Arthrodesis of the knee using a custom-made intramedullary coupled device

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Nine patients underwent arthrodesis of the knee using a customised coupled nail (the Mayday arthrodesis nail), five after infected arthroplasty, one following failed arthrodesis, one for intractable anterior knee pain, one for Charcot instability and one after trauma.

Comparison was made with 17 arthrodeses, eight undertaken using external fixation, four with dual compression plates, and five with long Küntscher nails. Union was achieved in all patients (100%) at a mean time of ten months using the customised implant. There were no complications despite early weight-bearing. No further procedures were required. This contrasted with a rate of union of 53% and a complication rate of 76% with alternative techniques. Of this second group, 76% required a further operative procedure.

We compared the Mayday arthrodesis nail with other techniques of arthrodesis of the knee. The differences in the need for further surgery and occurrence of complications were statistically significant ($p < 0.001$), and differences in the rate of nonunion and inpatient stay of less than three weeks were also significant ($p < 0.05$) using Fisher's exact test.

We conclude that a customised coupled intramedullary nail can give excellent stability allowing early weight-bearing, and results in a high rate of union with minimal postoperative complications.

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There are many techniques for arthrodesis of the knee, all of which have complications and yield less than optimal results.¹⁻⁸ Compression arthrodesis using an external fixator has been popular, but pin-track infection and adjustments of the fixator which require hospital admission are common. The use of compression plates often requires prolonged restriction of weight-bearing.⁹ Intramedullary fixation using a Küntscher nail has an acceptable rate of fusion, but a high complication rate.⁶ Ilizarov techniques have been used more recently but require further operative procedures, and again have numerous complications.⁴ Two-part locked nails for arthrodesis have been introduced recently largely for the treatment of tumours. There are now several modular systems which require a substantial inventory to be available.⁸

We report our early experience with the Mayday arthrodesis nail (Orthodesign, Christchurch, UK) which avoids the need for an extensive inventory since it is a custom-made two-part intramedullary coupled device² (Fig. 1). Both components are inserted through a single incision and are then joined by means of an interlocking taper fit and an antero-posterior (AP) locking pin. The tibial and femoral components can both be locked to provide rotational stability. Early weight-bearing is encouraged to promote compression at the site of the arthrodesis.

Patients and Methods

Since 1997 nine patients have been treated with the Mayday intramedullary nail by two surgeons (JHN, WM-C) in two centres. Between 1993 and 2000, 17 patients were treated in Bristol using other methods by seven surgeons. Details of the patients and indications are given in Tables I to III.

We retrospectively reviewed the notes and radiographs of all arthrodeses undertaken using the Mayday nail and all those carried out by other techniques. Follow-up examination ranged from four to 18 months. Union was assessed both clinically and radiologically and defined as lack of movement on examination, with evidence of trabecular bone crossing the site of fusion in two planes on plain radiographs. The angles of flexion and valgus of each arthrodesis were measured from the AP and lateral radiographs.

Operative technique. Preoperative planning from scaled AP and lateral radiographs is essential (Fig. 2). Each nail is then custom-made to ensure a snug intramedullary fit and

Fig. 1a

Fig. 1b

Photographs showing a) the femoral and tibial components of the Mayday arthrodesis nail with locking screws and b) the locking jig for the tibial component.

Fig. 2

Preoperative AP radiograph showing the cement spacer.

appropriate curvature. The nail is designed to hold the knee in 12° of flexion and 5° of valgus.

Positioning of the patient is as for an arthroplasty. The knee should be capable of flexion to allow the insertion of both components. Release of the posterior joint capsule may be required to gain adequate extension for the final reduction. The femoral and tibial articular surfaces are resected using instrumentation for total knee arthroplasty to achieve two opposing surfaces of viable bone stock. Minimal or no resection of the tibia is recommended. The femoral cut is made parallel to the condyles, 5° valgus to the femoral shaft. Both the femur and tibia are reamed according to a preoperative plan, designed for each patient, using a combination of straight and flexible reamers. Both components are introduced using dedicated introducers. The tibial component is locked, if required, using a jig (Fig. 1b).

The femoral component can be locked, but it is recommended that it is left unlocked, to allow some subsidence and compression of the arthrodesis. Engagement holes for locking both components are aligned and an AP locking pin inserted. The patella, if present, is often a useful source of bone graft if required.

After operation, the patient is encouraged to bear weight as soon as possible. Some subsidence of the femoral component is allowed within the design. A brace may be useful to prevent excessive rotational forces. Rotational stability is assured in the tibia by means of locking screws, but the use of such a screw in the femur would prevent the controlled subsidence required. Some rotational stability on the femoral side is provided by the width of the distal end of the femoral component.

Results

In the patients who received the Mayday nail, the number of procedures carried out before definitive arthrodesis ranged from 0 to 3. Of the five infected arthroplasties, four were removed as a separate staged procedure before attempted arthrodesis. Bone allograft was used in two knees. The mean hospital stay was 15 days (2 to 29). After operation, six patients were allowed to bear full weight immediately. The patient who had severe trauma was unable to bear weight for three months because of coexisting injuries. Two patients were initially placed in a cylinder plaster cast for

Table I. Details of the nine patients who underwent arthrodesis using a Mayday nail and the 17 treated by alternative techniques

	Mayday nail	Alternative techniques
Number of patients	9	17
Mean age in years (range)	68 (39 to 91)	64 (35 to 82)
Gender		
M	3	5
F	6	12
Mean number of previous procedures (range)	1.3 (1 to 3)	2.82 (0 to 8)
Previous history of infection (%)	67	65

Table II. Details of the nine patients who underwent an arthrodesis using the Mayday nail

Case	Age (yrs)	Indication	Hospital stay (days)	Fusion (mths)
1	68	Infected TKR*	24	11
2	78	Infected TKR	22	7
3	74	Infected TKR	14	16
4	78	Infected TKR	8	8
5	39	Anterior knee pain	2	2
6	78	Failed arthrodesis for infected TKR	15	16
7	53	Trauma (severe tibial plateau destruction)	29	14
8	58	Instability (Charcot joint)	6	7
9	91	Infected TKR	N/A	N/A

*total knee replacement

two and six weeks, respectively. One was subsequently treated in a brace for four weeks. All nine patients have achieved union (Fig. 3). The mean time to union in the patients with complete follow-up data was 10.1 months. The ninth patient was lost to follow-up for four years, but has been reviewed subsequently and has clinical and radiological union. There were no complications in these patients and no further operative procedures were required. None of the patients with infected arthroplasties showed evidence of recurrence of infection in the arthrodesis.

The above results contrast with our experience using other techniques. In this group, the mean hospital stay was 26 days (7 to 90), with fusion achieved in only 53%. Complications occurred in 76% of patients and required a total of 22 procedures with a mean hospital stay of 19 days. For all methods, except the Ilizarov frame, patients required a longer period in plaster after operation.

Table IV gives the mean valgus and flexion angles for the various techniques. Use of the Mayday nail consistently achieved angulation closer to anatomical alignment, while the Küntscher nail and Ilizarov apparatus were the worst at restoring anatomical valgus. Detailed results for each individual case are given in Tables II and III. Table IV shows a summary of results by each method of arthrodesis.

Fig. 3a

Fig. 3b

Postoperative radiographs showing a) an AP view of the Mayday nail and b) a lateral view.

Using Fisher's exact test, comparisons were made between the Mayday nail group and the other patients. The difference in time to fusion was not significant. The differences in the need for further surgery and occurrence of complications were both significant ($p < 0.001$). The differences in the rate of nonunion and the inpatient stay of less than three weeks were also significant ($p < 0.05$).

Discussion

Arthrodesis of the knee is undertaken relatively infrequently, usually as a salvage procedure when previous surgery has failed. It is important to obtain solid fusion with minimal complications, since the patients are often elderly. Previous methods of arthrodesis have usually failed for a variety of rea-

Table III. Details of the 17 patients who underwent arthrodeses using alternative techniques

Case	Age (yrs)	Indication	Technique	Hospital stay (days)	Fusion (mths)	Complications	Further procedures		
							Number	Hospital stay (days)	Reason
1	36	Instability (Charcot joint)	Orthofix	20	4	None	2	14	Adjustments and removal
2	76	Infected TKR*	Küntscher nail	40	18	Bleeding	1	Same admission	Return for haemostasis
3	63	Failed arthrodesis for infected TKR	Ilizarov	11	Nonunion	Infected nonunion	4	37	Adjustments and removal
4	35	Failed surgery for anterior knee pain	Küntscher nail	7	Nonunion	Nonunion	0	0	N/A
5	35	Failed arthrodesis for anterior knee pain	Dual compression plates	8	8	Infection	1	8	Treatment of infection
6	73	Infected TKR	Küntscher nail	26	Nonunion	Infection/nonunion	0	0	N/A
7	67	Infected TKR	Orthofix	24	Nonunion	Infected nonunion	2	6	Adjustment and removal
8	47	Anterior knee pain	Dual compression plates	15	Nonunion	Nonunion	1	13	Bone grafting
9	69	Failed arthrodesis for infected TKR	Orthofix	25	4	Infection	1	3	Removal
10	73	Post-traumatic arthritis	Orthofix	14	7	Infection	1	3	Removal
11	79	Failed arthrodesis for progressive recurvatum (polio)	Charnley clamps	90	6	None	1	3	Removal clamp
12	67	Failed arthrodesis for infected TKR	Ilizarov	60	4	Infection	2	6	Removal wire and frame
13	71	Infected TKR	Dual compression plates	29	Nonunion	Infected nonunion	2	28	Debridement and removal metal
14	82	Infected TKR	Küntscher nail	30	Nonunion	Nonunion	0	0	N/A
15	72	Infected TKR	Küntscher nail	20	18	None	0	0	N/A
16	66	Failed arthrodesis for infected TKR	Dual compression plates	15	Nonunion	Infected nonunion	3	135	Removal and infection treatment
17	72	Failed arthrodesis for infected TKR	Ilizarov	6	3	None	1	3	Removal frame

*total knee replacement

sons including inadequate fixation, persisting infection, deficient bone stock and lack of solid bony contact.¹⁰ External fixation has been popular, but subsequent admissions for pin-track complications or adjustments are often required. Thornhill, Dalziel and Sledge¹¹ reported a rate of multiple operations of up to 33% in order to achieve union in an external fixator group, in addition to a further procedure to remove the fixator. Rand and Bryan¹⁰ had a complication rate of 68% with external fixation. Garberina et al¹² described a series using circular external fixators with a complication rate of 84%, pin-track infection of 55% and nonunion of 32%. We have studied the need for further operative procedures and hospital admissions. In addition, consideration is required of the need for more frequent attendance at outpatient clinics which can be a burden to a patient who may already have had numerous attendances and previous treatment before arthrodesis.

The Ilizarov technique has been used more recently, but similar admissions for adjustments are required. Oostenbroek and van Roermund⁴ reported a complication rate of 80% in a series of 15 knees using the Ilizarov frame and acknowledge some limitations of the technique such as the complication rate and the cumbersome nature of the device.

Patients often have to be placed in a cast after removal of the fixator.

Longer intramedullary devices such as the Küntscher nail require surgical access to the trochanteric region, and do not allow restoration of anatomical knee alignment or control of tibial rotation.^{8,13} They cannot be used when an ipsilateral hip arthroplasty or bony deformity is present.⁵ Ellingson and Rand⁶ reported a complication rate of 55% using standard intramedullary devices and a mean blood loss of 2975 ml with a mean operating time of six hours. We have found a similarly high complication rate with this technique. Use of dual compression plates has achieved good rates of union, but there are concerns about the risk of fracture at the bone-plate junction and patients are often immobilised in an above-knee cast until fusion has occurred. Nichols et al³ achieved a rate of union of 100% but immobilised their patients in plaster for a mean of 5.6 months.

The ideal method of arthrodesis should have a high rate of union with a low complication rate, no cumbersome device, minimal visits to hospital and a reduction in the need for further treatment. The normal anatomical alignment should be restored. Our experience with the Mayday intramedullary nail suggests that this method comes nearest

Table IV. Summary of results by technique of arthrodesis

Method	Number	Radiological fusion rate (%)	Time (mths)	Complications (%)	Mean length of stay (days)	Mean number of further procedures	Mean length of further treatment (days)	Mean time in plaster (wks)	Mean valgus angulation (degrees; range)	Mean flexion angulation (degrees; range)
External fixation	5	80	5.25	60	35	1.4	6.0	13.6	6.0 (2 to 12)	9.0 (3 to 14)
Ilizarov	3	66	3.5	66	26	2.3	15.3	0.0	1.7 (-2 to 4)	13.0 (2 to 20)
DCP*	4	25	8.0	100	17	1.75	46.0	4.5	4.5 (-8 to 18)	10.5 (-2 to 22)
K nail†	5	40	18.0	80	25	0.2	0.0	18.6	0.6 (-2 to 4)	5.4 (2 to 12)
Mayday	8	100	10.0	0	15	0.0	0.0	1.6	3.6 (2 to 6)	10.0 (8 to 12)

*dual compression plate

† Küntscher nail

to achieving these objectives, since it offers a superior rate of union without the need for further admissions for treatment. The device can be inserted through the previous incision. The patient is allowed full weight-bearing from the outset and external splintage is not mandatory, and if used is only required for a short period. By mobilising earlier, we believe that improved compression at the site of the arthrodesis is achieved, although this is not necessarily reflected in the rates of time to union. As experience in the technique has improved, so the postoperative stay has reduced, and the time to union has decreased. None of our patients has required further admission to hospital or a further operative procedure, and we believe this to be a distinct advantage, especially when most patients have had numerous previous hospital admissions with general anaesthesia. The time to the achievement of union has been overestimated since patients were often only reviewed every four to six months and we have taken the 'date of union' to be the clinic visit at which clinical and radiological evidence confirmed union. We believe that prospective follow-up of future arthrodeses will yield improved times of union. Our results compare favourably with those of similar modular intramedullary devices.^{2,14} It is now our practice to use the Mayday nail as our standard device for arthrodesis of the knee while alternative methods, such as the Ilizarov frame, are considered when there is extensive bone loss or resistant infection.

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