EXPERIENCES WITH BOILED CADAVERIC CANCELLOUS BONE
FOR FRACTURES OF LONG BONES

GRANT WILLIAMS, LONDON, ENGLAND

From the London Hospital Medical College

The literature on the subject of bone transplantation is now so voluminous (Chase and Herndon 1955) that any attempt to add to it constructively is difficult. Much of this literature attempts to compare techniques which are not strictly comparable. Either it extols the virtue of a clinical approach to the problem, excluding laboratory research, or it concentrates so much on experimental work that it is difficult to see the clinical application. In these circumstances the basic principles of bone transplantation are easily overlooked.

It is usually accepted that better results are obtained from autogenous bone transplants than from any other form of bone transplant (Reynolds and Oliver 1950, Carnesale and Spankus 1959, Herndon 1960). This is now known to be a consequence of antibody formation to the homograft or heterograft when used in their fresh forms (Bongfiglio, Jeter and Smith 1955; Chalmers 1959; Zeiss, Nisbet and Heslop 1960; Burwell and Gowlan 1962). However, there are certain disadvantages in the exclusive use of fresh autogenous bone. It usually involves a second incision with its inevitable discomfort, the quantity of bone is limited and there is the risk of infection, fracture, deformity or hernia, depending on the situation of the donor area (Bosworth 1955). In addition there are other factors which influence the choice of bone transplant. These can be summarised under the headings of osteofixation and osteosynthesis. It is difficult to see how these factors can be effective at the same time in a bone transplant, as the most suitable method for osteofixation is not as successful from the viewpoint of osteosynthesis. The classical cortical graft—whether by a Campbell (1923), Albee (1930) or Phemister (1947) technique—can have little value for osteofixation. This is not necessary if the graft can be used with simultaneous internal fixation of bone fragments by a metal implant (Bishop, Stauffer, and Swenson 1947; Boyd, Lipinski and Wiley 1961; Watson-Jones 1963).

When osteosynthesis is considered certain broad principles emerge. Firstly, cancellous bone shows more osteogenic potency than cortical bone as a transplant (Abbott, Schottstaedt, Saunders and Bost 1947; Ray, Degge, Gloyd and Mooney 1952; Withers 1955; Nicoll 1956; Wilson 1957; Ray and Holloway 1957). Secondly, although osteocytes can survive autotransplantation or homotransplantation, the numbers are so small that they are unlikely to be of any use for osteogenesis (Cohen, Maletskos, Marshall and Williams 1957; Urist, MacDonald and Jowsey 1958; Chalmers 1959; Nishimura, Yaeger and Sabet 1962; Ray and Sabet 1963). Thirdly, osteogenesis can be induced by dead bone, inert minerals such as plaster-of-Paris, transitional-celled epithelium or alcohol (Nyström 1928, Edberg 1930, Levander and Willestaedt 1946, Johnson and McMinn 1955, Bridges and Pritchard 1958, Peltier 1959, Mukhopadhyay and Mehta 1962). Finally, when antigenically incompatible bone is transplanted, new bone formation is slower and in smaller quantities than when an autograft is used (Hutchison 1952, Hammack and Enneking 1960, Williams 1962).

Arising out of this fourth principle, attempts have been made successfully to modify the bone homograft so that it is antigenically inert (Loose and Hurley 1956; Hancox, Owen and Singleton 1961; Bassett, Hurley and Stinchfield 1962). The results of using this "anorganic" bone vary considerably (Boyne and Lyon 1959, Kirk 1962). This same "anorganic effect" can be obtained by boiling bone, as cellular survival is not necessary in the bone transplant for the promotion of osteogenesis.

398 THE JOURNAL OF BONE AND JOINT SURGERY
TABLE I
CLINICAL MATERIAL

<table>
<thead>
<tr>
<th>Case number</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Diagnosis</th>
<th>Primary treatment</th>
<th>Time between injury and grafting (months)</th>
<th>Time between grafting and union (months)</th>
<th>Complications and comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>33</td>
<td>Compound fractured shaft of tibia</td>
<td>Toilet, reduction and plaster</td>
<td>5</td>
<td>7</td>
<td>Weight bearing in plaster at six months</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>22</td>
<td>Compound fractured shafts of tibia and fibula</td>
<td>Toilet, reduction and plaster</td>
<td>5</td>
<td>5</td>
<td>Weight bearing in plaster at five months (Figs. 2 and 3)</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>46</td>
<td>Fractured shaft of humerus</td>
<td>Reduction and plaster cutasse</td>
<td>4</td>
<td>—</td>
<td>Non-union, but excellent function</td>
</tr>
<tr>
<td>4</td>
<td>Female</td>
<td>25</td>
<td>Fractured shafts of tibia and fibula</td>
<td>Reduction and plaster</td>
<td>4</td>
<td>3</td>
<td>Weight bearing in plaster at ten weeks</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>28</td>
<td>Compound fractured shafts of tibia and fibula</td>
<td>Toilet, reduction and plaster</td>
<td>3</td>
<td>6</td>
<td>Weight bearing in plaster at five months</td>
</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>57</td>
<td>Fractured shafts of tibia and fibula</td>
<td>Reduction and plaster</td>
<td>8</td>
<td>5</td>
<td>Weight bearing in plaster at four months</td>
</tr>
<tr>
<td>7</td>
<td>Male</td>
<td>29</td>
<td>Fractured mid-shaft of radius</td>
<td>Reduction and plaster</td>
<td>4</td>
<td>3</td>
<td>Radiological union at two months</td>
</tr>
<tr>
<td>8</td>
<td>Female</td>
<td>34</td>
<td>Fractured shaft of tibia</td>
<td>Reduction and plaster</td>
<td>5</td>
<td>5</td>
<td>Weight bearing in plaster at four months</td>
</tr>
<tr>
<td>9</td>
<td>Female</td>
<td>80</td>
<td>Fractured mid-shaft of femur</td>
<td>Traction</td>
<td>5</td>
<td>5</td>
<td>Radiological union at three months</td>
</tr>
<tr>
<td>10</td>
<td>Male</td>
<td>46</td>
<td>Fractured shafts of tibia and fibula</td>
<td>Reduction and plaster</td>
<td>4</td>
<td>4</td>
<td>Weight bearing in plaster at three months</td>
</tr>
<tr>
<td>11</td>
<td>Male</td>
<td>23</td>
<td>Fractured mid-shaft of femur</td>
<td>Traction</td>
<td>3</td>
<td>5</td>
<td>Staphylococcal infection resolved with antibiotics. Radiological union at three months</td>
</tr>
<tr>
<td>12</td>
<td>Male</td>
<td>54</td>
<td>Fractured shafts of femur, tibia and fibula</td>
<td>Kuntscher nail. Reduction and plaster</td>
<td>7</td>
<td>4</td>
<td>Kuntscher nail removed at time of tibial graft</td>
</tr>
<tr>
<td>13</td>
<td>Male</td>
<td>30</td>
<td>Fractured shafts of tibia and fibula and mid-shafts of radius and ulna</td>
<td>Reduction and plaster</td>
<td>6</td>
<td>3</td>
<td>Weight bearing out of plaster at three months</td>
</tr>
<tr>
<td>14</td>
<td>Male</td>
<td>17</td>
<td>Compound fractured shafts of tibia and fibula</td>
<td>Toilet, reduction and plaster</td>
<td>5</td>
<td>4</td>
<td>Weight bearing out of plaster at four months</td>
</tr>
<tr>
<td>15</td>
<td>Male</td>
<td>23</td>
<td>Compound fractured shaft of tibia</td>
<td>Toilet, reduction and plaster</td>
<td>6</td>
<td>3</td>
<td>Weight bearing out of plaster at three months</td>
</tr>
</tbody>
</table>
The fact that boiling bone renders it antigenically inert has now been well established. The T antigens of most tissues are altered by heating to 50 degrees Centigrade (Billingham, Brent and Medawar 1958). Burwell and Gowland (1962) showed that there were no changes in the proximal lymph nodes draining boiled bone homografts such as are seen in lymph nodes draining fresh bone homografts. Burwell (1963) further found that boiled bone does not evoke any detectable change in the sensitivity of the host; and second set grafts of skin, following the first set grafts of bone, did not suffer any accelerated rejection.

**MATERIAL**

A series of fifteen patients is presented in whom boiled, minced cadaveric bone was used. The series is comprised of a consecutive number of patients with fibrous union of a long bone.

Table I shows the clinical details. No patient was excluded by selection; if it was considered that a bone transplant was needed, then boiled minced cadaveric cancellous bone was used.

Table II compares the overall results of this series with some other published figures of bone grafting for non-union.

**TECHNIQUE**

A block of bone, approximately ten by eight centimetres, is removed from each ilium of a cadaver so as to include the anterior half of each iliac crest.

These blocks are boiled for two hours. The boiling loosens soft tissues which are then removed by scraping. The bone is then boiled again for thirty minutes and stored in a sterile container.

Before operation the bone is sterilised by boiling for twenty minutes, and an assistant, using a non-touch technique, cuts it into small pieces which are then minced in a bone mill. Meanwhile the surgeon exposes the site to be grafted and, when there is fibrous union, cuts a slot in the long axis of the bone, across the

**TABLE II**

**COMPARISON OF RESULTS OF THE TREATMENT OF DELAYED UNION**

<table>
<thead>
<tr>
<th>Author</th>
<th>Type of graft</th>
<th>Number of cases</th>
<th>Failure (per cent)</th>
<th>Infection (per cent)</th>
<th>Average time to union (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campbell (1923)</td>
<td>Cortical onlay</td>
<td>59</td>
<td>8.5</td>
<td>1</td>
<td>Unknown</td>
</tr>
<tr>
<td>Burns and Michaelis (1944)</td>
<td>Cortical inlay</td>
<td>26</td>
<td>4</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Bishop, Stauffer and Swenson (1947)</td>
<td>Cortical inlay. Both</td>
<td>34</td>
<td>121</td>
<td>11</td>
<td>27</td>
</tr>
<tr>
<td>Present series</td>
<td>Boiled, minced cancellous bone</td>
<td>25</td>
<td>8</td>
<td>Unknown</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>235</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIG. 1**

Diagram of the slot cut across the fibrous ring at the site of delayed union in the shaft of a long bone.
fracture. This slot penetrates the full thickness of the cortex, exposing the medullary cavity, but preserving most of the fibrous ring joining the bone ends. Fibrous tissue lying in the medullary cavity is removed and to do this it is sometimes necessary to remove more of the fibrous ring (Fig. 1).

In the case of the tibia the fibrous ring extends on to the posterior and lateral surfaces and should be left intact. It very effectively immobilises the fracture site in conjunction with a plaster. The medullary cavity exposed by the slot is then packed with the minced bone graft, then the slot that has been cut is filled and some of the minced material is placed around the outside of the fracture site. The soft tissues are closed and the limb immobilised in plaster or with traction.

DISCUSSION

The aim of this procedure is to obtain the benefits of inlay and onlay grafting. The graft presumably acts as a vascular bridge (Trueta 1963) and allows the speedy re-establishment of medullary and periosteal circulation with subsequent osteogenesis. The material used is sterile, easily obtained and easily handled.

It might be argued that the fractures with delayed union could have proceeded to bony union with longer immobilisation (Pritchard 1961) but once the bone ends were sclerosed and rounded off, it was not considered justifiable to extend the period of observation because of the risk of no further improvement. Further, although one of the tibiae was grafted three months after the fracture because the ends were sclerosed and rounded off, the average time between injury and bone transplant in the whole series was five months.
In this small number of patients it was never once necessary to use internal fixation with metal at the same time as the bone transplant. The fibrous ring provided sufficient immobilisation, but there would have been no objection to obtaining this immobilisation with a metal implant had this been necessary.

The use of boiled bone is no recent addition to the technology of bone transplantation (Hopkins and Penrose 1890, Brooks and Hudson 1920, Leriche 1922, Lloyd-Roberts 1952), but it is not often used nowadays.

**SUMMARY**

1. Fifteen cases of bone transplantation for fibrous union of fractures of long bones are described, using boiled minced cancellous bone from cadavers. One transplant became infected but the infection responded to treatment.
2. In one patient with non-union of the shaft of the humerus, bony union was not obtained, but a good functional result obviated further treatment.
3. It is suggested that this relatively simple method of bone transplantation could be used more widely if its potentialities were appreciated more fully.

It is a pleasure to thank Mr S. A. Jenkins, Consultant Orthopaedic Surgeon, Eastbourne, for allowing me access to his results.

**REFERENCES**


