, and a Hawlett Packard Moseley recorder, model AM 7001 or AM 7030 (Figure 2). Flat testing plates were used to test *type I* and *III* grafts (Figure 3 a), and a specially constructed half circle connector was employed to test *type II* grafts (Figure 3 b).

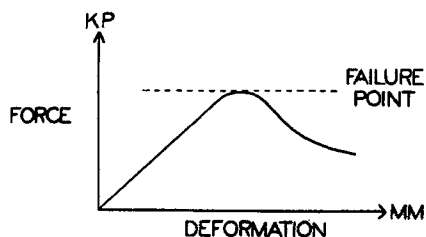


Figure 4. Diagram to show failure point on the load deformation curve.

Testing Procedures

The specimens were taken directly from the Ringers solution and tested immediately so as to avoid completely any dessication. The load was applied vertically as indicated in Figure 1, at a rate of 0.5 millimeters per minute. The failure point of the graft in all tests was taken as that point at which the specimen could no longer support an increasing load (Figure 4). This quantity could be read directly from the recorder as the peak load of the load deformation curve.

RESULTS

The data are not expressed in terms of force per unit area because of the variation in the surface configuration and composition of the material being tested. The goal is to provide information about the comparative behavior of the different types of grafts under vertical loads. The failure point as defined was taken for each sample. The

Table 1. Failure points in kiloponds for the various grafts from each subject.

Subject	Age	Type				
		I-A	I-B	II-A	II-B	III
3	44	590	475	380	180	255
4	73	175	140	100	70	90
5	67	355	330	140	90	235
6	69	195	200	190	125	140
7	80	390	390	250	40	165
8	77	360	380	130	90	220
9	77	380	340	220	220	120
10	85	280	220	125	60	165
1	33	480	550	250	140	330
2	63	360	300	199*	75	260
Mean	66.8	365.5	332.5	198.4	109.0	195.0

* This was a missing value substituted for by a statistical analysis (Scheffe 1963).

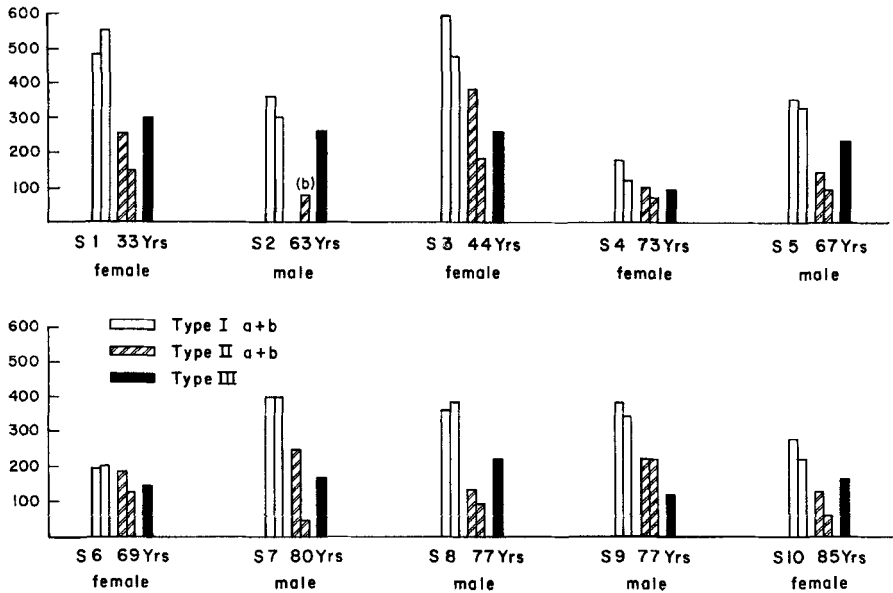


Figure 5. Histogram of failure point in kiloponds for the different types of grafts.

failure point is reported in kiloponds. Kilopond (kilogram-force or kilogram-weight) is defined as a force in any direction of 9.80665 newtons. The force of a kilopond is equivalent to the weight of one-kilogram mass under standard earth gravity (Cochran 1971). The values obtained are in Table 1. The histograms show comparisons of the values for the individual subjects (Figure 5).

1. The two younger specimens tended to be stronger than the older ones.
2. The failure point for *type I* was higher than for *type II* and *type III*. Statistical evaluation employing a two way classification and analysis of variance showed this statement to be significant at the .01 level of confidence (Ruff 1950).
3. *Type II a* tended to have a higher failure point than *type II b*. This is significant at the .10 level of confidence.

DISCUSSION

In this study we have sought to provide an answer to the question: Given a particular patient's ilium, which of the three commonly employed configurations of bone grafts would withstand the greatest

compressive load? The manner of loading in this experimental situation does not simulate exactly the type of loading that the graft undergoes clinically. It is reasonable to assume, however, that the major vector of force in the clinical situation is that of vertical compression as diagrammed in Figure 1. Consequently, the end point or failure point that was chosen was considered the best objective indication of the strength of the graft configuration. Based on the findings here, it seems a justifiable interpretation that the *type I* graft is most suitable for withstanding vertical compressive loads in the orientation in which these grafts were tested.

A striking outcome of this investigation was the discovery of the very high vertical load tolerances of these configurations of bone. This study has shown that prior to the time that the graft is acted upon by any biological processes, they can bear sizable loads. The range for the averages for these specimens was approximately 2.5 to five times the average body weight. Calculations based on publications by Ruff (1950) and Henzel et al. (1968) estimate the weight in a seventy kg man to be 6.3 kg above the first thoracic vertebra and 33 kg above the twelfth thoracic vertebra. The high tolerance ranges observed suggest that the graft configuration itself may not be the weak point in the system, certainly not in the early postoperative period. The weakness lies in the over-all mechanical construct consisting of the graft, its associated vertebrae, and the manner in which the vertebrae are changed to accept the graft.

It is of interest to note that a good quantity of this strong bone came from aged individuals. The average for the group was 66.8 years. The specimens from the two younger subjects (1 and 3) were found to be stronger, as might be expected (Lindahl & Lindgren 1968).

The follow mechanical consideration should be included. It can be appreciated that the *type I* and the *type II* grafts were essentially the same in cross section dimensions and that they were loaded in the same orientation relative to these dimensions. These tests show, however, that the longer *type III* grafts fail at a lower load (average 195 kiloponds) than the *type I* grafts (average 344 kiloponds). If these similar configurations of grafts are idealized as perfectly elastic homogeneous rods different only in height (length), then elementary strength of material theory could be applied. The phenomenon of the higher (longer) graft failing at the given lower point could be explained by an energy criterion of failure.

The strong tendency for *II a* to be stronger than *II b* was probably

due to the observed slightly thicker anterior portion of the outer table of the ilium. This finding indicates that if it is necessary to use a dowel type graft, it should probably be taken from the more anterior portion of the ilium.

SUMMARY

The strengths of three types of bone grafts were compared using the ilii from ten fresh autopsies. The grafts were tested for their ability to withstand vertical compressive loads. All three types were found to bear sizable loads. The failure point in the horsehoe-type grafts was significantly higher than the dowel-type and the modified strut-type grafts. The findings are thought to have certain implications in the evaluation of the immediate postoperative mechanical characteristics of different constructions for anterior spine fusions.

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