THE TREATMENT OF DISPLACED FRACTURES OF THE NECK OF THE FEMUR BY COMPRESSION

A Preliminary Report

J. CHARNLEY, N. J. BLOCKEY and D. W. PURSER, MANCHESTER, ENGLAND

In the treatment of medial fractures of the femoral neck by the Smith-Petersen nail one can distinguish two problems: the first concerns failure to initiate the process of union, as shown by complete separation of the head and the recurrence of the original deformity; the second concerns necrosis and collapse of the femoral head after successful union at the site of the fracture. Complete separation of the femoral head is an early complication, usually occurring within twelve months of the fracture, but collapse of the femoral head after union of the fracture is frequently delayed till well into the second year after operation.

Though it may be suspected that ischaemia of the femoral head lies at the root of most cases of defective union, non-union can still occur in the presence of a viable head; but how frequently this happens is difficult to estimate from published work, because of the notorious unreliability of the ordinary radiological signs of ischaemia. It seemed possible that some light might be shed on this matter by applying our experience of the union of cancellous bone under spring-loaded compression (Charnley 1953). We considered that if this mechanical principle could be applied to the femoral neck it ought to precipitate "first intention" osseous union in every case in which the head was viable, but it would be unlikely to do so when the
head fragment was unable to participate actively in the process of union by reason of a restricted blood supply.

In cases in which the head fragment is ischaemic it seemed possible that the results of using a device designed to exert spring-loaded compression parallel to the axis of the neck of the femur might test the theory of Pauwels (1935) that ischaemia could be prevented if the action of shearing forces on the fracture line could be eliminated. This idea, that ischaemic necrosis is to a large extent the result of defective mechanical treatment, has recently been championed again by Dickson (1953) with his advocacy of "shaft fixation" for all subcapital fractures.

The principle of impacting fractures of the femoral neck with a "lag-screw" has been tried many times in the past (Henderson 1939, Putti 1940, Godoy-Moreira 1940, Lippmann 1939), and in one instance the lag-screw was combined with a spring (Virgin and MacAusland 1945). It seems probable that all these efforts were unsuccessful because, in the absence of shaft fixation, they permitted the femoral head to shear into the position of varus and lateral rotation. This mechanical defect arises because the femoral neck in elderly patients is nothing more than a hollow tube (Fig. 1) in which the fatty marrow offers no resistance to the lateral movement of the screw—a fact that was recognised by Putti, from whose monograph the illustration (Fig. 2) is taken. In the same work Putti showed experimentally that it was unnecessary to use screws with very large helical flanges because, even though the marrow of the neck was soft, the head of the femur was usually remarkably dense. Using a screw of the type adopted in this study Putti showed that an axial pull of from 125-475 kilograms was needed to tear it out of the femoral head even in elderly subjects (the greatest figure was in a subject aged sixty-five and the lowest in one aged fifty).

With these ideas and historical precedents in mind, the spring-loaded compression screw was devised, which is described in detail below. It soon became apparent in clinical trials that this device, in addition to being an excellent method of treatment, was a most important research tool because the design enabled measurements to be made concerning the presence, or absence, of progressive collapse in the healing fracture with an accuracy of \(\pm 0.5\) millimetres. Measurements of this kind revealed that fractures which on ordinary radiographic standards
might be considered united often were still showing continuous absorption at the fracture site. It was soon found that progressive extrusion of the screw, revealed by the spring-loading even before the patient was permitted to bear weight, was a sensitive indication of ischaemia, whereas the radiographic tests were unreliable.

In presenting this preliminary report we are aware that one-year results are open to criticism in that the full effects of ischaemic necrosis have yet to develop. However, we consider that the high failure rate of completely displaced fractures, during the first year after nailing, constitutes the crux of the treatment of medial fractures of the femoral neck, because this type of failure is essentially the complete recurrence of the original displacement with the return of total disability for the patient. The development of ischaemic necrosis after the first year is often a much less urgent matter and, though disappointing and the source of pain and disability, frequently it can be handled palliatively in very elderly patients.

**APPARATUS AND TECHNIQUE**

**The appliance**—The appliance consists of two principal parts, the screw and the sleeve-plate (Fig. 3). The screw, five-sixteenths of an inch in diameter, bears a coarse thread of wood-screw type on its inner end, and a fine thread on the outer end which engages with a nut shaped externally as a cylinder. To enable the screw to be inserted, the outer end is provided with a screwdriver slot. The sleeve-plate is essentially a tube which gives a sliding fit for the screw in the medial two-thirds of its length and which opens to a wider diameter at the outer end to accommodate the cylindrical nut and compression spring. The outer end of the sleeve is
attached to a short plate by which shaft fixation is obtained. In the interests of strength
the sleeve and the plate are forged and machined from a single piece of stainless steel.

A special feature of design in this instrument is that only one length of screw is required
to cope with all lengths of femoral neck: this is obtained, while avoiding excessive subcutaneous
prominence of the appliance, by recessing the spring and nut below the surface of the bone
in the wide part of the sleeve (Fig. 12). Only one angle of sleeve is used—120 degrees—because
the method of insertion is adapted to the appliance without regard to the angle of the femoral
neck. The angle of 120 degrees was chosen in preference to 130 degrees so that the direction
of spring-loading might neutralise rather more effectively the vertical shearing component of
gravity (which would, of course, be done best with an angle of 90 degrees).

The spring exerts a maximal force of approximately twenty-five pounds and has a range
of expansion of six millimetres. To avoid electrolytic action the spring, like the rest of the
appliance, is made of Austenitic stainless steel.

![Fig. 4](image)

Instrument for inserting compression screw: A—2-millimetre guide wire,
B—60-degree cannulated protractor, C—"counter-boring" tool to recess
the barrel of the sleeve-plate in the bone, D—tapping drill for lag-screw,
E—screwdriver for lag-screw, F—"torque-controlled" spanner for cylindrical
nut.

**TECHNIQUE OF INSERTION**

Special instruments are required to insert the appliance (Fig. 4). The following are the
steps of the operation.
1. The fracture is reduced on a fracture table under radiographic control, with antero-
posterior and lateral radiographs as in the standard Smith-Petersen technique.
2. The skin is incised over the trochanter, and a quarter-inch (6-millimetre) drill-hole is
made through the femoral cortex about half an inch (12 millimetres) below the vastus lateralis
ridge (that is, higher than is usual with the Smith-Petersen nail). A two-millimetre guide wire
is inserted at an angle of 120 degrees to the axis of the shaft of the femur, using the simple
cannulated protractor (Figs. 4 and 5). The direction of the guide in the lateral view is controlled
by eye, but can be assisted by radiological guides such as the Engel-May if desired.

In the radiological check after this first insertion of the guide it will be found that any
error in the antero-posterior view will be that the guide may be either too high or too low.
If this is the case, in order to preserve the angle of 120 degrees, a second wire will have to be
inserted parallel with the first through another drill-hole in the cortex either cephalic or caudal
to the first. If the head has been reduced into a valgus position the guide will have to
be placed slightly higher than the axis of the neck if it is to strike the centre of the head. This changing of the point of entry of the guide through the lateral cortex of the femur is quite unlike the alteration of the angle of the guide more familiar in the Smith-Petersen technique. Any error in the lateral view is corrected by orthodox techniques.

3. The "counter-boring" tool (Fig. 4), which is cannulated, is slid over the guide wire and turned by a brace (Fig. 6) until it will go no farther. This point is reached when the wide diameter cutting edge has sunk below the surface of the cortex until a shoulder at the base
of the cutter prevents further entry. It is important during this procedure to watch the external end of the guide wire where it is visible in the fenestrated tubular shaft of the instrument in order to try to keep it central.

4. The sleeve is passed into the hole cut by the boring tool and the plate settled against the shaft of the femur and attached by one screw (Fig. 7), the remaining screws being inserted during the intervals needed for radiography in the subsequent stages of the operation.

5. The guide wire is extracted and the tapping drill (Fig. 4) is inserted to its full distance (Fig. 8), which is reached when the shoulder makes contact with metal, when it can then go no farther.

6. The screw is passed into the sleeve and turned with a screwdriver (Fig. 4) for no more than two or three turns.

7. Radiographs are taken to estimate how much farther the screw must be driven to reach the subchondral bone of the head. This extra distance, from the tip of the screw to a point just below the cortex of the head, is measured in terms of the pitch of the coarse screw-thread to avoid errors from radiological magnification. For example, a distance of four and a half screw-threads would mean that a further nine half-turns of the screw would be needed.

8. While the screw is being driven to its full distance an increase in resistance is often encountered of such a degree that the force exerted by the screwdriver might damage the screw-slot and burr the fine screw-thread. If this thread is damaged the engagement of the cylindrical nut is impossible. Therefore, if resistance of this magnitude is encountered, it is most important to apply the cylindrical nut to the outer end of the screw at this stage. The screwdriver can then be passed down the centre of the cylindrical nut to engage with the screw-slot (Fig. 9) and then full penetration of the screw can be obtained without fear of being unable to engage the nut.

9. The fracture is impacted by screwing up the cylindrical nut until the outer surface of the nut is flush with the outer edge of the sleeve (Fig. 11). In this position the spring is fully compressed. The special spanner (Fig. 4) provided for this purpose is "torque-controlled" in that it has a narrow handle which limits the amount of power that can be applied; without "torque-control" the too violent use of this spanner might avulse the coarse-threaded screw from the head of the femur if the bone were particularly soft. Impaction is completed by shaking the shaft of the femur and straining the fracture a few times in various directions, and then re-tightening the cylindrical nut if any further "settling-in" of the fracture is thereby produced.

Technical points of special interest—The "counter-boring" tool is constructed so that it makes a central hole approximately three millimetres deeper than the length of the central sleeve of the appliance; this facilitates impaction.

There is no danger of the head of the femur slipping between the extraction of the guide wire and the insertion of the screw, because the reduction is held by the position on the fracture table as firmly as it was before the insertion of the wire.

The head of the femur does not rotate, even when it offers great resistance to insertion of the screw, because irregularities at the fracture line interdigitate and so cause locking.

If the screw is not placed centrally it is best to err towards a posterior situation to minimise any tendency for the screw to cut out by the forces tending to cause lateral rotation of the shaft.

Though the armamentarium looks rather formidable, the insertion of the appliance is remarkably simple and straightforward. All who have used it are agreed that it is easier to insert than the Smith-Petersen nail. The quality of the reduction is always improved when the spring-loaded impaction is applied, and this is still true even when the screw has been inserted considerably "off-centre." This is not true of Smith-Petersen nailing, in which there is a tendency for the insertion of the nail to disturb a good reduction and for the head to be widely displaced if the nail is imperfectly centred.
RESULTS

Of eighty-one patients who have had this operation, there are forty-four on whom it was carried out more than a year ago. Only thirty-three are available for study because of the difficulties peculiar to accurate follow-up of this very fragile geriatric age group (the average age in this series was 73·4 years). Six patients could not be persuaded to come for a final radiographic examination and therefore were excluded. Four patients died after operation (Table I). There was one case of sepsis which ended in non-union.

Of the thirty-three cases that were available for analysis (Table II), twenty-seven were "clinical successes" and six were failures. If expressed as a percentage, 82 per cent of the cases were thus satisfactory—that is, the patient was capable of walking, free from significant pain, and had no symptoms sufficient to demand further surgical intervention. Only 18 per cent, on these criteria, were failures. This is a considerable improvement on the failure rate

<table>
<thead>
<tr>
<th>Age</th>
<th>Interval between operation and death</th>
<th>Contributory cause of death</th>
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</thead>
<tbody>
<tr>
<td>86</td>
<td>4 days</td>
<td>Senility</td>
</tr>
<tr>
<td>75</td>
<td>3 weeks</td>
<td>Bronchopneumonia</td>
</tr>
<tr>
<td>74</td>
<td>4 months</td>
<td>Senility and hemiplegia</td>
</tr>
<tr>
<td>84</td>
<td>8 months</td>
<td>Senility</td>
</tr>
</tbody>
</table>

Fig. 13

Behaviour of cases in which extrusion did not become arrested within a year. Numbers correspond to Case numbers in Table II.
### TABLE II

**Details of Thirty-three Cases Followed for a Year and of One Patient who Died at Four and a Half Months**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age</th>
<th>Sex</th>
<th>Interval after fracture before operation</th>
<th>Extrusion at 3 months (millimetres)</th>
<th>Extrusion at 12 months (millimetres)</th>
<th>Radiological result at one year</th>
<th>Clinical result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>57</td>
<td>F</td>
<td>2 days</td>
<td>5</td>
<td>5</td>
<td>Good trabeculation. Fracture line disappeared</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>63</td>
<td>F</td>
<td>4 days</td>
<td>4</td>
<td>4</td>
<td>Good trabeculation. Fracture line disappeared</td>
<td>Excellent</td>
<td>Spastic hemiplegic</td>
</tr>
<tr>
<td>3</td>
<td>85</td>
<td>F</td>
<td>12 hours</td>
<td>1</td>
<td>1</td>
<td>No trabeculation. Line of fracture dense</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>83</td>
<td>F</td>
<td>24 hours</td>
<td>1</td>
<td>1</td>
<td>Good trabeculation. Slight density of fracture line</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>75</td>
<td>F</td>
<td>18 days</td>
<td>1</td>
<td>1</td>
<td>Good trabeculation. Fracture line disappeared</td>
<td>Excellent</td>
<td>Screw extracted after 4 months—originally in too far</td>
</tr>
<tr>
<td>6</td>
<td>75</td>
<td>F</td>
<td>24 hours</td>
<td>1</td>
<td>1</td>
<td>Good trabeculation. Fracture line disappeared</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>60</td>
<td>F</td>
<td>24 hours</td>
<td>1</td>
<td>1</td>
<td>Good trabeculation. Fracture line disappeared</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>61</td>
<td>F</td>
<td>24 hours</td>
<td>2</td>
<td>2</td>
<td>Good trabeculation. Fracture line disappeared</td>
<td>Excellent</td>
<td>Screw extracted at 7 months—prominent under fascia lata</td>
</tr>
<tr>
<td>9</td>
<td>67</td>
<td>F</td>
<td>10 days</td>
<td>3</td>
<td>3</td>
<td>Good trabeculation. Fracture line disappeared</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>78</td>
<td>F</td>
<td>5 days</td>
<td>3</td>
<td>3</td>
<td>Good trabeculation. Fracture line disappeared</td>
<td>Excellent</td>
<td>Screw pulled out of the head between 3 months and one year, allowing spring to expand fully</td>
</tr>
<tr>
<td>11</td>
<td>84</td>
<td>M</td>
<td>7 days</td>
<td>3</td>
<td>3</td>
<td>Good trabeculation. Fracture line disappeared</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>72</td>
<td>M</td>
<td>3 days</td>
<td>3·5</td>
<td>3·5</td>
<td>Good trabeculation. Fracture line disappeared</td>
<td>Excellent</td>
<td>Screw fractured between 7th and 10th months, though radiologically bone thought to be united. No detectable ischaemia</td>
</tr>
<tr>
<td>13</td>
<td>53</td>
<td>M</td>
<td>5 days</td>
<td>4·5</td>
<td>4·5</td>
<td>No trabeculation. Line of fracture dense</td>
<td>Excellent</td>
<td>Screw bent between 6th and 9th months, though radiologically bone thought to be united. Patient hemiplegic and did not walk</td>
</tr>
<tr>
<td>14</td>
<td>75</td>
<td>F</td>
<td>3 days</td>
<td>4·5</td>
<td>4·5</td>
<td>No trabeculation. No sclerosis</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>76</td>
<td>M</td>
<td>24 hours</td>
<td>4·5</td>
<td>6·0</td>
<td>No trabeculation. No sclerosis. Head flattening</td>
<td>Fair— uses sticks</td>
<td>No evidence of ischaemia preceded crumbling of the head first noticed between 9th and 12th months</td>
</tr>
</tbody>
</table>

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TABLE II—contd.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age Sex</th>
<th>Interval after fracture before operation</th>
<th>Extrusion at 3 months (millimetres)</th>
<th>Extrusion at 12 months (millimetres)</th>
<th>Radiological result at one year</th>
<th>Clinical result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>72 F</td>
<td>7 days</td>
<td>4·5</td>
<td>7·5</td>
<td>Good trabeculation. Head flattening on summit</td>
<td>Excellent</td>
<td>Trace of flattening of the top of the head suggesting start of collapse. Never any evidence of ischaemia</td>
</tr>
<tr>
<td>17</td>
<td>73 F</td>
<td>5 days</td>
<td>2·5</td>
<td>3·5</td>
<td>No trabeculation. No sclerosis</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>91 F</td>
<td>24 hours</td>
<td>3·5</td>
<td>5·0</td>
<td>No trabeculation. Head sinking on neck in “mushroom”</td>
<td>Very good for her age</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>58 F</td>
<td>2 days</td>
<td>3·0</td>
<td>7·5</td>
<td>No trabeculation. No sclerosis</td>
<td>Good, though has some pain</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>83 F</td>
<td>11 days</td>
<td>3·5</td>
<td>7·5</td>
<td>Not united. Ischaemic and head slipping</td>
<td>Good for her age</td>
<td>Died 18 months after the operation. Would have been a failure in a younger patient. Collapse between 6th and 12th months</td>
</tr>
<tr>
<td>21</td>
<td>67 F</td>
<td>2 days</td>
<td>3·5</td>
<td>7·5</td>
<td>Sclerosis. Head sunk on neck in “mushroom.” Otherwise good</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>79 F</td>
<td>2 days</td>
<td>6·5</td>
<td>8·0</td>
<td>Head ischaemic and collapsing</td>
<td>Good</td>
<td>Screw removed as cutting into acetabulum. Head revascularised and further collapse arrested at 20th month</td>
</tr>
<tr>
<td>23</td>
<td>77 F</td>
<td>6 days</td>
<td>7·5</td>
<td>10·5</td>
<td>No trabeculation. No sclerosis. Head sinking on neck in “mushroom”</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>87 F</td>
<td>24 hours</td>
<td>7·5</td>
<td>12·0</td>
<td>No trabeculation. No sclerosis. Head sinking on neck in “mushroom”</td>
<td>Good for her age and frailty</td>
<td>Died at 14 months—specimen illustrated (Figs. 34 to 36)</td>
</tr>
<tr>
<td>25</td>
<td>71 F</td>
<td>3 days</td>
<td>7·5</td>
<td>13·5 at 14 months</td>
<td>No trabeculation. No sclerosis. Head sinking on neck in “mushroom”</td>
<td>Good</td>
<td>After “mushroom” collapse suggests osseous union at 17th month</td>
</tr>
<tr>
<td>26</td>
<td>84 M</td>
<td>4 days</td>
<td>6·0</td>
<td>7·5</td>
<td>No trabeculation. ? Ischaemia</td>
<td>Good for age and frailty</td>
<td>Nut came loose and all pressure lost between 3rd and 4th weeks</td>
</tr>
<tr>
<td>27</td>
<td>83 F</td>
<td>—</td>
<td>4·0</td>
<td>6·0</td>
<td>? Trabeculation. No sclerosis</td>
<td>Excellent. Initially collapsed</td>
<td>Not included in graph as only 2 radiographs at 8 weeks and 12 months</td>
</tr>
<tr>
<td>28</td>
<td>62 F</td>
<td>16 days</td>
<td>0</td>
<td>12·0</td>
<td>Ischaemic head with complete failure</td>
<td>Failure</td>
<td>Screw cut out and head came off between 7th and 11th months. Remarkable case as radiologically appeared united at 6 months</td>
</tr>
</tbody>
</table>
we experienced in the past when using the Smith-Petersen nail. In a small series, from which were excluded all the undisplaced abduction fractures, we encountered approximately 50 per cent of failures before the end of the first year.

Of the six early failures, three were due to the screw's cutting out of the head, one to breakage of the screw and two to complete collapse of the head from necrosis.

**TABLE II—contd.**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age</th>
<th>Sex</th>
<th>Interval after fracture before operation</th>
<th>Extrusion at 3 months (millimetres)</th>
<th>Extrusion at 12 months (millimetres)</th>
<th>Radiological result at one year</th>
<th>Clinical result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>70</td>
<td>F</td>
<td>5 days</td>
<td>4.5</td>
<td>—</td>
<td>No evidence of ischaemia or necrosis</td>
<td>Failure</td>
<td>Screw cut out of head between 3rd and 4th months</td>
</tr>
<tr>
<td>30</td>
<td>85</td>
<td>F</td>
<td>4 days</td>
<td>1.5</td>
<td>—</td>
<td>No evidence of ischaemia or necrosis</td>
<td>Failure</td>
<td>Perfect reduction and perfectly centred screw. Bearing weight and very successful till screw cut out between 4th and 5th months</td>
</tr>
<tr>
<td>31</td>
<td>66</td>
<td>F</td>
<td>14 days</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Failure</td>
<td>Patient insane and walked before 3 months. Screw fractured at 5th month and head came off. Head ischaemic</td>
</tr>
<tr>
<td>32</td>
<td>78</td>
<td>F</td>
<td>4 days</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Failure</td>
<td>Cut out at 16th day. Very soft bone. Technical error. Failure predicted at time of operation</td>
</tr>
<tr>
<td>33</td>
<td>58</td>
<td>M</td>
<td>2 days</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Failure</td>
<td>Screw cut out in 4th month and head came off</td>
</tr>
<tr>
<td>34</td>
<td>72</td>
<td>F</td>
<td>2 days</td>
<td>4.0</td>
<td>—</td>
<td>—</td>
<td>Died at 4½ months</td>
<td>Bedridden hemiplegic. Practically no weight bearing</td>
</tr>
</tbody>
</table>

**MEASUREMENT OF ABSORPTION AT THE FRACTURE LINE**

The design of the appliance makes it a simple matter to measure the extrusion of the screw by counting the threads of the coarse screw that project from the sleeve into the head. If collapse occurs the number of exposed threads will diminish, and since the distance between each thread is an eighth of an inch (3.1 millimetres) there is no need to correct for distortion or magnification. The screw is in effect a "ruler" in the centre of the femoral neck.

Twenty-six of the twenty-seven patients classified as clinical successes had been examined radiographically often enough to enable the progress of extrusion of the screw to be made into curves, which are reproduced in Figures 13 and 19. The horizontal line drawn across both figures at the six millimetres level of extrusion indicates the amplitude of the compression spring; therefore at points above this line a fracture is no longer under spring-loading. The vertical right ordinate gives the force in pounds to which the fracture was subjected. Each curve is designated by a case number so that the data of the case can be traced from Table II.

As regards extrusion of the screw, the cases ranged in behaviour between two clearly recognisable extremes, with between them a less clearly defined intermediate group. At one extreme the total extrusion of the screw was gross and progressed continuously throughout the year. This type seemed to be predictable in that the extrusion during the first three months was never less than three millimetres. It seemed obvious that these must be cases of ischaemia, even though no radiological sign of a relative increase in density of the femoral head was
detectable. Seven of the twenty-six cases included in the graphs were of this type (Fig. 13). A typical example is shown in Figures 14 to 18.

At the other extreme were cases in which the total extrusion of the screw was insignificant and arrest of this extrusion took place with the spring still exerting over half its force (12.5 lb.). These cases seemed to be predictable by the arrest of extrusion within three months, and the amount of extrusion never exceeded three millimetres. Eleven of the twenty-six cases in the graphs were of this type and all proceeded to unequivocal radiological union in less than a year, as shown by complete disappearance of the fracture line and the re-establishment of trabeculation (Fig. 19). A typical example is shown in Figure 20.

There were seven cases which occupied an intermediate group between these two extremes of behaviour (Fig. 13—Cases 12, 13, 14, 15, 16; Fig. 19—Cases 17, 18).

It is difficult to say with certainty what normal or pathological states these intermediate cases represent. It seems significant that the two cases of this intermediate group which showed the greatest total extrusion before finally becoming arrested (Cases 15 and 16) both showed the beginnings of ischaemic collapse of the femoral head twelve months after the injury. The arrest of extrusion, which was delayed until six and seven months, seems to
indicate that the fracture had united; but the degree of extrusion (6 millimetres and 7·5 millimetres) might indicate ischaemia too great to allow revascularisation from the distal fragment and hence necrosis might be predicted. The radiological appearances in Case 15 are illustrated in Figures 21 to 24.

It is necessary to emphasise that despite the extrusion that took place, indicating defective union, all of these twenty-six cases in the graphs represent clinical successes. **Extrusion in the unsuccessful cases**—In six cases the operation failed because the head became completely detached. Radiographs were sufficiently numerous for measurements of extrusion to be made in three (Fig. 25).

![Graph](image)

**Fig. 19**

Behaviour of cases in which extrusion was arrested. Vertical left ordinate indicates extrusion. Right ordinate indicates force of spring at corresponding amount of extrusion. Numbers correspond to Case numbers in Table II.

**Case 28**—The position was held without a trace of extrusion for three and a half months. The screw then extruded three millimetres by the seventh month. Even at this date no evidence of ischaemia was present. Sudden failure by cutting out of the screw occurred at the tenth month, at which time radiological evidence of ischaemia, as shown by a dense head, had developed.

**Case 29**—This conforms to the criteria of Figure 19 because the screw had extruded more than three millimetres at three months. It could be predicted that primary osseous union would not occur. The screw cut out completely at four months. There was no radiological evidence of ischaemia either before or after failure.

**Case 30**—The position was held for six weeks without a trace of extrusion. The screw was then extruded 1·5 millimetres between the sixth and twelfth weeks. Complete failure by detachment of the head with cutting out of the screw occurred at the fifth month. There was no radiological evidence of ischaemia before failure, but after failure the head appeared dense.

**Site of bone absorption**—It is obviously of great importance to decide whether the extrusion of the screw is caused by collapse of the head, or by absorption of the neck of the femur. It is no uncommon thing to suspect absorption of the neck when a Smith-Petersen nail is used, though the lateral rotation of the distal fragment usually associated with non-union complicates, or renders impossible, accurate measurements. In this series a relatively accurate measurement of the length of the neck was possible by noting a fixed point on the sleeve of the compression device. Provided the hip was in a position of comparable rotation (recognition of which the sleeve-plate moving with the shaft made easy) measurements taken from serial radiographs were proved experimentally to be comparable.

We were completely satisfied that when gross extrusion occurred the absorption took place entirely in the head and that the neck fragment almost always retained its original length intact.
The mushroom or umbrella effect—When this compression screw is used the collapse of an ischaemic head on to the femoral neck takes place in a manner quite unlike the collapse that one is accustomed to see after Smith-Petersen nailing. In the latter case an ischaemic head invariably shears into varus and one has the impression that shortening of the femoral neck takes place as a result of repeated shearing friction at every step taken by the patient. In cases treated by the compression screw a striking feature was that if collapse developed the head settled down concentrically on to the femoral neck. The dense tubular cortex of the femoral neck, under the pressure of spring-loading, sank into the head until the latter sat on it like a cap or mushroom (Figs. 14 to 18, 26 to 29). In this position the subchondral shell of cortical bone of the head, which is quite a strong element in the head, obtains a stable purchase over the neck which is capable of resisting shearing stresses. In these cases the hollow ischaemic head acts as a "natural prosthesis" (rather like the "cartilage-cup" operation of Moore (1948)) and gives reasonable functional activity even with fibrous union. The more the head collapses into this "mushroom" form, so as to enclose the stump of the neck, the more effectively is shearing strain relieved from the screw, and relieved from it just when the danger of cutting out becomes greatest.

**PATHOLOGICAL MATERIAL**

Two important specimens were obtained. They were the complete upper ends of the femurs from patients who died four and a half months and fourteen months after operation with no symptoms referable to the hip—that is, they had been "clinical successes." *

**Specimen 1.** Case 34—Woman aged seventy-five years. Death occurred at four and a half months. The extrusion of four millimetres was arrested at seven weeks and remained constant thereafter.

* The patient who died at four and a half months is not included in the main series because the follow-up was less than a year, but the clinical details are recorded as Case 34 in Table II.
Case 15. Figure 21—First post-operative radiograph. Figure 22—Total extrusion six millimetres. Extrusion arrested at seven months. Figure 23—At twelve months. Start of ischaemic necrosis. Figure 24—At twenty months severe collapse (see Fig. 13).
Radiographs of the intact specimen (Fig. 30) showed no evidence of ischaemia and clinical radiographs while the patient was alive were the same.

In sharp contrast to the radiological appearance, the naked eye appearance of the cut surface of the fresh specimen (Fig. 31) shows without doubt that the femoral head was totally ischaemic. A zone of revascularisation is spreading into the dead head for a distance of about half a centimetre at the point where the inferior surface of the neck is impacted (under pressure) into the dead head.

The specimen was sawn into slices and digested in trypsin. Two of the slices showed osseous union between the head and the neck (Fig. 32) whereas the other slices fell apart, indicating that the head was uniting by bone only through a small bridge.

In histological preparations (Fig. 33) it was noticeable that in contrast to the heavily engorged blood vessels of the femoral neck the head of the femur showed a complete absence of blood vessels. The fatty marrow between the trabeculae in the femoral head was necrotic. The trabeculae themselves were atrophic. There was very little evidence of new bone formation and what new bone was present was restricted to the immediate vicinity of the end of the fractured femoral neck.

Specimen 2. Case 24—Woman aged eighty-seven years. Death occurred at fourteen months. There had been continuous extrusion throughout the year (Fig. 19). The total extrusion was twelve millimetres. The result was a clinical success, but the patient was frail and hardly ever tried to walk.

Radiographs taken while she was alive showed no definite evidence of ischaemia. Radiography of the bisected specimen also failed to show ischaemic necrosis. The naked eye appearance of the cut surface of the fresh specimen (Fig. 34) showed that, except for two small zones at the periphery, the head was not completely ischaemic.

Digested preparations were made from the slices that were not used for histology. Osseous union was present in two (Fig. 35), but the others fell apart at the fracture when all collagen had been dissolved away.

Histologically (Fig. 36) it was noticeable that new bone was very scanty, being restricted to the inferior margin of the femoral neck. The presence of a limited circulation in the femoral head was confirmed histologically, but despite this the fat cells were necrotic and the trabeculae were even more atrophic than in the totally ischaemic head of the previous specimen.

**DISCUSSION**

A feature which we wish particularly to emphasise in the selection of cases for this study is that no undisplaced fracture has been included. Only cases that required manipulative reduction before fixation have been considered. The inclusion of undisplaced fractures in statistics for osseous union in fractures of the femoral neck treated by any method produces an improvement of 10 or 20 per cent in the results and does not help the study of the essential problem, which is the treatment of the displaced fracture of the femoral neck. Truea and Harrison (1953) showed that varus displacement at the initial injury must always rupture the "lateral epiphysial" arterial blood supply, which is the most important contribution from the neck to the head, while in valgus or undisplaced fractures this source of blood supply will be intact.
Case 21—Good example of "mushroom" collapse with stump of the neck burying itself into the interior of the head under the influence of spring-loading. Figure 26—Immediately after operation. Figure 27—Ten months later.

Case 25—Gross extrusion followed by bony union. Figure 28—Immediately after operation. Figure 29—Seventeen months later. Excellent result.
FIG. 30
Case 34—Radiographs of specimen obtained at necropsy four and a half months after operation. No radiological evidence of ischaemic necrosis.

An obvious criticism of this technique is the possibility that the spring-loaded compression might be the factor responsible for destroying the blood supply of the head fragment. That pressure is not harmful to osseous union is supported by the following considerations:

1. Eleven cases of the series (33.3 per cent) showed perfect osseous union, demonstrated by retrabeculation in the radiographs. The early arrest of extrusion in these eleven cases indicated moreover that this was "first intention" osseous union. The fact that the other
cases in the series showed progressive and continuous extrusion of various degrees of severity is taken to imply that the cause of the extrusion was resident in the condition of the head and not in the action of pressure *per se*.

2. The ischaemic head of the specimen illustrated in Figure 31 indicates that revascularisation is proceeding most actively at the point where the cortex of the femoral neck is being driven deep into the ischaemic head, and therefore presumably at the point of highest pressure. There is no revascularisation at any other point in the broken surface of the head.

3. The pressure on the cancellous bone of the head must obviously be localised to the relatively small area in direct contact with the edges of the broken neck of the femur which has the shape of a hollow tube (Fig. 1). The marrow in the interior of the neck is of almost fluid consistency and there must therefore be a large cancellous surface of the head fragment not exposed to pressure.
4. The use of this compression screw in basal and pertrochanteric fractures (if they are not too grossly shattered to permit the fragments to be compressed) has been very satisfactory in seventeen cases. Indeed the results in fractures in which both fragments are known to

![Image](66x31 to 546x761)

**Fig. 34**
Case 24—Bisected specimen obtained at necropsy fourteen months after operation.

![Image](66x31 to 546x761)

**Fig. 35**
Case 24—Slices of specimen digested in trypsin, showing, when all collagen was removed, that true osseous union was present at a localised point.

have an intact blood supply have been most remarkable in that union seems to take place in about four weeks, just as we are accustomed to expect union in compression arthrodesis of the knee. Our experience suggests that the use of compression in lateral fractures of the
neck of the femur which are not excessively comminuted may be one of the most dramatic applications of compression in the healing of cancellous bone.

5. It has been shown by direct biopsy examination in compression arthrodesis of the knee (Charnley 1953) that the load is transmitted entirely by the bone trabeculae and the circulation can proceed unimpeded in the cancellous spaces.

Spring-loading versus simple extrusion—It is apparent from recent publications (Schumpelick and Jantzen 1955, Pugh 1955) that independent work in Germany and America has led to the development of appliances for fractures of the neck of the femur giving shaft fixation which at the same time allow the fractures to collapse. Both these instruments concentrate on directing the force of body weight or muscle tone along the axis of the neck of the femur to produce intermittent compression and neither of them uses spring-loading to enhance impaction.

Without spring-loading no advantage is taken of the friction grip at the fracture line by which to secure absolute immobilisation against rotational strains. In the Pugh nail rotation is prevented by using a triflanged nail; but rotation of the nail in the sleeve-plate has to be prevented by a pin engaging a longitudinal slot. One suspects that if sufficient clearance is given to guarantee freedom, then slight rotational play will be unavoidable, and though this may seem very little, its effect will be considerably magnified at the periphery of the neck. It is impossible to use spring-loading in the Pugh device because it would pull the triflanged nail out of the head; indeed to prevent spontaneous expulsion of the nail from the head a special "friction ring" is an essential part of the device, which will have a slight effect of holding the fracture apart (as all nails tend to do) until the patient is able to take weight on the limb to overcome the grip of the friction ring.

In the German device a screw is used but no spring-loading is incorporated. Because of its obvious inability to resist rotational movement, this design of appliance appears to be
unsuitable for medial fractures though, like the Pugh nail, it is likely to be highly satisfactory in trochanteric fractures.

The use of spring-loading increases the sensitivity of extrusion of the screw as an indicator of defective blood supply. At the time of operation the compression of the spring by the nut produces an initial impaction, and extrusion under spring-loading will therefore start from a true base line. Without spring-loading it will be impossible to be sure to what extent the first stages of extrusion merely indicate mechanical "settling down" of the fracture line as opposed to biological absorption.

CONCLUSIONS

We adduce the following conclusions from our experience of using this spring-loaded compression screw on completely displaced medial fractures of the femoral neck:

1. That this method probably eliminates non-union when the head is fully viable.
2. That primary "first-intention" osseous union occurs in approximately 33.3 per cent of cases.
3. That a vascular complication, of varying severity, undetectable by orthodox radiological tests, is revealed by extrusion of the screw in 66.6 per cent of cases.
4. That these observations disprove the idea that the main obstacle to revascularisation of an ischaemic head is the existence of forces so inclined to the axis of the femoral neck as to cause "shear."
5. That, compared with the Smith-Petersen nail used for completely displaced fractures, continuous spring compression can materially reduce the incidence of utter mechanical failure within the first year after operation. This is the result of "mushroom" impaction which itself can resist shearing strain and so can permit function as a fibrous union.
6. That early and rapid extrusion is a sensitive indication of a vascular complication in the head. Forewarned by this, activity can be restricted, or possibly other measures adopted, to anticipate or permanently postpone serious trouble.

We wish to thank surgeons in charge of units in the Manchester area for their co-operation in making available cases for this study, most notably Mr D. Lloyd Griffiths, and also Mr W. Sayle-Creer and Mr C. H. Cullen. The compression screw is made by Messrs Chas. F. Thackray Limited, Park Street, Leeds, 1.

This device has been patented in the United Kingdom and principal countries overseas, and royalties are to be used to form a research fund for the advancement of orthopaedic surgery, which fund is to be administered by the University of Manchester.

REFERENCES


vol. 39 B, no. 1, February 1957