VOLUME II

Thesis

A CLINICAL AND BIOMECHANICAL STUDY OF CAST-BRACE TREATMENT OF FRACTURES OF THE FEMORAL SHAFT

submitted by

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for degree of

Master of Surgery
University of Edinburgh
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C O N T E N T S

FIGURES

FIGURE 1

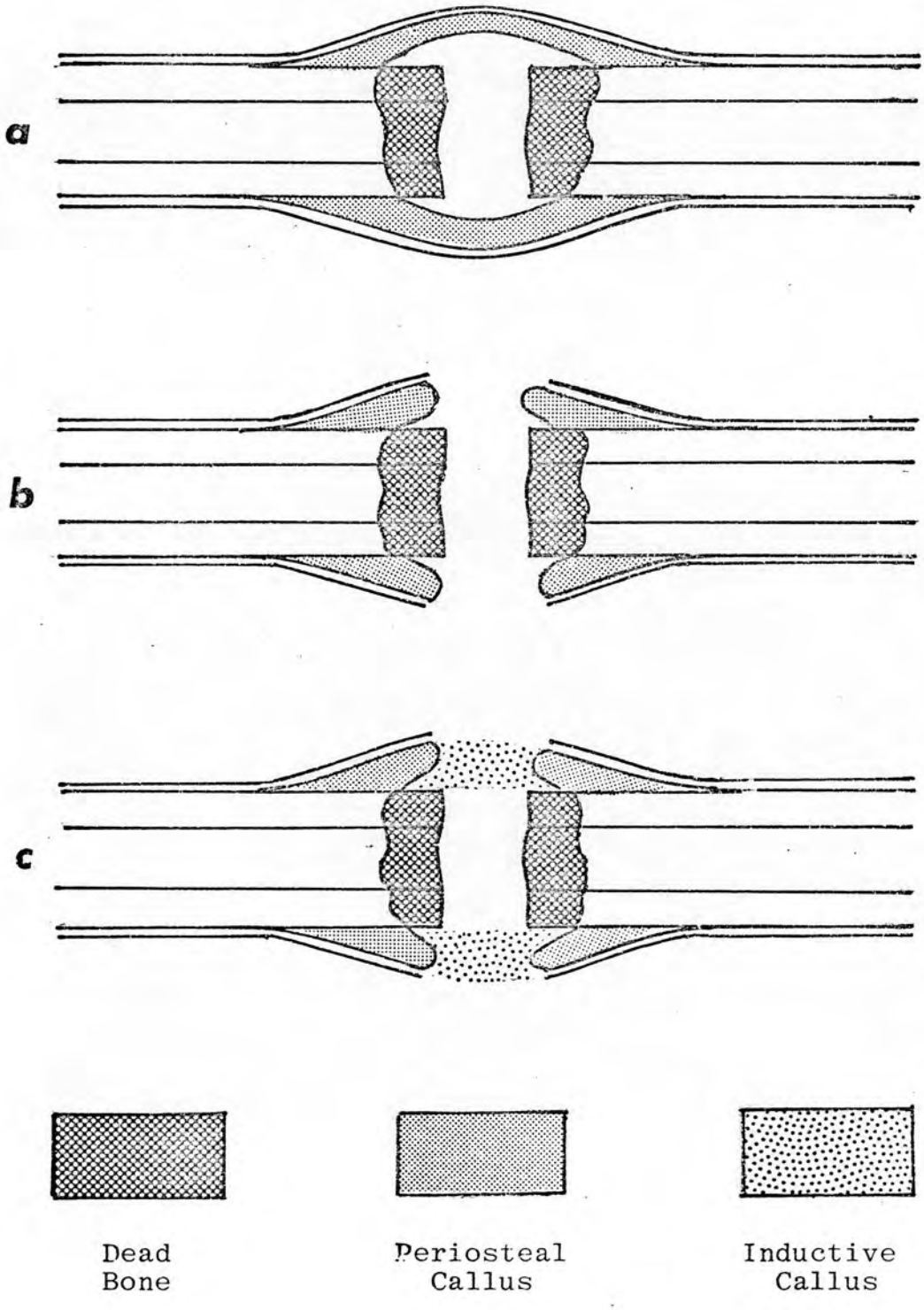


FIGURE 2

Diffuse Callus

FIGURE 3

Periosteal Callus

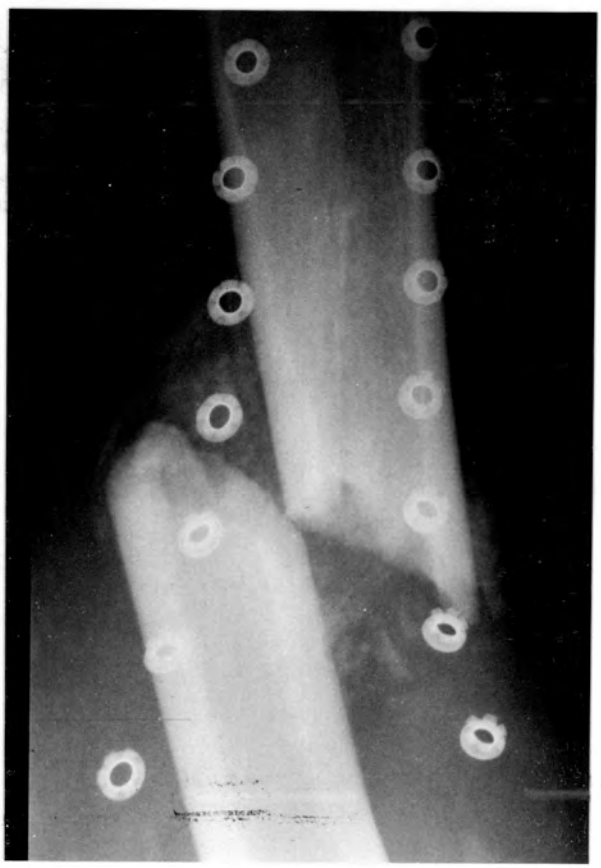


FIGURE 4

Type of healing	Speed	Ability to bridge gaps	Tolerance of movement	Tolerance of total rigidity	Importance of external soft tissues
Primary callus response	++++	+	++++	++++	-
External bridging callus	+++	+++	+++	-	++++
Late medullary callus	++	++++ (slow)	++	+++	-
Primary cortical	+	-	-	++++	-

(Reproduced with permission from McKibbin (1978). The Biology of Fracture Healing in Long Bones. Journal of Bone and Joint Surgery, 60B, 150-162).

FIGURE 5

Classification of Results (After Dencker 1965)

	Excellent or good	Satisfactory	Poor	Very Poor
Discomfort	Slight or O	Mod.	Severe	V. Severe
Shortening	O - 3 cms.	→ 5 cms.	→ 8 cms.	> 8 cms.
Angulation	O - 15 cms.	→ 20^{o}	> 20^{o}	Non-union
Knee - Flexion	90^{o}+	$45\text{-}90^{o}$	< 45^{o}	Refracture
Extension lag	O	$0\text{-}5^{o}$	> 5^{o}	Thigh amputation
Instability	O	$0\text{-}10^{o}$	> 10^{o}	
Thigh Atrophy	O - 2 cms.	→ 3 cms.	> 3 cms.	

FIGURE 6

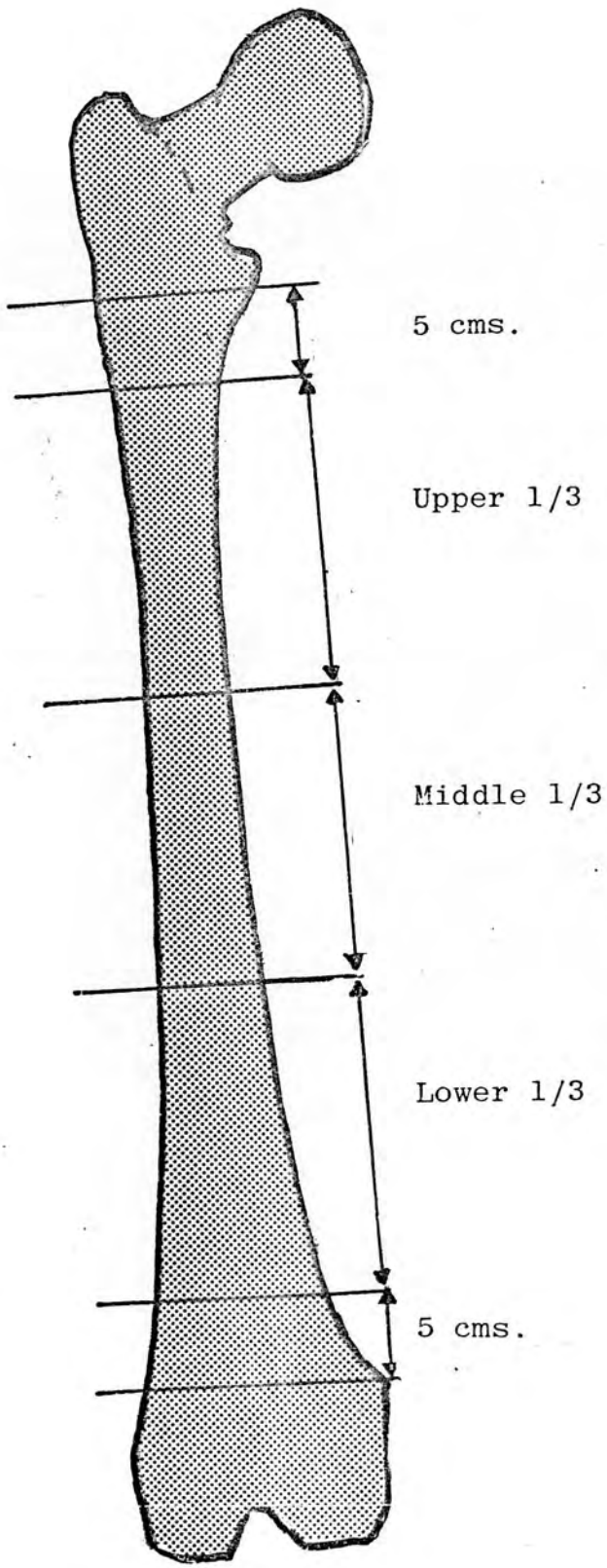
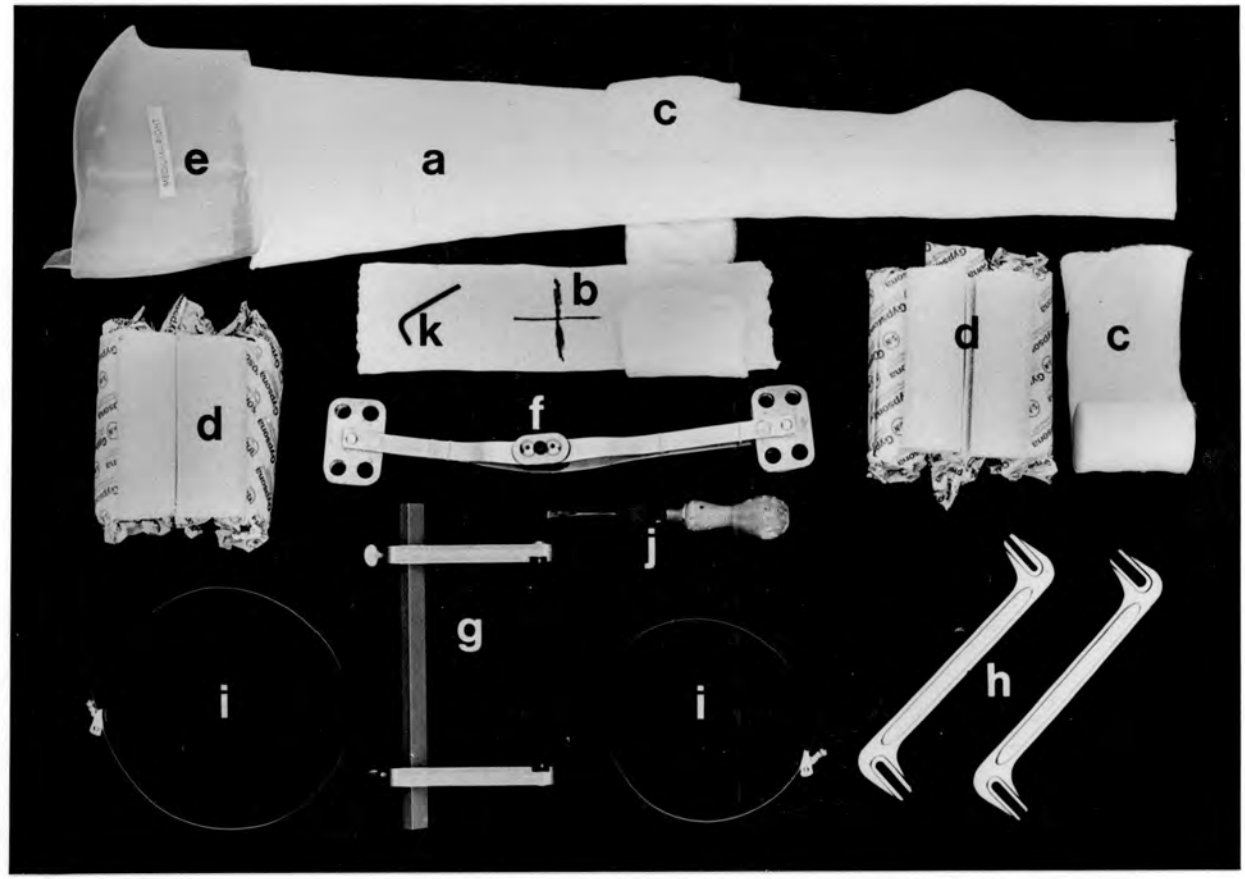


FIGURE 7

Cast-brace Components


e
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i
h

FIGURE 8

FIGURE 9

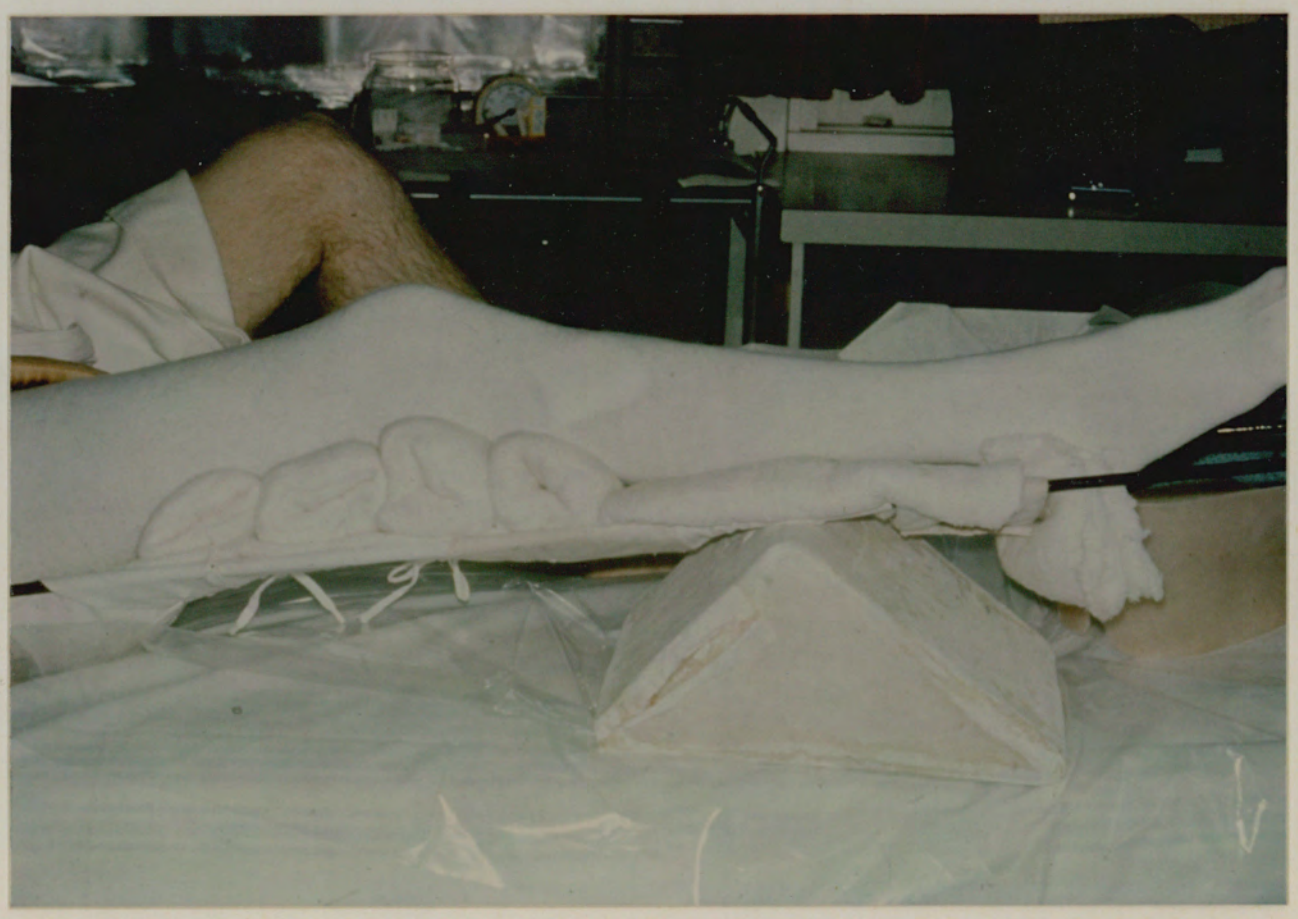

FIGURE 10

FIGURE 11

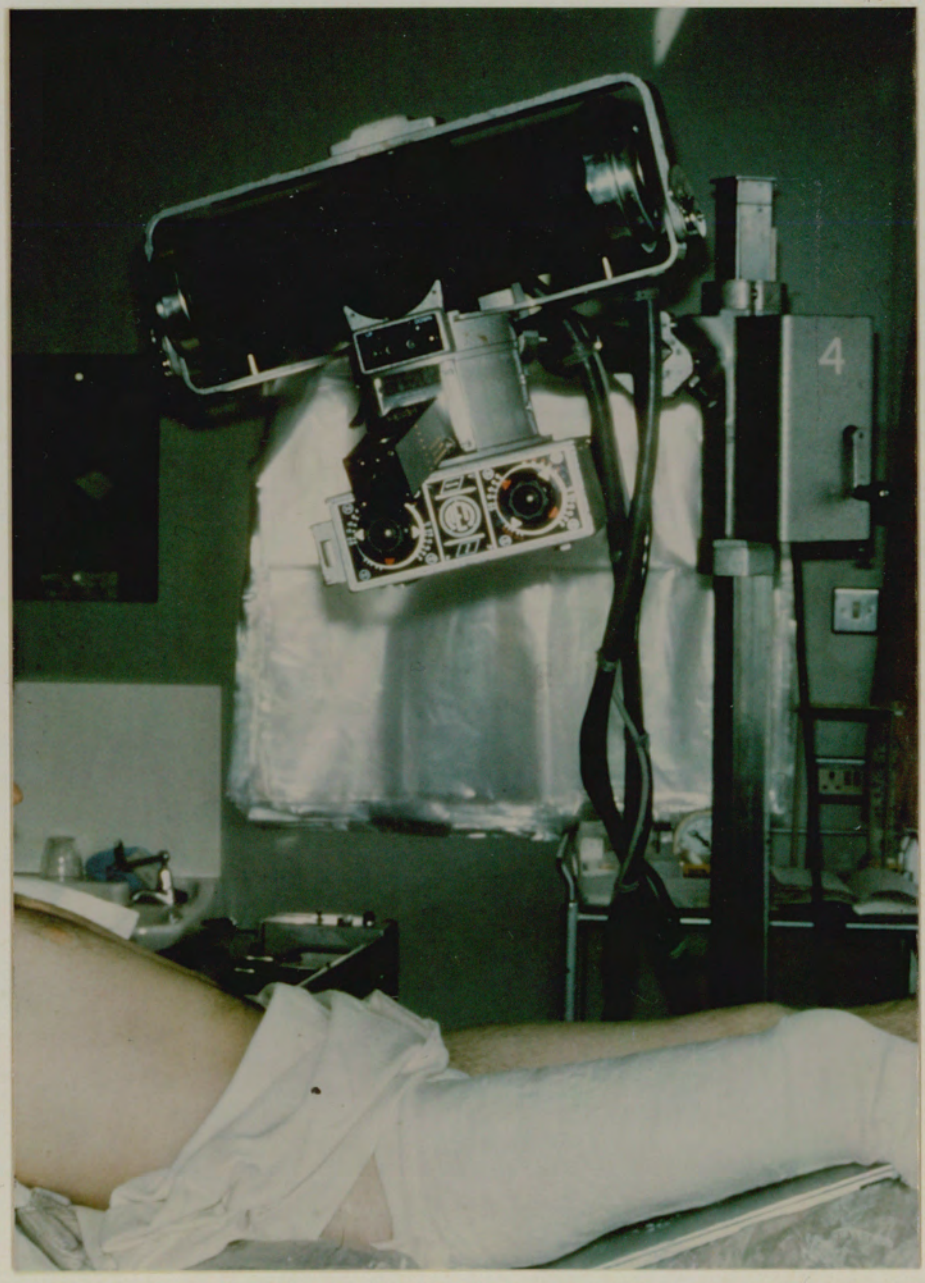
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FIGURE 12

FIGURE 13

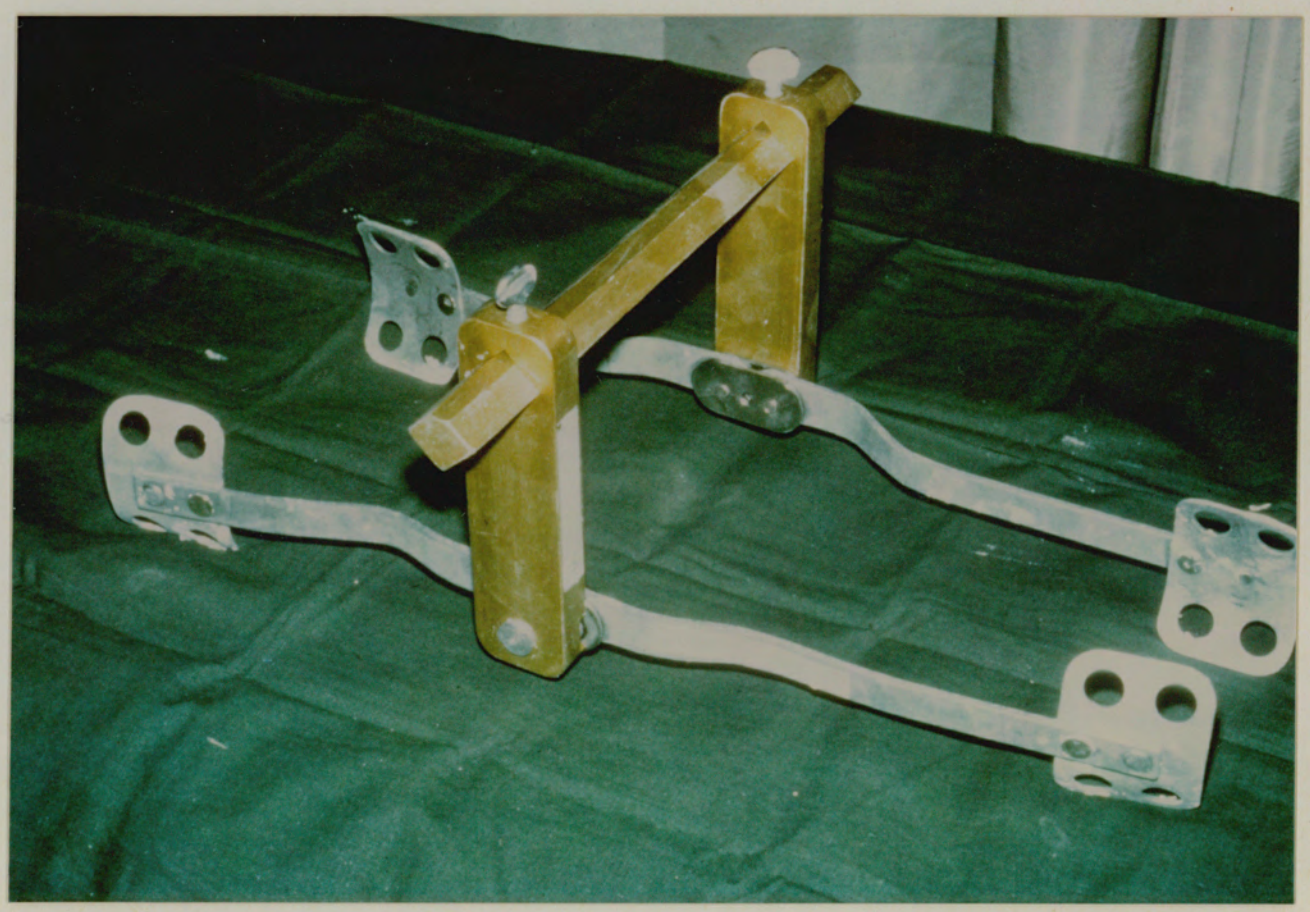
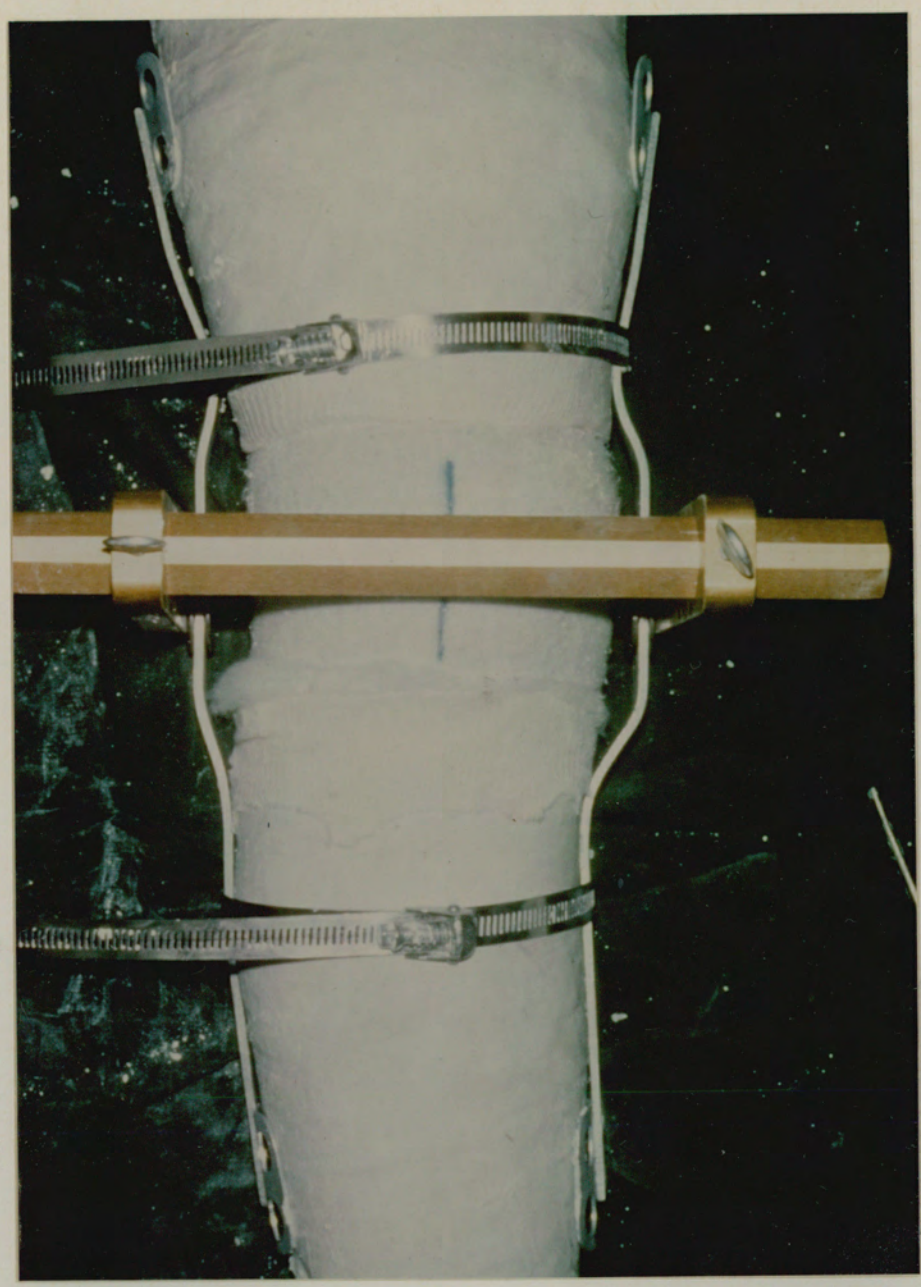


FIGURE 14

FIGURE 15



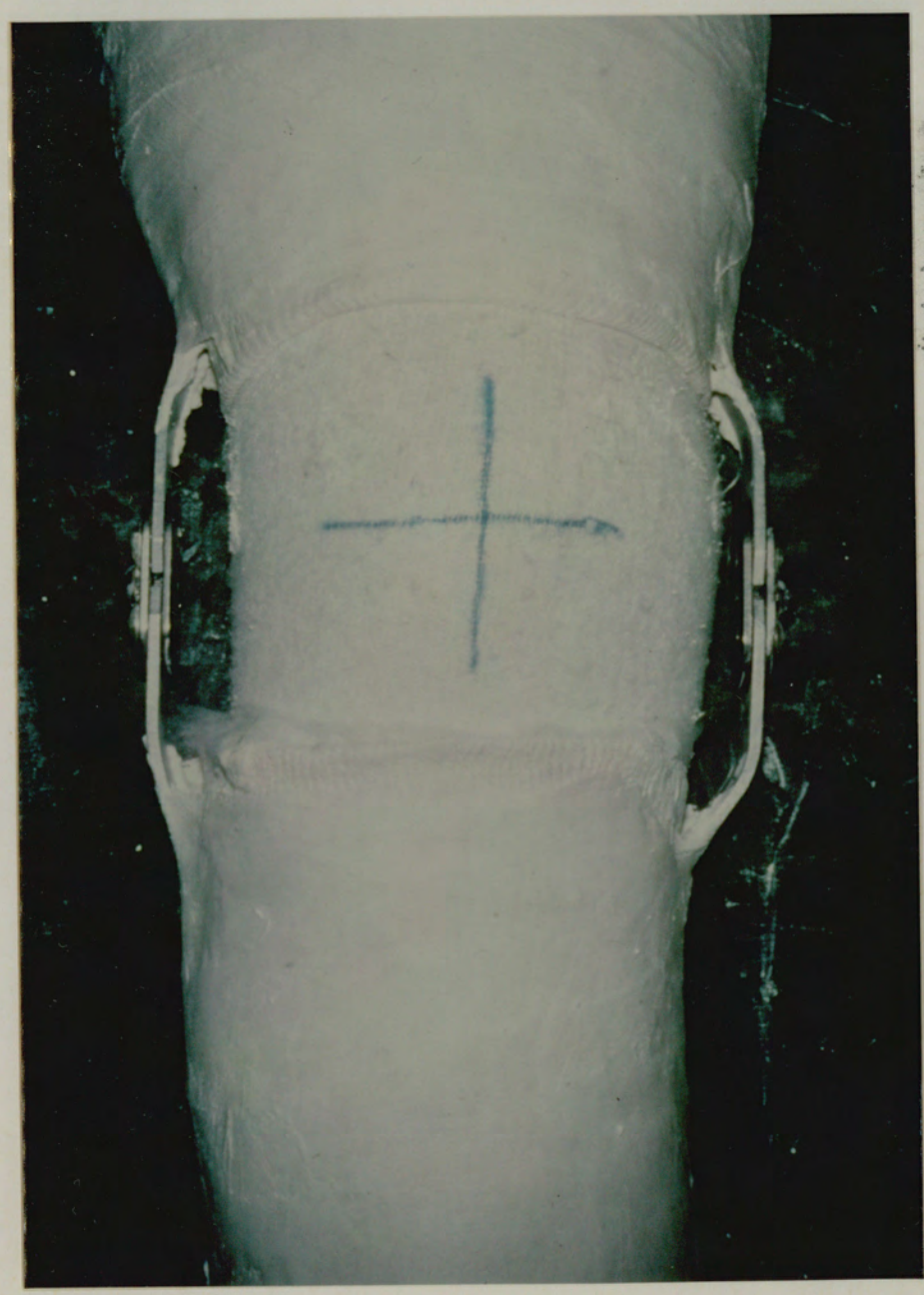


FIGURE 16

FIGURE 17

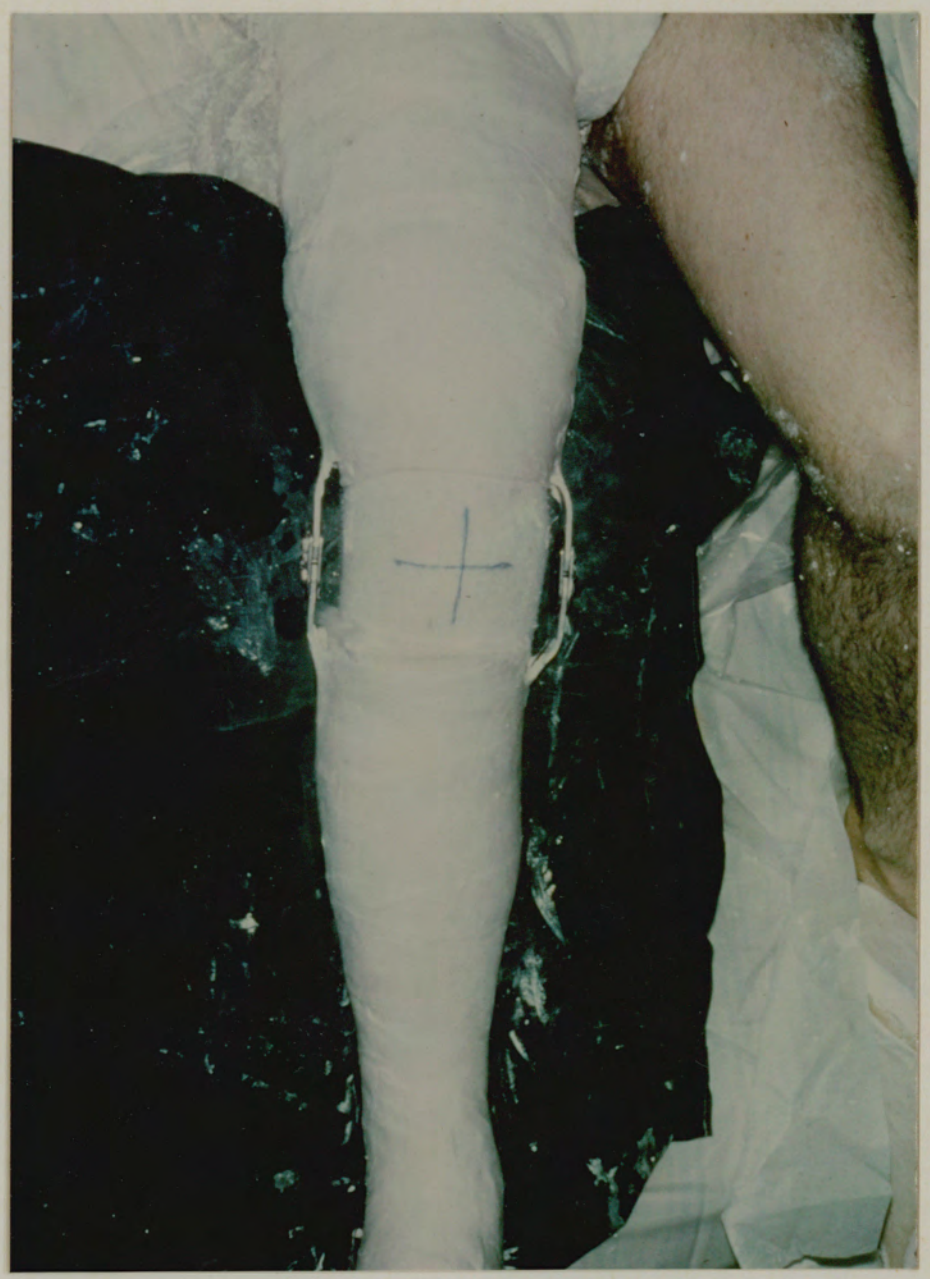


FIGURE 18

Moulding quadrilateral shape

by hand

FIGURE 19

Moulding quadrilateral shape

using jubilee clip

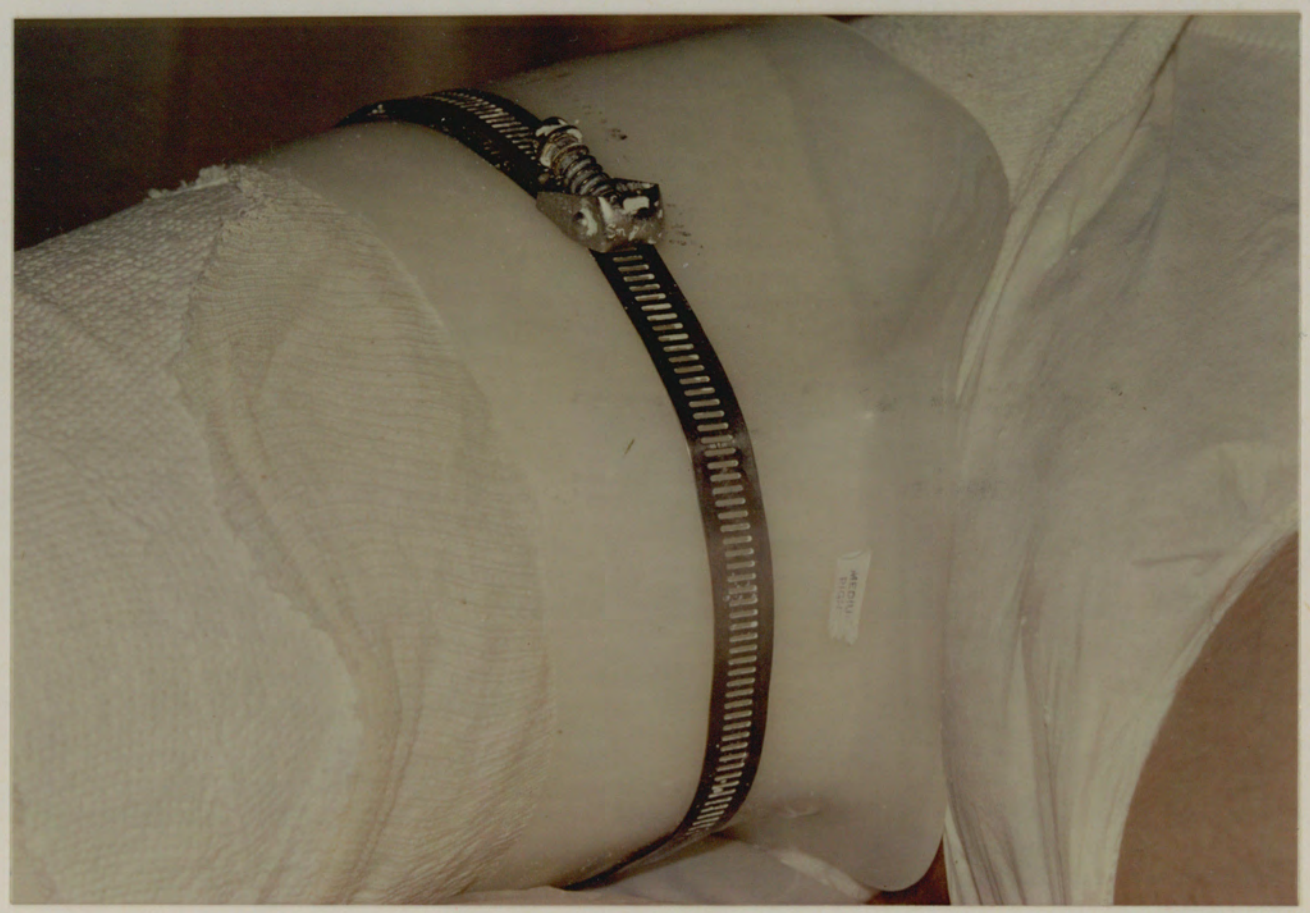


FIGURE 20

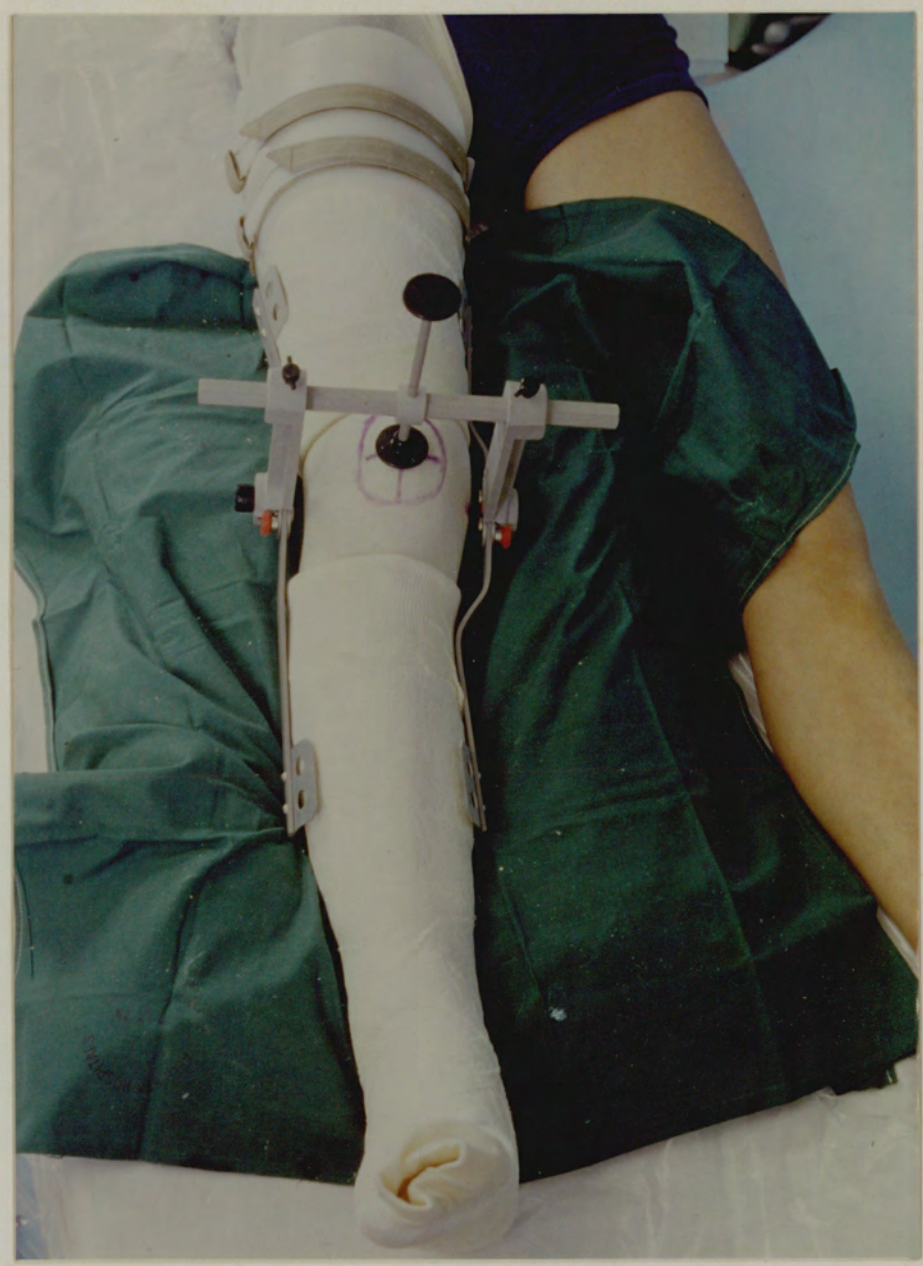
FIGURE 21

FIGURE 22

FIGURE 23

FIGURE 24

FIGURE 25



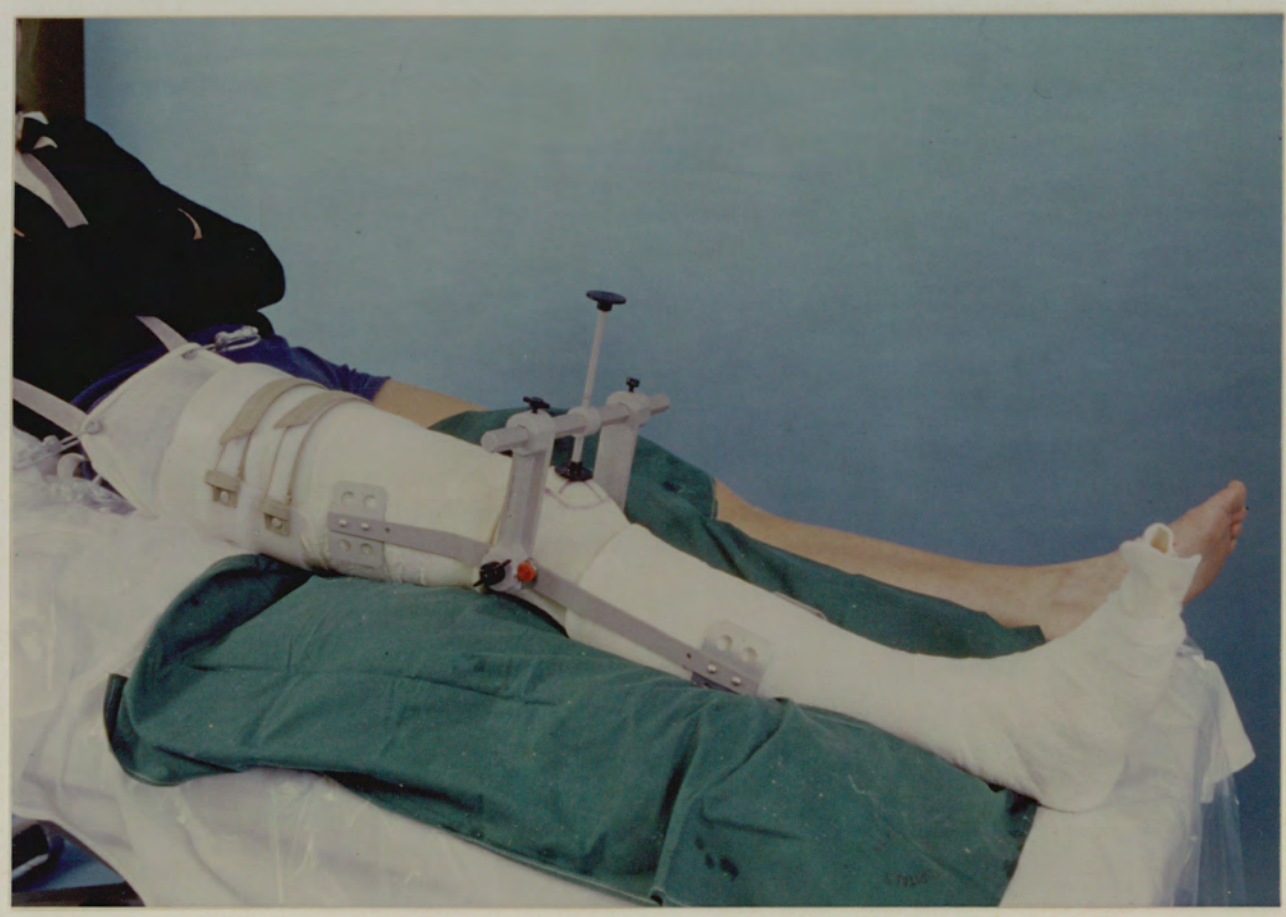


FIGURE 26

FIGURE 27

FIGURE 28

FIGURE 29

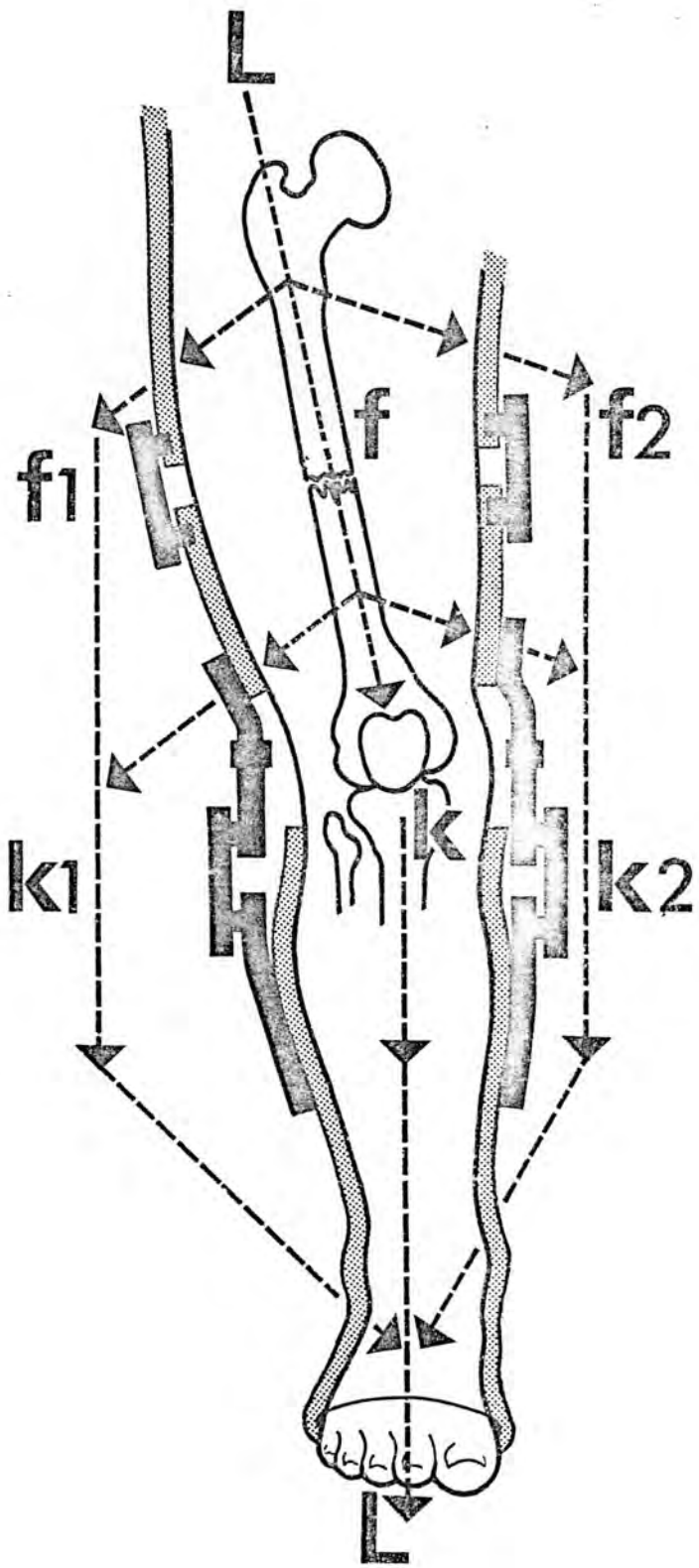


FIGURE 30

From left to right: transducer,
modified hinge with blanking plate,
and standard hinge.

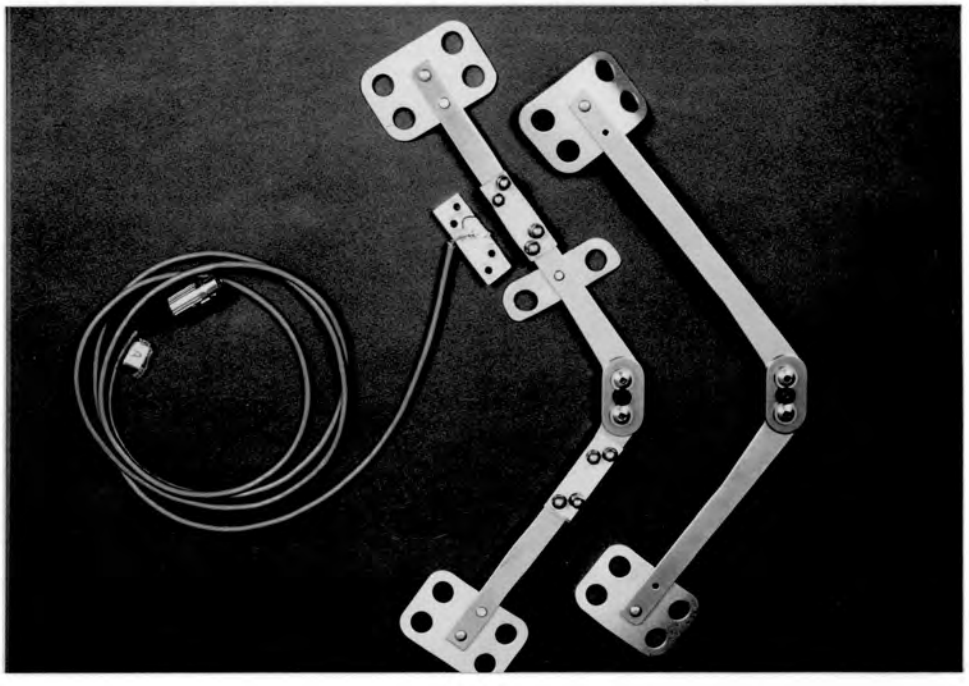
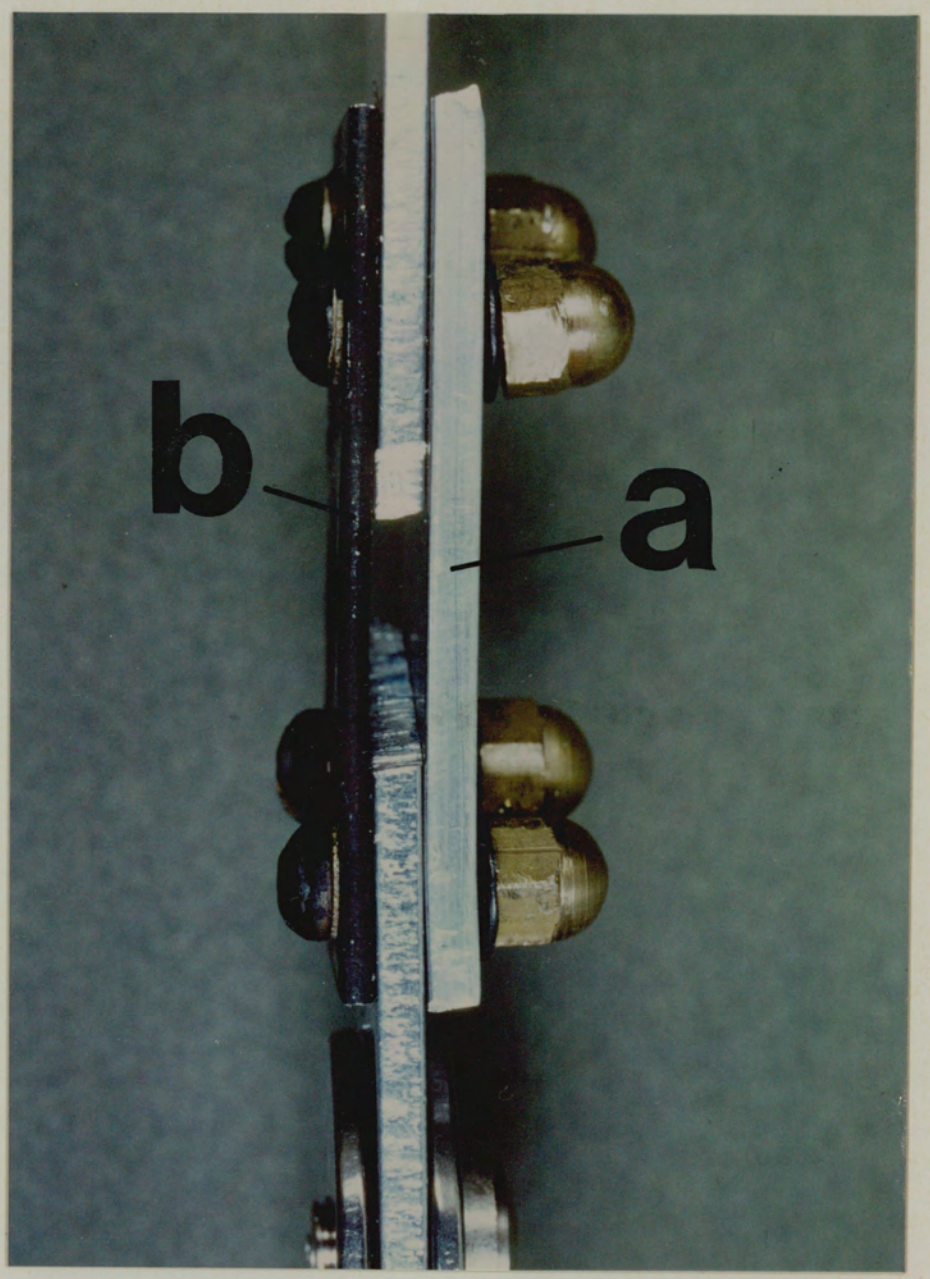


FIGURE 31

Force measuring apparatus with
backplate (b) and blanking plate (a)

FIGURE 32

Transducers in position at fracture
level where cast is split,
and knee level


b
a

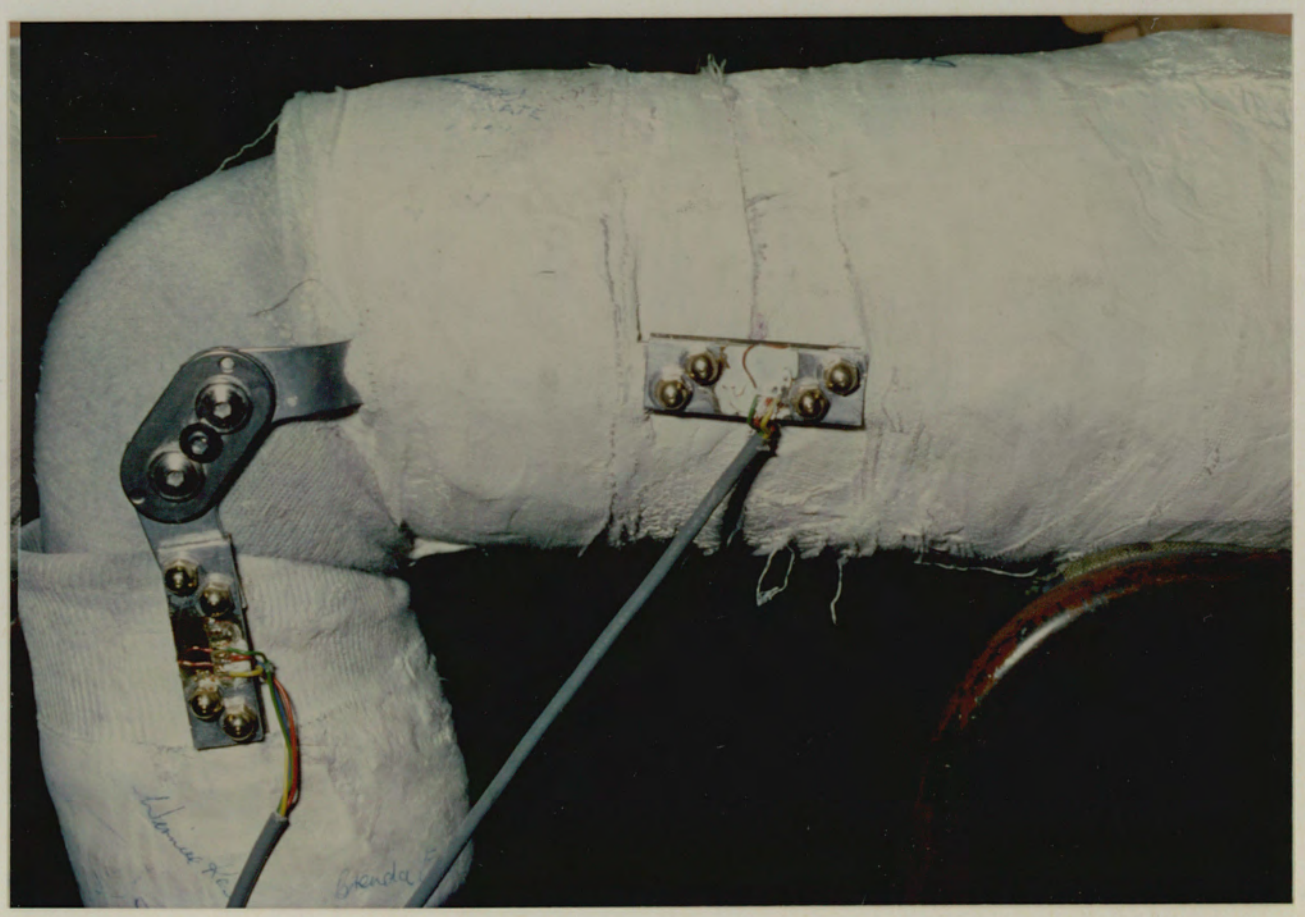


FIGURE 33

Force plate of single leg or "mushroom" type of construction, with foot plate removed

FIGURE 34

Force plate

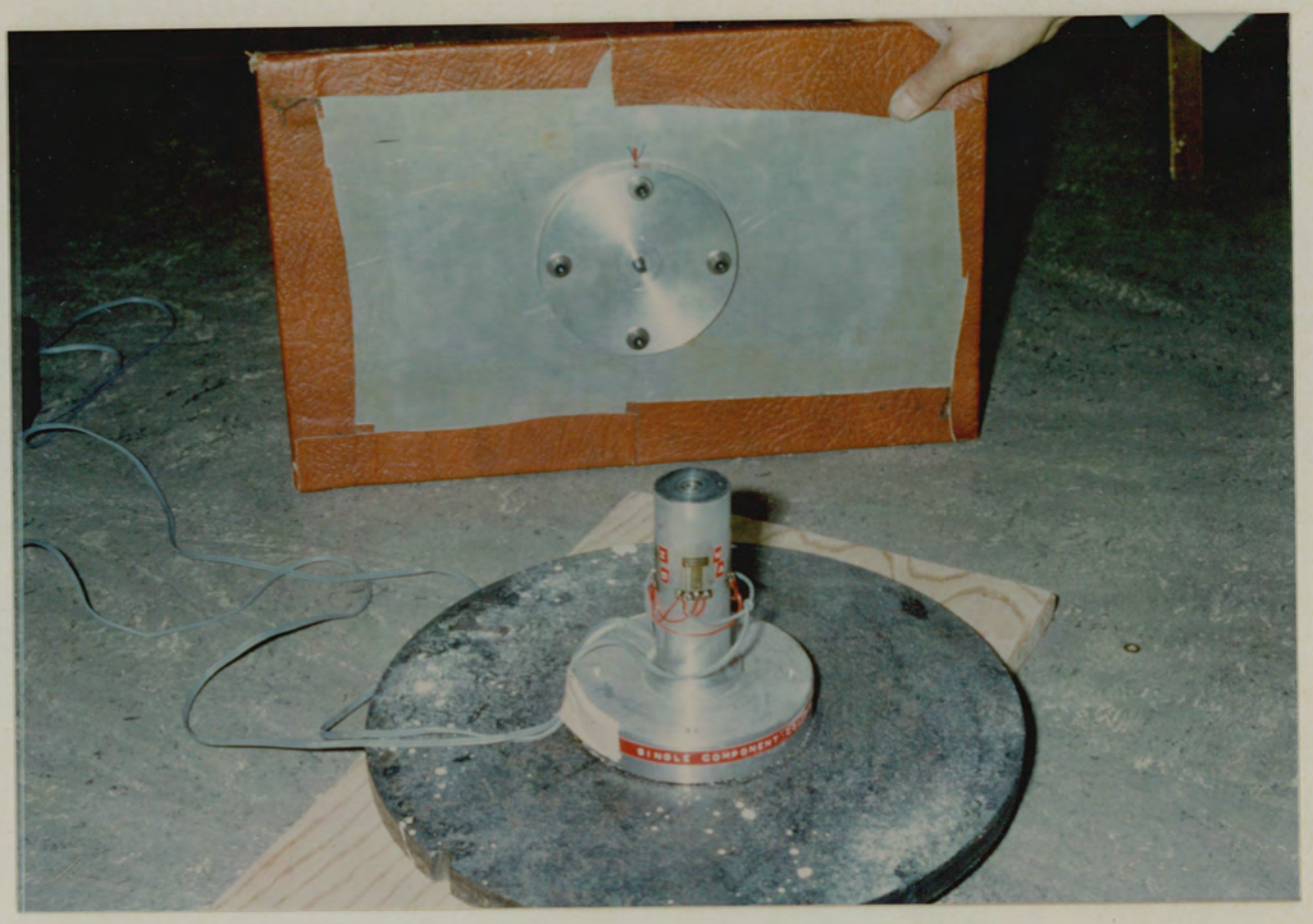


FIGURE 35

Patient during a measuring session showing leads from transducers to ultra-violet recorder and force plate incorporated into wooden platform

FIGURE 36

A short oblique upper third fracture

FIGURE 37

Fracture at union in a cast-brace

FIGURE 38

X-ray of a compound short oblique middle third fracture

FIGURE 39

Fracture (Figure 38) united


R

FIGURE 40

Fracture of femur and ipsilateral tibia

FIGURE 41

Antero-posterior x-ray of femur in a cast-brace

FIGURE 42

Ipsilateral tibia in cast-brace

FIGURE 43

Antero-posterior and lateral x-ray of

femur united

FIGURE 44

Sacral sores

FIGURE 45

Ischaemic ulceration of leg

FIGURE 46

Patient with bed sores and

leg ulcer in bed in cast-brace

FIGURE 47

Fracture following a fall does not show any definite refracture

FIGURE 48

Fracture developing "elephant's foot" type of non-union


L

FIGURE 49

Fractures of patient with multiple injuries

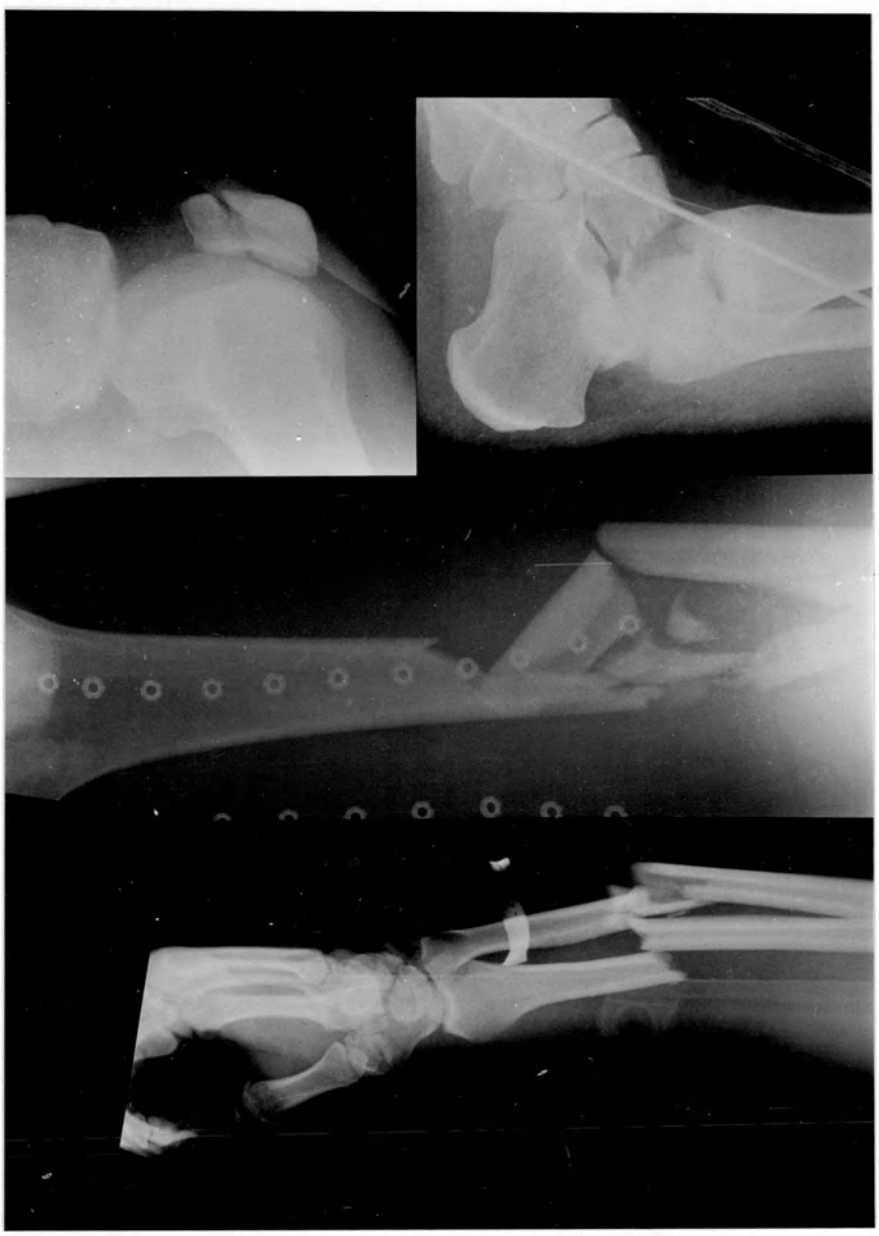


FIGURE 50

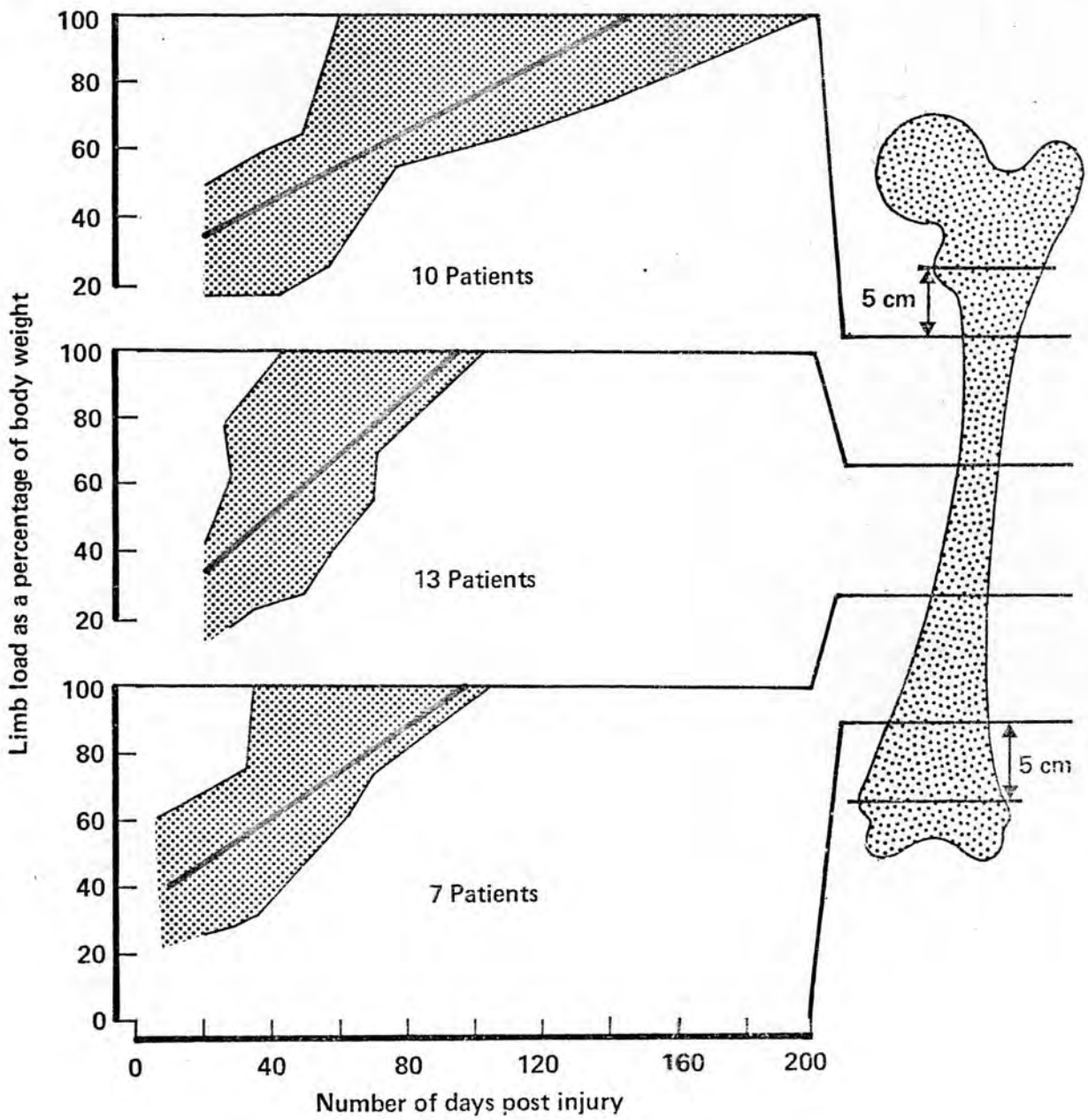

Limb load as a percentage of body weight
100
80
60
40
20
10 Patients
13 Patients
7 Patients
0
40
80
120
160
200
Number of days post injury
5 cm
5 cm

FIGURE 51

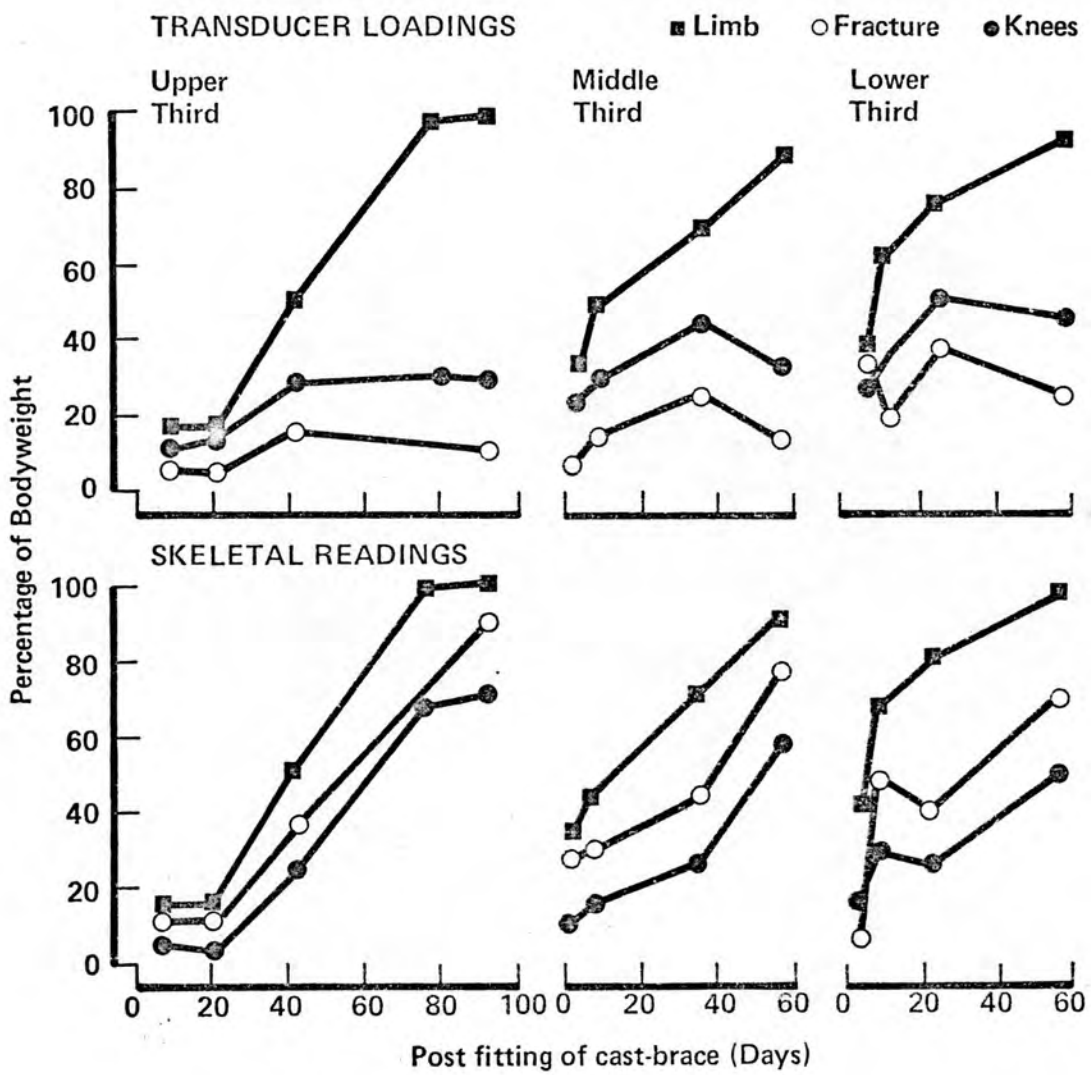
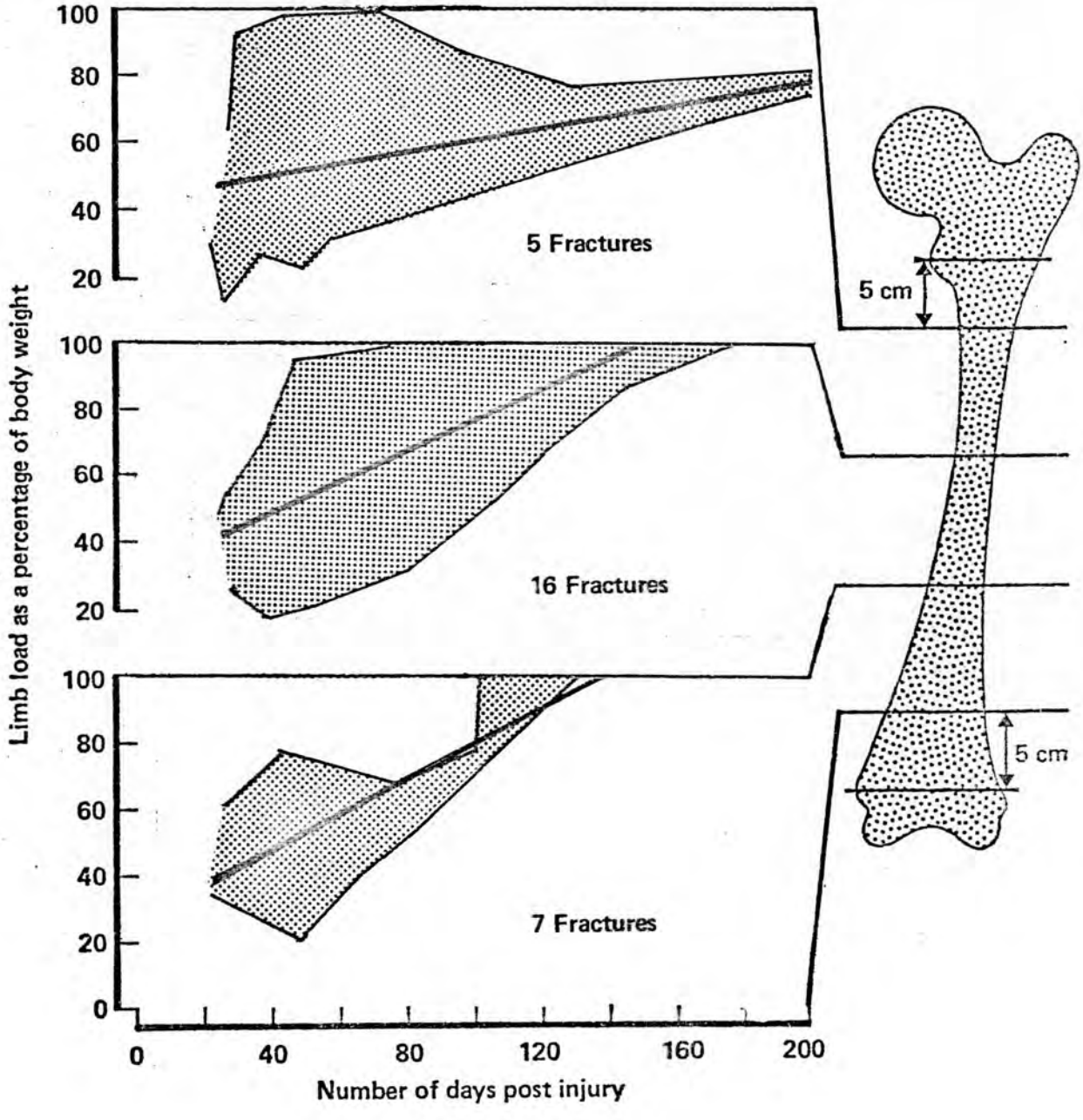

TRANSDUCER LOADINGS
Limb
Fracture
Knees
Upper Third
Middle Third
Lower Third
SKELETAL READINGS
Percentage of Bodyweight
100
80
60
40
20
0
0
20
40
60
80
100
Post fitting of cast-brace (Days)

FIGURE 52


Limb load as a percentage of body weight
100
80
60
40
20
5 Fractures
16 Fractures
7 Fractures
0
40
80
120
160
200
Number of days post injury
5 cm
5 cm

TABLES

TABLE 1

Infection With Open Nailing

	No. of fractures	Deep infection rate %
Street (1950)	90	2.2
Obrien (1964)	53	11.3
Fraser (1965)	136	3.7
Wickstrom and Corban (1967)	298	2.3
Rush (1970)	164	2.4
Carpenter and Couk (1970)	103	7.7
Savastano and Cadena (1971)	132	4.8
Kamdar and Arden (1973)	136	4.4 *
Kovacs, Richard and Miller (1973)	80	8.7
Warmbrod, Weiss and Yelton (1975)	233	1.6
Weiss (1976)	169	2.0

* 1 amputation for infection

TABLE 2

Infection With Closed Nailing

	No. of fractures	Deep infection rate %
Cloke (1970)	65	1.5
Clawson, Smith and Hansen (1971)	46	0 *
Brown, Nahigian and Rascher (1971)	25	4
Rascher, Nahigian and Macys (1972)	42	2.3
Winquist, Hansen and Clawson (1977)	244	0.8 *
Rush (1978)	104	1.0
Rothwell and Fitzpatrick (1978)	102	0

* given prophylactic antibiotics

TABLE 3

Proforma Sheet

CAST-BRACE STUDY

NAME: UNIT NO.:

SEX:

AGE: COMPOUND YES/NO

Aet.: R.T.A. (in car), R.T.A. (motor cycle), Pedestrian, Work, Home, Spont. Other:-

Fracture type: Transverse, short oblique, long oblique, slightly comminuted, greatly comminuted, double. Other:-

Fracture level: Upper third, middle third, lower third. Other:-

Associated injuries: Head, cervical spine, chest, upper limbs, dorsal spine, abdomen, pelvis, lumbar spine, lower limbs.

Note -

Treatment: Immediate: Closed, hitched, remanipulation (1), remanipulation (2). Other:-

Later: Time of cast-brace application.....(wks.

Time of starting knee flexion.....(wks.

(if treatment continued by splint)

Complications: Infection - soft tissue - bone, delayed union, non-union, refracture, thrombo-embolism, fat embolism, shock, death.

Other:-

Time of removal of traction.....(wks.)

Time of discharge from hospital.....(wks.)

Time in cast-brace .....(wks.)

Time of final discharge.....(wks.)

Time of return to work.....(wks.)

Results at final assessment

Knee flexion - less than 45^{o}, at least 45^{o}, at least 90^{o} (range if not full)

Shortening .....(cms)

Angulation - 0, less than 10^{o}, $10\text{-}15^{o}$, $16\text{-}20^{o}$, more than 20^{o}

Extension lag - 0, less than 5^{o}, $5\text{-}10^{o}$, more than 10^{o}

Thigh measurement.....(cms)

(difference of good thigh from side of fracture)

TABLE 4

Part One. Number of Femoral Fractures and Primary Treatment

		Traction	Traction + C.B.	Other
1974	56 (1 bilateral case)	48	4	4
1975	42 (1 bilateral case + 3 refractures)	10	30	2
Total Treated (98)		58	34	6

TABLE 5

Part One. Number in Each Study Group (Fractures)

	Males	Females	Total
Traction Alone	30	8	38
Traction and Cast-Bracing	21	10	31
Other	6	0	6

TABLE 6

Case No	Age	Sex	Open or Closed	Fracture type and level	Case No	Age	Sex	Open or Closed	Fracture type and level	Comments, other injuries
1	19	M	Closed	Transverse P	31	63	M	Closed	Transverse P	K nailed
2	20	M	Closed	Transverse P	32	57	M	Closed	Comminuted P	Delayed union
3	19	M	Closed	Comminuted P	33	14	M	Closed	Oblique P	Severe degloving injury to foot
4	23	M	Open	Comminuted P	34	45	M	Closed	Comminuted P	Contusion same knee, fracture same ankle
5	31	M	Closed	Comminuted P	35	20	M	Closed	Comminuted P	Right femur) bilateral
6	15	F	Closed	Oblique P	36	20	M	Closed	Comminuted M	Left femur)
7	50	M	Closed	Oblique P	37	17	M	Closed	Transverse M	Subtalar dislocation same ankle
8	30	M	Open	Comminuted P	38	42	M	Closed	Comminuted M	Fracture same clavicle and stiff shoulder
9	15	F	Closed	Oblique P	39	17	M	Closed	Oblique M	Fracture both tibiae
10	15	M	Closed	Comminuted P	40	25	M	Closed	Comminuted M	Fractured femoral condyle other leg, torn ligament same knee
11	20	M	Closed	Transverse M						
12	14	F	Closed	Transverse M	41	17	M	Closed	Transverse M	Fracture same acetabulum
13	17	M	Closed	Transverse M	42	60	M	Closed	Comminuted M	Fracture same tibia
14	16	M	Closed	Oblique M	43	72	M	Closed	Comminuted M	Subluxation acromio-clavicular joint, fracture acetabulum same hip, fracture tibia other leg
15	18	M	Open	Transverse M						
16	19	M	Closed	Transverse M						
17	26	M	Open	Comminuted M	44	19	M	Closed	Comminuted M	Compound fracture same tibia
18	15	M	Closed	Oblique M	45	21	M	Open	Comminuted M	Fracture other tibia
19	15	M	Closed	Oblique M	46	19	M	Closed	Comminuted M	Fracture same tibia, fracture scaphoid
20	31	M	Closed	Comminuted M	47	20	M	Closed	Oblique M	Avulsion anterior tibial spine same knee
21	21	M	Closed	Comminuted M	48	41	M	Closed	Comminuted M	Rib fractures and fractured neck 5th metacarpal
22	19	F	Closed	Comminuted M	49	51	F	Closed	Transverse M	
23	22	M	Closed	Oblique M	50	16	M	Closed	Comminuted M	Fracture same tibia
24	20	F	Closed	Transverse D	51	90	F	Closed	Oblique M	Osteoarthritis same hip
25	19	M	Closed	Transverse D	52	57	F	Closed	Oblique D	
26	18	M	Closed	Transverse D	53	53	F	Closed	Comminuted D	
27	17	M	Closed	Comminuted D	54	32	M	Closed	Comminuted F	Contusion same knee, fracture other tibia
28	19	M	Closed	Oblique D	55	73	F	Closed	Oblique D	Diabetic sore on calf and heel
29	30	M	Open	Oblique D	56	17	M	Closed	Transverse D	Comminuted fracture same tibia
30	22	M	Open	Comminuted D	57	17	M	Closed	Comminuted D	Fracture anterior tibial spine same knee
					58	79	F	Closed	Comminuted D	Cast-brace applied at 15 weeks

TABLE 7

Part One. Aetiology of Fractures

	Traction	Traction + C.B.	Other
R.T.A. - In vehicle	17	11	1
Motor cycle	5	6	1
Pedal cycle	-	1	-
Pedestrian	13	7	1
Work	5	3	1
Sport	2	1	-
Home	10	2	-
Other	8	1	2

TABLE 8

Part One. Fracture Types

	Traction Alone	Traction + C.B.	Other
Transverse	8	10	2
Short Oblique	8	7	-
Long Oblique	15	9	-
Slightly Comminuted	5	-	-
Grossly Comminuted	11	8	3
Double	4	1	-
Other	7	-	1

TABLE 9

Part One. Fracture Level

	Traction Alone	Traction + C.B.
Upper third	12	9
Middle third	14	13
Lower third	8	8
Other	3 Double 1 Not Known	1 Double

TABLE 10

Part One. Age Distribution of Study Group (Fractures)

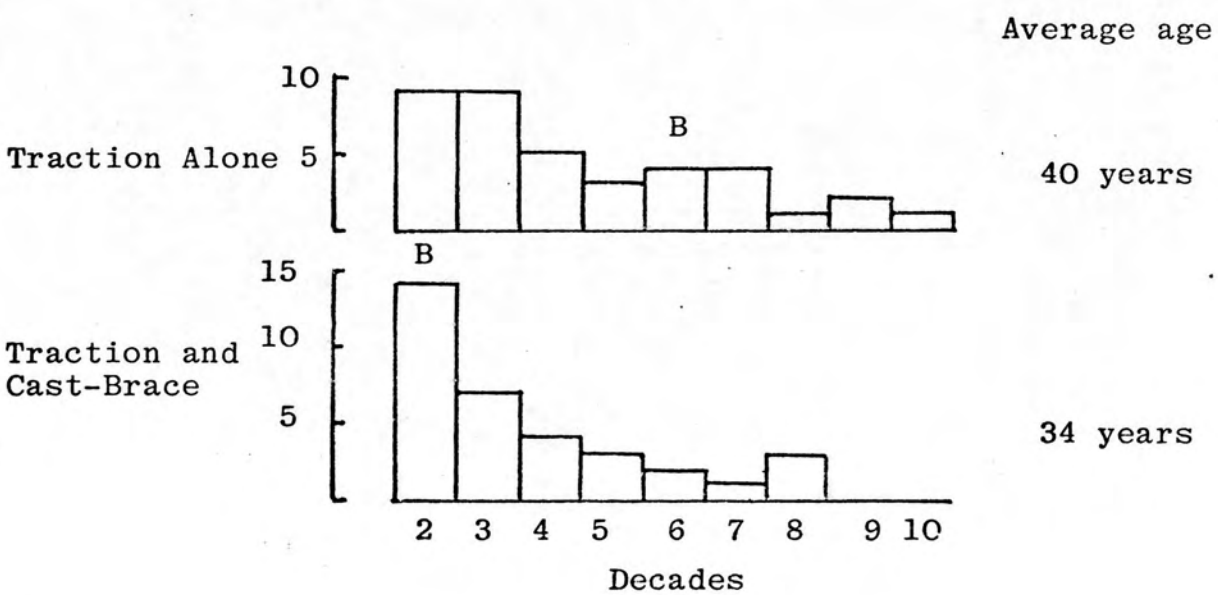


TABLE 11

Part One. Concommitant Injuries (All Fractures)

Head - Simple		31
	Fractures	2
	Facial Fractures	8
Chest		6
Thoracic Spine		1
Upper limb - fractures and dislocations		18
	degloving/lacerations	6
Abdomen		5
Pelvis (all fractures)		9
Lower limb (same side)	- fractures and dislocations	17
Lower limb (same side)	- degloving/ lacerations	9
Lower limb (opposite side)	- fractures and dislocations	8
	- degloving/ lacerations	3
Burns (head, same arm and thigh as fracture)		1

TABLE 12

Part One. Complications (All Fractures)

	Traction only	Traction + C.B.	Other
Infection - superficial	-	-	-
bone	-	-	2
Delayed Union	2	-	1
Non-union	1	1	-
Refracture	3	-	-
Thrombo-embolism	8	1	-
Fat Embolism	4	2	-
Nerve Damage	1	-	-
Vascular Damage	-	-	1
Amputation (due to vascular damage)	-	-	1
Amputation (due to infection)	-	-	1
Death	2	-	2
Knee swelling	-	3	-
Angulation (increase in, after application of Cast-Brace)	-	7	-

TABLE 13

Part One. Final Angulation of Fractures

	Traction only	Traction + C.B.
0^{o} - 10^{o}	27	24
11^{o} - 15^{o}	5	3
16^{o} - 20^{o}	4	3
more than 20^{o}	1	1
Not known	1	-

TABLE 14

Part One. Results

	Traction Alone		Traction + C.B.	
	No.	%	No.	%
Good or Excellent	24	63	24	78
Satisfactory	6	16	5	16
Poor	3	8	1	3
Very Poor	5	13	1	3

TABLE 15

Part Two. Treatment of Patients

	1976	1977
Treated in other ways	8	17
Died of multiple injuries	4	0
Lost to follow-up treated by traction and cast-bracing 5 fractures in	4	1
Treated by internal fixation and cast-bracing	0	2
Treated by traction and cast-bracing		
27 fractures in	26	44
44 fractures in	42	64

TABLE 16

Part Two. Patients Treated by Cast-Bracing

	1976	1977
Average time of cast-brace application	6.3	5.0
Average time of hospital discharge	7.7	7.4 (7.0)
Average time in a cast-brace	8.5	9.3
Average time to union	14.7	14.3

TABLE 17

Part Two. Fracture Level

	1976	1977
Upper third	8	13
Middle third	13	22
Lower third	3	7
Other	0	1 (segmental)
	24	43

TABLE 18

Part Two. Results

	1976		1977	
	No.	%	No.	%
Excellent	16	66.7	29	67.4
Good	2	8.3	9	20.9
Satisfactory	3	12.5	2	4.7
Poor	3	12.5	1	2.3
Very poor	0	0	2	4.7
Totals	24	100	43	100

TABLE 19

Part Two (1976). Assessment of Satisfactory, Poor and Very Poor Results

Classification	Age	Fracture type and level	Open or Closed	Weeks in traction	Weeks in cast-brace	Reason for classification	Other parameters
satisfactory	21-30	short oblique middle third	open	9	5	Angulation of 19^{o} present on cast-brace application.	excellent
satisfactory	21-30	greatly comminuted middle third	open	6	7	Angulation of 18^{o} present on cast-brace application.	excellent
satisfactory	18	greatly comminuted middle third	closed	9	12	No angulation on cast-brace removal when fracture considered united. One month later angulation of 18^{o} had developed.	good
poor	21-30	greatly comminuted proximal third	closed	4	10	Angulation increased from 17^{o} on removal of brace to 24^{o} as fracture consolidated.	excellent
poor	21-30	transverse proximal third	open	6	7	Developed anterior angulation from 4^{o} on removal of brace to 28^{o} during following month.	good
poor	41-50	greatly comminuted proximal third	open	9	13	Angulation was 8^{o} in traction and increased to 18^{o} after application of cast-brace, and further increased to 28^{o} after removal of brace during following month.	satisfactory

TABLE 20

Part Two (1977). Assessment of Satisfactory, Poor and Very Poor Results

Classification	Age	Fracture type and level	Open or closed	Weeks in traction	Weeks in cast-brace	Reason for classification	Other parameters
satisfactory	18	Comminuted proximal third and fracture of same tibia and fibula	open	6	8	Persistent thigh discomfort and limp.	good
satisfactory	51-60	Comminuted proximal third	closed	10	13	10 weeks in traction accepting angulation of 12^{o}. On starting exercises developed a refracture. Cast-brace applied under general anaesthetic with further angulation to 17^{o}.	excellent
poor	81-90	Long oblique distal third	closed	2	12	extension lag of knee of 18^{o}.	excellent
very poor	61-70	Comminuted proximal third	closed	7	35	Cast-brace loose allowing excessive movement of fracture. Non-union at 42 weeks. Treated by Kuntscher nail.	At 15 months following fracture had a wasted thigh, full knee extension with 85^{o} of flexion and shortening of 2 cms.
very poor	41-50	Transverse proximal third	closed	11	31	Loose cast-brace noticed at 21 weeks when new brace applied. Despite this developed non-union at 42 weeks. Treated by Kuntscher nail.	18 months following fracture had good quadriceps full knee extension, flexion to 55^{o} amd shortening of 2 cms.

TABLE 21

Part Three. Treatment of Fractures

(Patients in Brackets)

Traction and Cast-Brace - available for review	50 (49)
- lost to follow-up	6
- died before fracture united	1
Internal fixation and cast-brace	2
Other treatment	13
Died of multiple injuries	2
TOTAL	74 (73)

TABLE 22

Part Three. Age Distribution of Patients Treated by Cast-Bracing

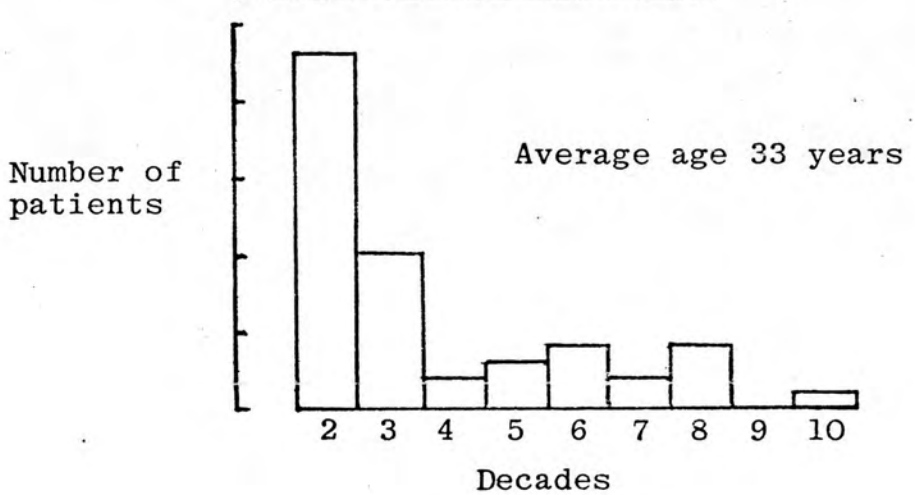


TABLE 23

Part Three. Aetiology of Fractures

Road traffic accidents	29
Pedestrians	12
Work	5
Home	4

TABLE 24

Part Three. Type of Fractures

Transverse	7
Short oblique	13
Long oblique	6
Slightly comminuted	11
Greatly comminuted	13

TABLE 25

Part Three. Level of Fractures

Proximal third	8
Middle third	35
Distal third	7

TABLE 26

Part Three. Time of Application of Braces

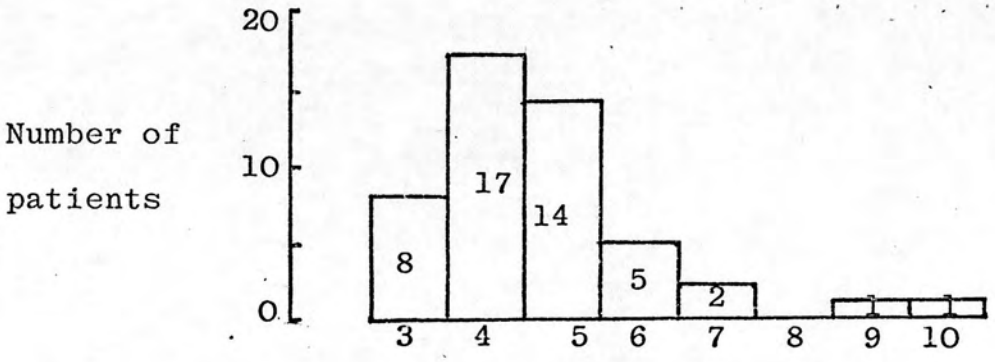


TABLE 27

Part Three. Treatment Schedule

(Average Time After Injury)

Time of application of cast-brace	4.7 weeks
Time of discharge from hospital	6.2
Time in a cast-brace	9.8
Time to union of fracture	14.5

TABLE 28

Part Three. Results Including All Patients Treated by Cast-Bracing

	1974/75	1976	1977	1978
Good or Excellent	24	18	38	43
Satisfactory	5	3	2	3
Poor	1	3	1	1
Very Poor	1	0	2	1

TABLE 29

Treatment of All Fractures of the Femoral Shaft (Patients in Brackets)

	1974	1975	1976	1977	1978	Totals
Traction and cast-brace	4	30(29)	32(30)	45	57(56)	168(164)
Internal fixation and cast-brace	0	0	0	2	2	4
Other treatment	52(51)	12	8	17	13	102(101)
Died of multiple injuries	0	2	4	0	2	8

282(277)

TABLE 30

Fractures Treated by Traction and Cast-Bracing

Available for Review

1974/75	1976	1977	1978
31(30)	24(23)	44	48(47)

Total : 147 fractures in 144 patients

TABLE 31

Main Injury Groups

	1974/75	1976	1977	1978	Totals
Femoral Fractures Alone	8	9	18	15	49
+Other Major Limb Injuries	17	9	24	27	77
+Major Limb and Abdominal and/or thoracic injuries	4	5	2	7	18
TOTAL					144

TABLE 32

Number of Injuries per Body System

	1974/75	1976	1977	1978	Totals
Head	13	7	14	19	53
Cervical Spine	0	0	0	1	1
Chest	3	1	2	3	9
Major Upper Limb	11	8	10	8	37
Abdomen	2	0	1	4	7
Pelvis	3	0	3	5	11
Lower Limb (same side)	10	6	16	14	46
Lower Limb (Opposite side)	6	1	6	13	26

TABLE 33

Major Extremity Injuries

		1974/75	1976	1977	1978
Upper Limb	Brachial plexus	-	-	1	-
	Shoulder girdle	1	1	1	4
	Humerus	3	0	1	0
	Elbow	2	1	0	1
	Forearm	0	1	2	1
	Wrist	3	4	2	1
	Hand	0	1	1	1
	Severe soft tissue	2	0	2	0
Lower Limb (opposite limb)	Hip	0	0	0	1
	Femur	0(1)	0(1)	0(1)	0(1)
	Knee	0(0)	0(0)	3(0)	3(4)
	Tibia	3(2)	0(0)	4(2)	5(3)
	Fibula alone	0(2)	0(0)	1(2)	1(4)
	Ankle	1(0)	2(0)	1(0)	2(0)
	Foot	1(0)	2(0)	2(1)	1(0)
	Severe soft tissue	5(1)	2(0)	5(0)	1(1)

TABLE 34

Results in Ipsilateral Lower Limb Injuries

	Tibial Fractures	Knee Injuries
Excellent	6	4
Good	2	1
Satisfactory	2	1
Poor	1	0

TABLE 35

Quadriceps Function. Fracture Type

Transverse	12
Short Oblique	16
Long Oblique	5
Slightly Comminuted	5
Greatly Comminuted	16

TABLE 36

Quadriceps Function. Fracture Level

Proximal Third	11
Middle Third	33
Lower Third	10

TABLE 37

RESULTS

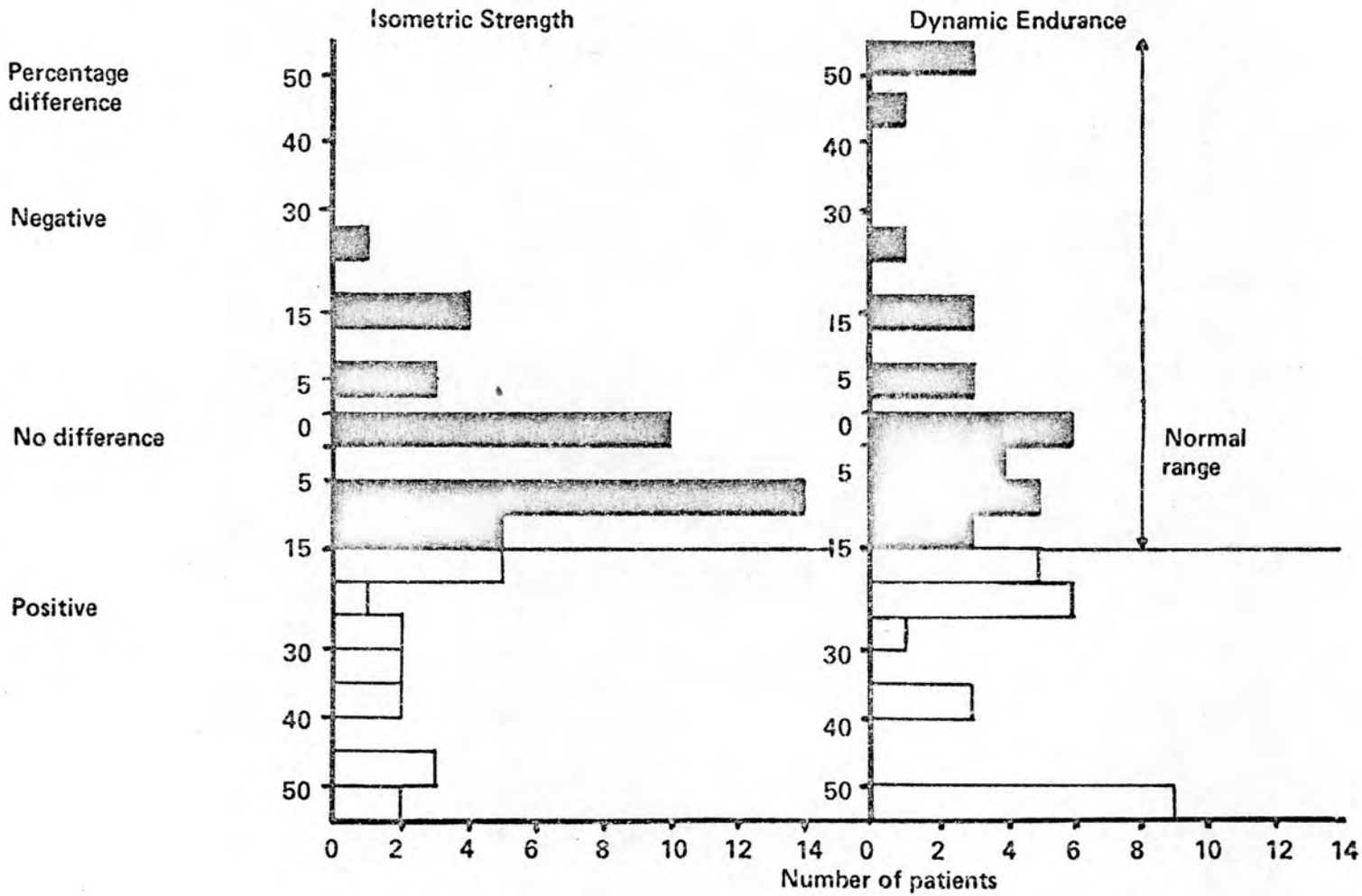
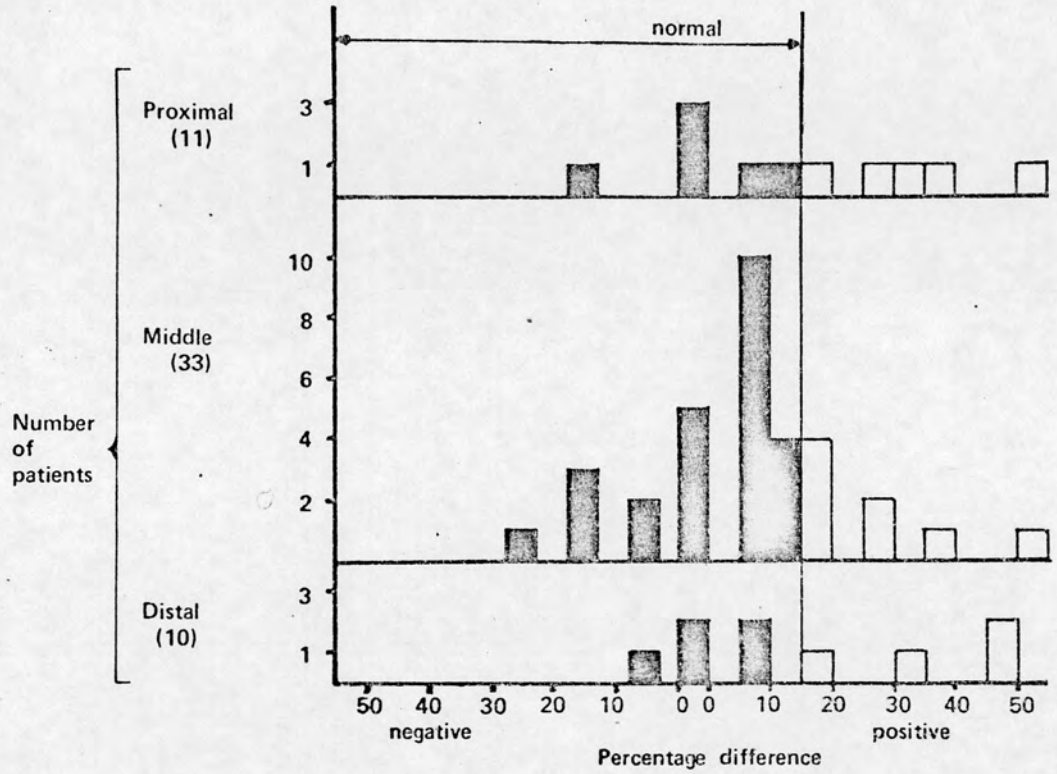


TABLE 38

ISOMETRIC STRENGTH COMPARED TO FRACTURE LEVEL



DYNAMIC ENDURANCE COMPARED TO FRACTURE LEVEL

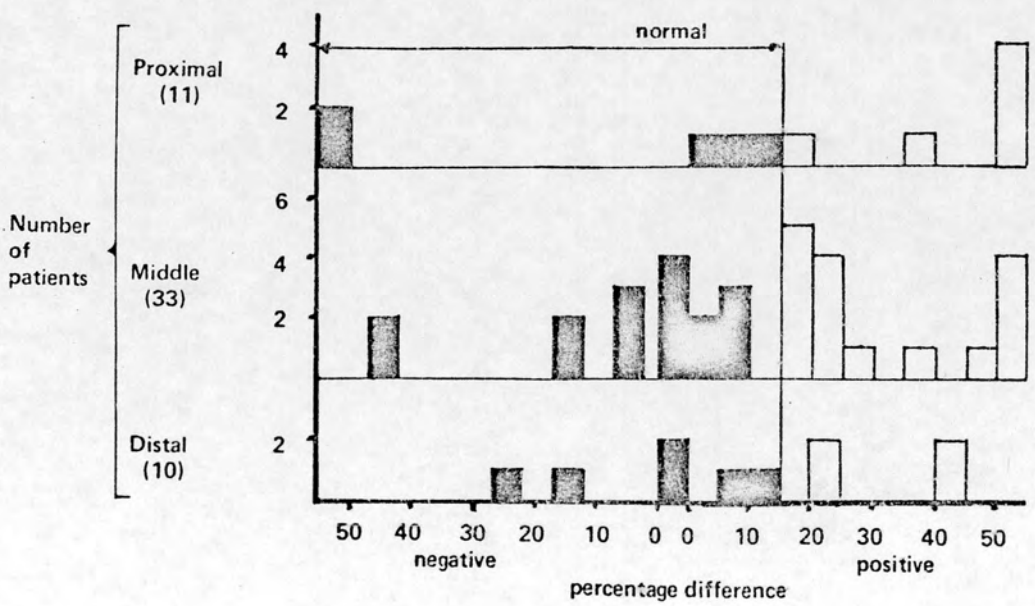
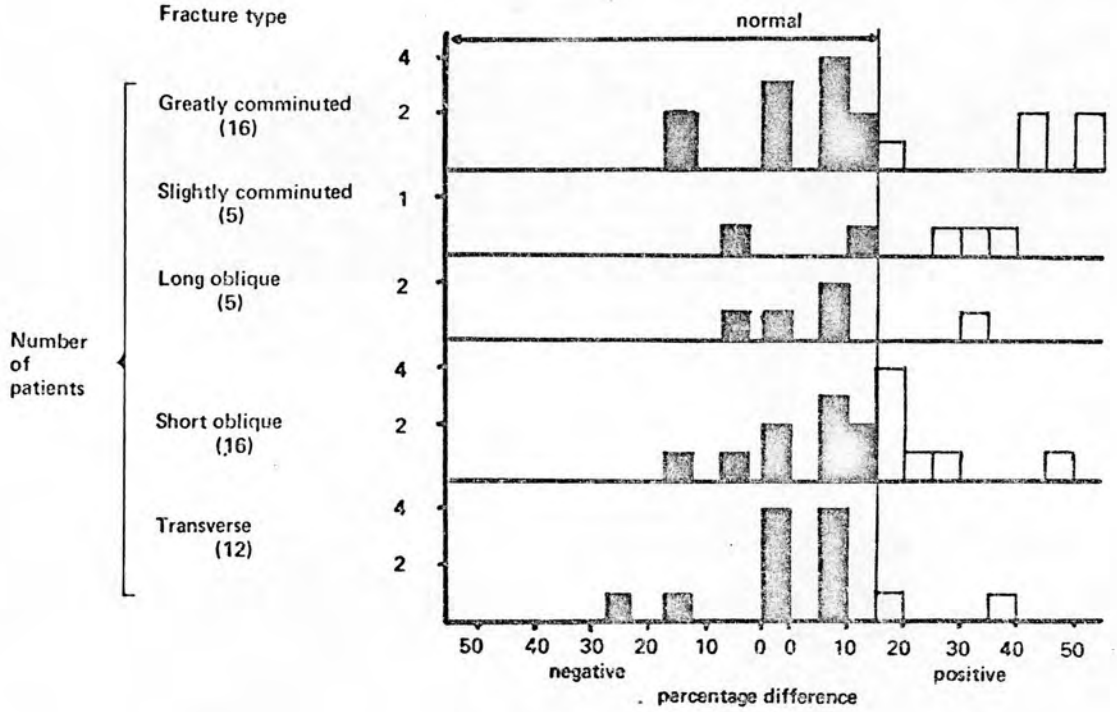


TABLE 39

ISOMETRIC STRENGTH COMPARED TO TYPE OF FRACTURE



DYNAMIC ENDURANCE COMPARED TO TYPE OF FRACTURE

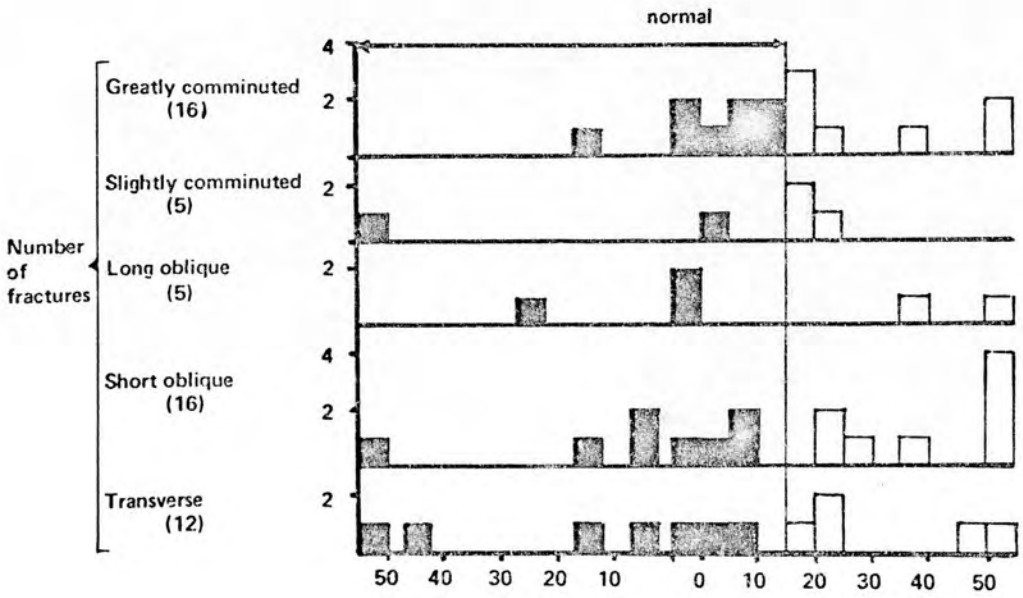
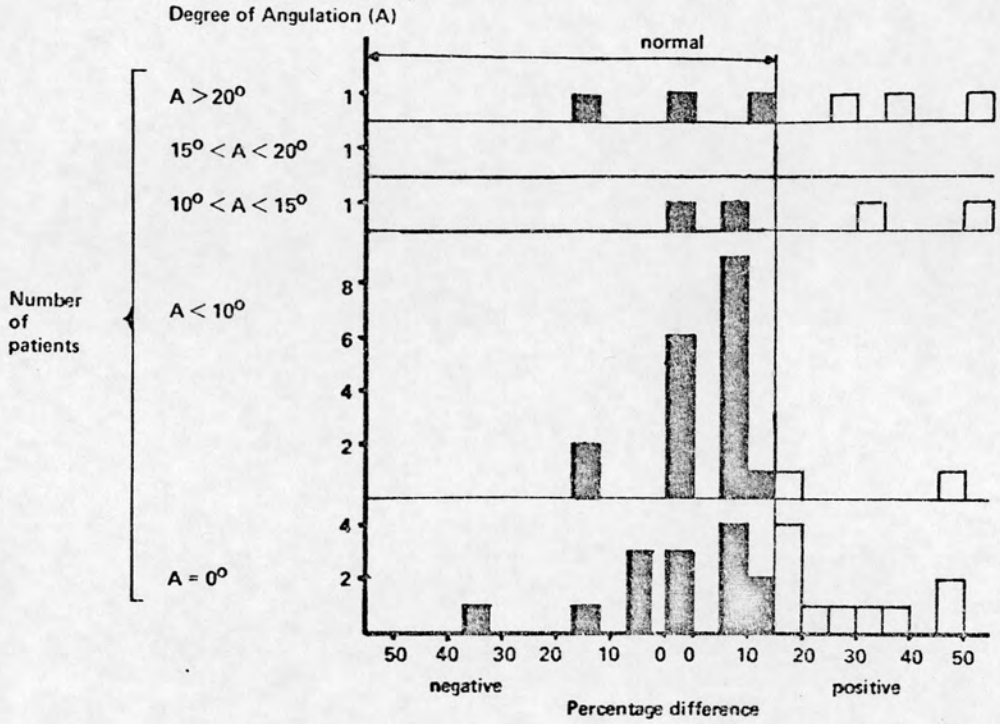


TABLE 40

ISOMETRIC STRENGTH COMPARED TO ANGULATION



DYNAMIC ENDURANCE COMPARED TO ANGULATION

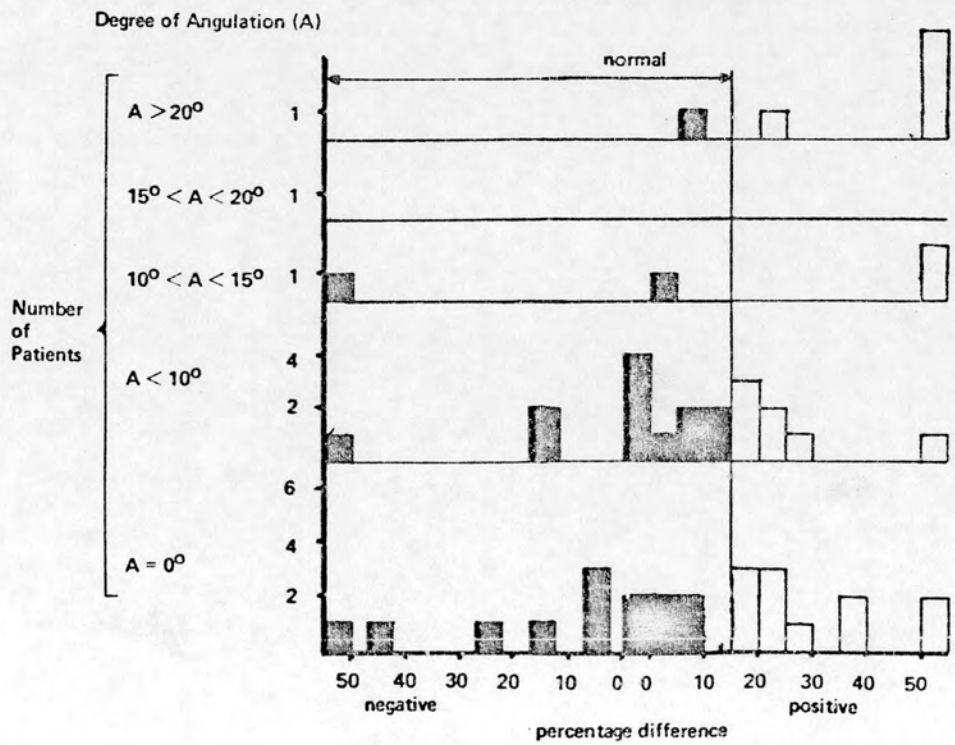
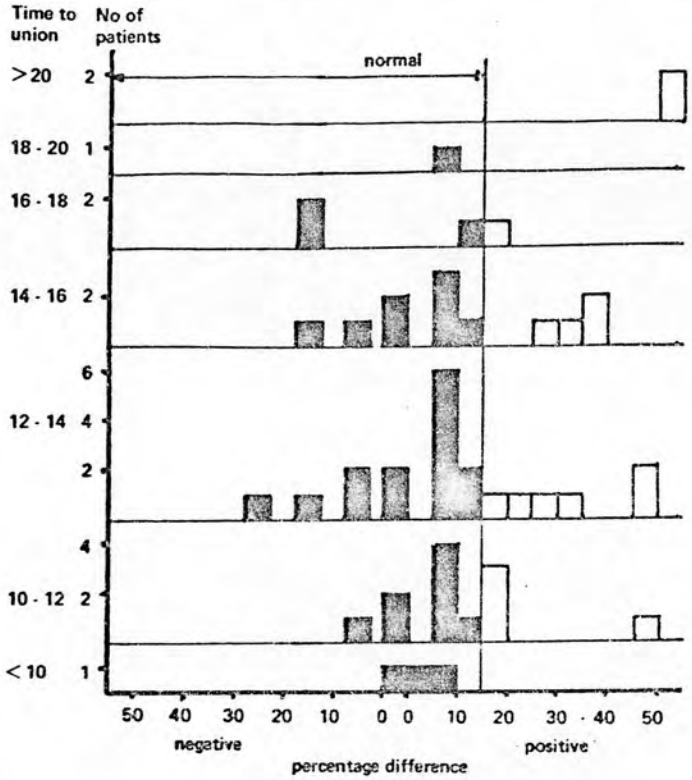


TABLE 41

ISOMETRIC STRENGTH COMPARED TO TIME TO UNION



DYNAMIC ENDURANCE COMPARED TO TIME TO UNION

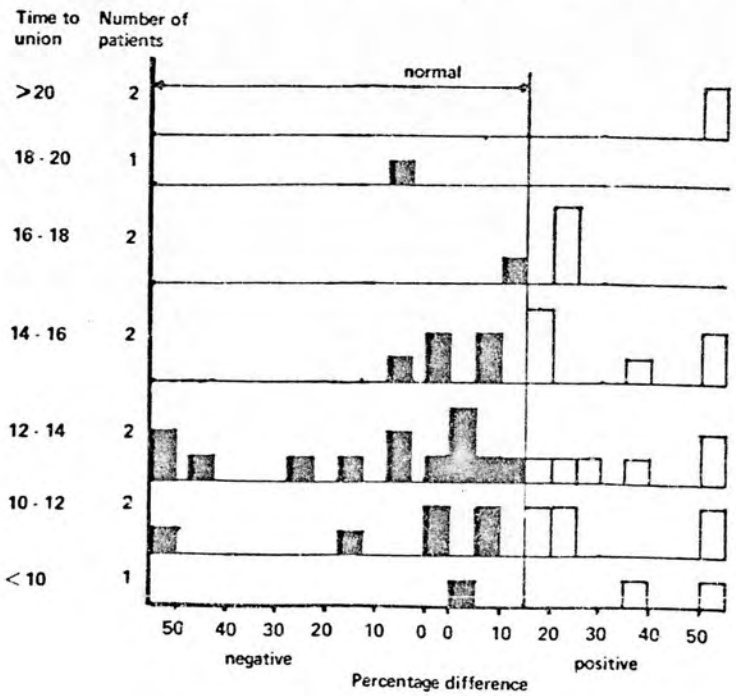


TABLE 42

Quadriceps Function. Comparison of Results

Percentage Difference	Isometric Strength		Dynamic Endurance	
	DZ	CB	DZ	CB
Negative	9	8	11	11
No Difference	0	10	0	6
0.1-5.0	5	0	2	4
5.1-10.0	4	14	3	5
10.1-15.0	9	5	6	3
More than 15.0	30(63%)	17(31.5%)	31(58.5%)	24(45%)
Total no. of patients	57	54	53	53

TABLE 43

Quadriceps Function. Comparison of Results

Percentage Difference	Isometric Strength		Dynamic Endurance	
	DZ	CB	DZ	CB
More than 20.0	1	1	1	5
10.1-20.0	1	4	1	3
0.1-10.0	4	3	2	3
No difference	4	10	3	6
0.1-10	4	14	7	9
10.1-20	4	10	3	8
More than 20.1	6	12	5	19
Total no. of patients	22	54	22	53

TABLE 44

Results of Isometric Strength

Compared to Treatment

Treatment	Number of Patients	Isometric Strength Mean Decrease
Direct Nailing	53	30.6%
Indirect Nailing	24	10.5%
Cast-bracing	54	11.4%

TABLE 45

Results of Dynamic Endurance

Compared to Treatment

Treatment	Number of Patients	Dynamic Endurance Mean Decrease
Direct Nailing	53	33%
Indirect Nailing	22	12.2%
Cast-bracing	53	15.4%

TABLE 46

Biomechanical Study. Data of Femoral Fractures Alone

Case No.	Days in traction	Days in cast-brace	Days to union	Degrees of knee flexion	% body weight on limb	
					at first	at union
1	38	26	64	100	60.4	93.9
2	21	91	112	115	16.4	99.3
3	40	35	75	95	55.6	96.6
4	76	56	132	75	55.5	94.7
5	49	35	84	90	45.0	92.6
6	25	54	79	100	22.6	100.0
7	42	42	84	75	45.5	100.0
8	37	154	191	90	20.1	100.0
9	49	63	112	45	46.8	100.0
10	32	28	60	115	36.7	100.0
11	24	62	86	100	45.5	96.6
12	28	63	91	100	34.8	100.0
13	34	43	77	120	53.6	96.0
14	27	56	83	110	18.8	100.0
15	8	56	94	90	36.5	100.0
16	25	56	81	110	60.4	93.9
17	37	56	93	75	28.1	94.6
18	20	56	76	110	34.3	100.0
19	21	56	77	90	45.1	100.0
20	40	56	96	100	34.4	90.1
21	28	28	56	100	78.5	100.0
22	24	49	73	100	27.5	100.0
23	25	42	67	90	53.4	100.0
24	18	54	72	100	40.9	94.3
25	25	56	81	100	43.0	100.0
26	33	49	82	110	30.7	100.0
27	37	49	86	100	35.9	100.0
28	6	35	41	100	60.3	100.0
29	24	63	87	80	26.1	100.0
30	25	77	102	60	30.4	100.0
Averages	31.6	54.9	86.5		39.9	98.0

TABLE 47

Biomechanical Study. Data of Patients with other Injuries and Aged over 50 years

Case No.	Days in traction	Days in cast-brace	Days to union	Degrees of knee flexion	% body weight on limb	
					at first	at union
31	20	70	90	85	31.4	71.4
32	30	203	233	70	13.8	84.6
33	26	49	75	100	66.2	98.6
34	52	56	108	90	24.6	
35	37	63	100	90	46.8	87.2
36	37	63	100	90	43.3	81.1
37	63	35	98	95	44.1	70.8
38	28	77	105	60	47.2	67.8
39	34	77	111	85	30.0	96.3
40	27	63	90	110	36.1	98.6
41	38	35	73	90	20.2	94.8
42	25	84	109	90	42.3	61.4
43	40	105	145	100	56.4	86.5
44	45	56	101	100	36.8	100
45	41	63	104	100	70.5	100
46	40	133	173	100	74.9	99.1
47	31	63	94	100	74.7	84.7
48	33	47	80	50	47.9	100
49	26	91	117	95	34.8	50.4
50	36	68	104	100	36.5	100
51	37	62	99	110	30.0	42.8
52	28	35	63	90	42.3	60.4
53	33	98	131	80	38.4	100
54	32	130	162	100	52.4	100
55	29	79	108	90	49.6	55.6
56	48	56	104	70	24.9	79.3
57	28	77	105	90	37.5	100
58	105	105	210	90	42.3	46.6
Averages	37.1	76.9	114		42.7	82.1

TABLE 48

Percentage of Thigh Cast Load

Of Proximal Thigh Cast Section

Proximal Third Fractures	50.4
Middle Third Fractures	68.4 (64)
Distal Third Fractures	59.2

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APPENDIX

THE CAST-BRACE TREATMENT OF FEMORAL SHAFT FRACTURES

D. WARDLAW, ABERDEEN, SCOTLAND

Ninety-eight fractures of the shaft of the femur were seen in one unit over the two years 1974 and 1975, and the results have been assessed in sixty-nine. Of these, thirty-eight were treated by skeletal traction in a Thomas's splint followed by skin traction, and thirty-one by skeletal traction followed by a cast-brace. The technique of application is described in some detail. The average time for application of the cast-brace was six weeks after the injury, the time in hospital eight weeks and the time till removal fifteen weeks. The patients selected for a cast-brace were in hospital for just over half the time of the others and their fractures on average united more quickly, though with some trouble from angulation of fractures of the uppermost third of the shaft. It is concluded that when used with all the judgment and skill it demands, the cast-brace method is a great advance in conservative treatment.

The main purpose of this paper is to report the early experience of the cast-brace treatment in Aberdeen. A survey of the three years 1971 to 1973 showed that 8 per cent of all hospital beds had been occupied by patients under treatment for fracture of the femoral shaft. At that time the conventional treatment was skeletal traction in a Thomas's splint through a Steinmann pin in the upper tibia, followed by skin traction. A long leg caliper was sometimes used at a later stage but was found to be cumbersome and to hinder use of the limb. Towards the end of 1974, however, a cast-brace was used occasionally, following the technique of Mooney, Nickel, Harvey and Snelson (1970), and was found to be acceptable. The method was used increasingly thereafter, the decision whether or not to use it after a period of skeletal traction being taken by one or other of the five consultants in charge of such cases.

As long ago as 1855 the American surgeon H. H. Smith designed an appliance for cases of non-union of a fracture of the femoral shaft. It consisted of a waist band, ischial support, and a "thigh-lacer" together with knee and ankle hinges. This was used in seven patients; all their fractures united. It was not until the last decade, however, that reports of methods that permitted early walking as part of the conservative treatment of certain fractures of the lower limb began to show superior results.

Küntscher (1958) maintained that external fixation of fractures was not possible in the true sense because a plaster cast could not give complete immobilisation, which he considered essential for sound union. However, more recent reports have shown that this is not so. As for the tibia, Brown and Urban (1969) found that compound fractures united and extensive skin and soft-tissue damage healed despite early walking, and Sarmiento (1967, 1970) has used his method, which permits early walking, with equal success.

With regard to the femur, Vieyra (1972) showed good results with severe compound femoral fractures treated by the use of a long leg cast. Snowdowne (1973) and Adair (1976) have successfully used a long leg plaster technique where the upper thigh part is moulded into a quadrilateral shape by applying an external box until it hardens, thus controlling rotation. Mooney and his colleagues (1970) have shown that cast-brace treatment for fractures of the condylar region and lowermost third of the femur gives excellent results when the device is applied after six weeks of traction. Connolly and King (1973) found that such fractures could be treated by cast-bracing at a much earlier stage—only three to four weeks after injury—and that comminuted fractures of the middle third were also suitable. They showed by cine-radiography that weight-bearing produced a piston effect on the bone ends which in most cases had ceased by the sixth week.

Connolly, Dehne and Lafollet (1973) reported 143 fractures treated by the cast-brace method and showed that fractures at all levels were suitable; those of the uppermost third sometimes required a pelvic band to hold the limb in abduction so as to align it with the proximal fragment. Brown and Preston (1975) reported on seventy-six femoral fractures, mostly in the middle and lowermost thirds; sixty-eight satisfactory results were obtained. The roughly average times were traction for five weeks, hospital stay six weeks, and treatment time fifteen weeks. They felt that their results clearly supported the use of the cast-brace.

TECHNIQUE OF APPLICATION

The use of a cast-brace not being common practice in Great Britain, various points in technique are given here in some detail.

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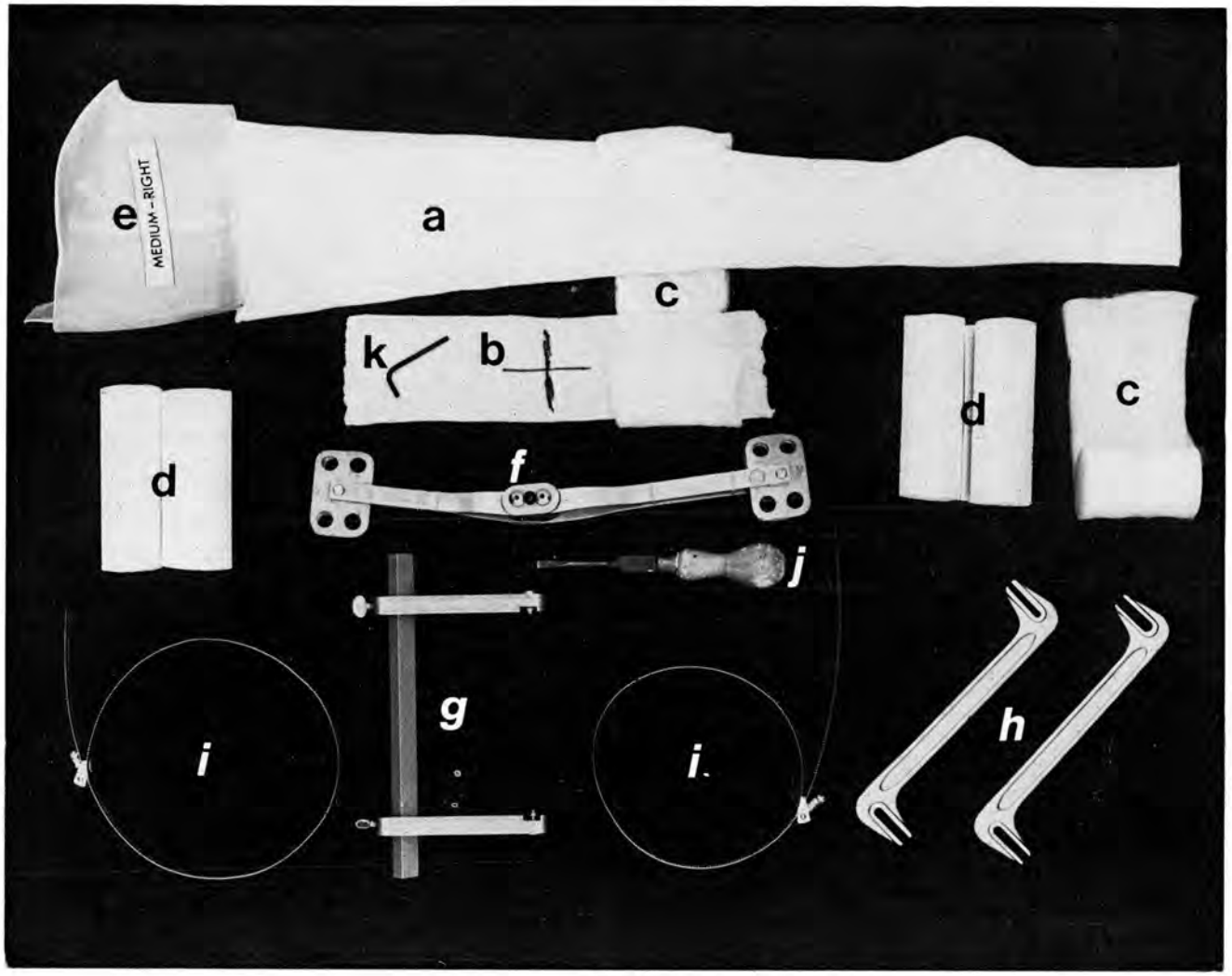

FIG. 1

The standard pieces of equipment referred to in the text.

The standard requirements are illustrated in Figure 1. In order of use, the special pieces of equipment, namely, shaped full-length elastic stockings (a), in three sizes, right and left; quadrilateral tops (e) made of polythene and split laterally, in three sizes; dicentric hinges (f) of one size only; and the jig (g), are now obtainable in this country*.

The ideal number of the team is three, with a radiographer standing by. As for the patient, enough sedation is usually provided by 10 to 20 milligrams of diazepam given intramuscularly. He is lifted onto a low stool or sandbag placed under the sacral region, just high enough to allow room for turns of plaster round the upper thigh, and reclines with the trunk at a comfortable 40 degrees or so from the horizontal. Manual traction is applied by an assistant gripping the limb just below the knee which is flexed 20 to 30 degrees. The Steinmann's pin and the Thomas's splint are removed and small dressings are applied to the pinholes. The elastic stocking, long enough to reach just above the groin without too much stretching, is rolled on. A piece of tubular stockinette (b) is drawn up over the knee, covering about 10 centimetres above and below it; a cross is pencilled on it to mark the centre of the patella.

The appropriate size of quadrilateral top is now seated firmly round the root of the limb; the medial lip under the tuber ischii usually requires to be trimmed back a little. The plastic socket is held closed, first by a strip of adhesive plaster and then by several turns of wet plaster bandage applied obliquely; any slight lateral gap or overlap is of no consequence. More plaster is applied to complete the thigh part of the cast. In a case of a fracture of the middle third the cast is moulded so as to ensure the natural forward bowing of the shaft. In any case of doubt radiographs are taken to check alignment, which may be improved by wedging at this stage. The manual traction on the tibia can now be gently released. A layer of plaster wool (c) is applied over the head and neck of the fibula, and also from the toes to just above the malleoli. A below-knee cast is then applied with the foot plantigrade.

While the plaster is setting, attention is turned to the hinges (f) and the jig (g). The short central screw of each hinge locks the neighbouring two screws, which are much longer and control frictional resistance. The central screws are removed, using the Allen key (k). The hinges, which have a block to extension, are loosened if necessary and flexed 5 to 10 degrees. They are then attached to the jig by the screws

*S.H. Camp and Co. Ltd., East Portaway, Andover, Hampshire SP10 3NL, as U.K. agents for the U.S. Manufacturing Co. Ltd., 623 South Central Avenue, P.O. Box 110, Glendale, California, U.S.A.

near the ends of the arms, using the screw-driver (j). This ensures that they are parallel and in the same axis. With the knee also in 5 to 10 degrees of flexion, the cross bar of the jig is held in front of the middle of the patella and the width between the arms is adjusted so that the hinges can clear the femoral condyles by at least 1 centimetre. The ensemble is manoeuvred so that the medial hinge is just below the adductor tubercle, with the lateral hinge in the same transverse axis. The malleable arms of the hinges always have to be shaped by the plate-benders (h) so that all four perforated rectangular ends can come everywhere into light contact with the two plaster casts. This done, and the axis through the hinges carefully checked, the position is held by two jubilee clips (i, i), care being taken that the quadrilateral top is firmly seated around the root of the limb. Turns of plaster are applied above and below, and allowed to harden. The jig is now removed. The long screws on each hinge are adjusted to give an appropriate amount of friction and are locked by the short central screw.

The short tube of stockinette is cut between the two casts and folded back to round off their edges; the upper and lower ends of the elastic stocking are treated similarly. Any weak part of the casts is strengthened; the part between the lower ends of the hinges and the ankle requires special attention. Finally, a thick layer of plastic sponge is fixed to the sole and a plaster boot is supplied (Figs. 2 and 3).

With this technique no cast has had to be removed because of breakage. The time taken for the whole procedure, at first about an hour, has come down to about thirty minutes in a straightforward case.

Back in the ward the patient rests in bed for two days to accustom himself to the cast and allow the plaster to set hard. He is then allowed up using a walking frame or a pair of crutches, and often proceeds to two sticks before being discharged home about a week later.

Problems of toilet are few, even in bilateral cases; soiling of the cast is quite unusual. Occasionally the lip of the socket may need to be reduced even more, or that region protected by non-porous adhesive plaster in a patient with loose bowel habits. Given this attention, a patient with bilateral fractures presents no special difficulty, apart from the need for a longer period on crutches. Because the brace is not truly ischial-bearing, the local skin requires no special attention.

CLINICAL MATERIAL

For the purposes of this study the two years 1974 and 1975 were taken. Pathological fractures of the femur were of course excluded. The shaft, arbitrarily regarded as starting 5 centimetres below the lesser trochanter and ending 5 centimetres from the adductor tubercle, was

FIG. 2

FIG. 3

Figure 2—Showing a patient standing in a cast-brace soon after its application. Figure 3—A photograph of the knee of the same patient as in Figure 2, showing the biaxial design of the hinges used for a cast-brace.

divided into equal thirds (Fig. 4). The type of fracture was classified according to Dencker (1965). An attempt was made to review personally all the patients in the survey, but for various reasons the information concerning a quarter of them had to be taken from the case notes.

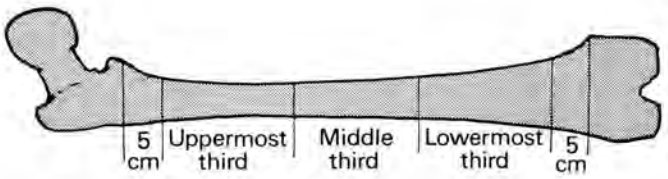

FIG. 4

A diagram showing the classification of level of fracture used in this report.

The fractures were divided into three groups according to their treatment: Group 1—traction alone; Group 2—traction and cast-bracing; and Group 3—internal fixation.

In 1974 there were fifty-six fractures of the shaft in fifty-five patients, one case in Group 1 being bilateral. In 1975 forty-two fractures were treated in forty-one patients; this included one bilateral case in Group 2 (see later) and three refractures after treatment by traction alone.

In 1974 there were forty-eight fractures in Group 1, only four in Group 2, and four in Group 3. In 1975 the corresponding figures were ten, thirty and two. The totals for both years were therefore fifty-eight, thirty-four and six.

Group 1—Of fifty-seven patients, two died from multiple injuries; ten were sent to other centres and were lost to follow-up; and a further eight were old ladies, three of whom died in hospital after the fractures had united and the other five were not reviewed because they lived at a distance. This left thirty-seven patients with thirty-eight fractures available for review.

Group 2—Of thirty-three patients, three were lost to follow-up after their discharge to other centres wearing the appliance. This left thirty patients with thirty-one fractures available for study—twenty-eight fresh fractures and three refractures after treatment by traction alone.

Group 3—These six patients all had specific indications for internal fixation.

In short, the fractures available for study, and for a measure of comparison, numbered thirty-eight in Group 1 and thirty-one in Group 2.

The six patients in Group 3 will not be mentioned again except to remark, with hindsight, that two deep infections developed in fractures that would have been suitable for cast-bracing.

In several respects, such as the cause of fracture, the type, the level, and the proportion of compound fractures, the cases in the two main groups were roughly comparable. The average age in Group 1, however, was forty years against thirty-four years in Group 2, which also had a higher proportion of males. None of the associated injuries proved to be a contra-indication to cast-bracing.

FINDINGS

Delayed union—This was taken to be present if the fracture was not united at thirty-two weeks or if the surgeon decided that further intervention was necessary to aid union. There were two cases, both in Group 1. One fracture took forty weeks to unite; the other showed no sign of union at ten weeks and then had Küntscher nailing and cancellous bone grafting, with an excellent result one year later.

Non-union—There were two cases, one in each group.

The patient in Group 1 had been discharged, the fracture having been considered united. When seen at the follow-up clinic a year later, however, he was found to have a fibrous non-union with increased angulation. This was corrected at the time of cast-bracing and the fracture united in good position after a further sixteen weeks.

The patient in Group 2 had suffered multiple injuries and a long oblique fracture of the mid-shaft with muscle interposition. Nevertheless a cast-brace was applied at eight weeks. When it was removed two months later, the fracture was still mobile. Another cast-brace was applied but unfortunately the hinges were not in correct position and flexion of the knee produced angular movement at the fracture site. The inevitable fibrous non-union was later treated by plating and grafting with a good final result. So far as the cast-bracing was concerned, however, the case had to be counted as a failure.

Refracture—There were three cases, all in Group 1, and all treated successfully by cast-bracing.

The first patient's fracture was considered united at thirteen weeks but refractured two weeks later; the second occurred at twenty-one weeks. The third patient also had fractures of the tibia and fibula on the same side. At eleven weeks, the femur was considered united and so a long leg cast was applied. Two weeks later he had a refracture of the femur which was treated by two weeks in a Thomas's splint and then a cast-brace.

Swelling of the knee—This may occur in patients treated by a cast-brace, but in only three patients was it either recorded in the notes or troublesome. In one case the swelling was such that the surgeon in charge split the cast-brace and admitted the patient to hospital for observation. After a few days of elevation the swelling went down, a new cast-brace was applied, and the problem did not recur.

Increased angulation—This occurred after application of the cast-brace in seven patients, five with uppermost third and two with middle third fractures. The increase was 5 degrees in four and 15 degrees in two, both comminuted fractures. In the last patient the angulation was already 17 degrees in the Thomas's splint and became 25 degrees, giving a poor result.

The patient, an alcoholic aged thirty, was admitted in a state of delirium tremens. He strongly resented traction and demanded his discharge. His cast-brace was applied almost under duress, and cooperation was entirely lacking. He was offered correction of the angulation at various times but refused.

Time in hospital—The average for the patients in Group 1 was fifteen weeks (range 9–30), and in Group 2, eight weeks (range 2–18). The reasons for the wide range in Group 2 were as follows.

The patient discharged at two weeks was a case of re-fracture without displacement from Group 1. A cast-brace was applied a week later and the fracture proceeded to unite uneventfully.

The patient discharged after eighteen weeks was a girl of eighteen with a double fracture of the shaft. Two days after application of the cast-brace at eight weeks she attended the Gynaecological Department for the insertion of an intra-uterine device, during which she developed pain over the upper fracture. No detectable refracture or angulation had occurred but the cast-brace was removed and the leg placed in a Thomas's splint for another eight weeks. The end result was excellent. In retrospect, it would perhaps have been better simply to have rested the patient in bed in her cast-brace till the discomfort subsided.

Time to union—In those treated by traction alone, union was said to have occurred when either the surgeon recorded that opinion or when full weight-bearing was allowed. In those treated by cast-brace, it was the day of removal. On this basis the average times were seventeen and fourteen and a half weeks respectively.

Final assessment—For Group 1 patients the average time from injury to review was sixteen months, and for Group 2 patients seven months. The classification of results was after Dencker (1965). Using his criteria the results obtained are shown in Table I. The five very poor results in Group 1 were due to one non-union, three refractures and one case of severe thigh atrophy after a degloving injury which required skin grafting. The single failure in Group 2 already mentioned was due to a contra-indication for a cast-brace, namely, muscle interposition.

TABLE I

RESULTS CLASSIFIED AFTER DENCKER (1965)

	Traction alone		Traction and cast-brace	
	Number	Percentage	Number	Percentage
Good or excellent	24	63	24	78
Satisfactory	6	16	5	16
Poor	3	8	1	3
Very poor	5	13	1	3

DISCUSSION

The application of a cast-brace is a technique which demands close attention to detail and a certain amount of practice. No doubt some of the less than satisfactory results would have been much better had our initial technique been more expert. One factor may have a bearing on angulation. At the time of application of the hinges the thigh portion of the cast tends to slip downwards and lose its snug fit, perhaps enough in some cases to allow angulation and even telescoping if the fracture is still sufficiently mobile.

It has now become the firm policy of the Unit to treat all suitable femoral shaft fractures by cast-bracing from around four weeks, with a delay of another two to

FIG. 5

FIG. 6

Figure 5—Antero-posterior radiographs of the right femur and tibia of a girl aged nineteen taken immediately after a car crash in which she also sustained burns of the face and of the right arm and thigh. A cast-brace was applied after eight weeks of skeletal traction. Figure 6—Corresponding radiographs of the same patient as in Figure 5 taken just before the removal of the cast-brace at fourteen weeks. Both fractures were found to have united, and stayed so.

four weeks for fractures of the uppermost third. As pointed out by Connolly and his colleagues, its use may well facilitate the nursing care of a severely ill patient. Certain fractures of the same limb can also be treated simultaneously by a cast-brace. The method is especially applicable when there is an associated tibial fracture. There were four such patients in the Group 2 series; all four were discharged from hospital within two months. Radiographs of a typical case are shown in Figures 5 and 6.

In short, patients treated by cast-bracing can be discharged from hospital at a much earlier date than those treated by traction alone, thus saving valuable hospital bed space. Their fractures unite more quickly and they enjoy an earlier return of normal function. Mobilisation in a cast-brace means that the morale of the patients is lifted greatly; they can, on occasion, even go back to work. Compare one patient still immobilised in bed on traction and another home again, using sticks or perhaps crutches but moving his limb freely and able to live a fairly normal life. Given the judgment and expertise, cast-brace treatment is indeed a real advance in the conservative management of femoral shaft fractures.

Credit must be given to Mr D. Begg, senior orthotist, and to Mr G. Hay for introducing this technique in Aberdeen. I wish to thank Mr J. McLauchlan, senior lecturer, for his encouragement and helpful criticism, and all the consultant staff of the Orthopaedic Department for allowing me to present their cases.

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