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Beneficial effects of continuous passive motion after total condylar knee arthroplasty

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A randomised, controlled study of the use of postoperative continuous passive motion (CPM) and immobilisation regimen after total condylar knee arthroplasty was performed. CPM resulted in a significant increase in both the early and late range of knee flexion. This increase occurred in both rheumatoid and osteoarthritic patients. The improvement of 10° at 12 months allowed additional important function to be attained. CPM resulted in significantly earlier discharge from hospital. It did not increase the clinical incidence of wound healing problems, nor did it significantly increase the postoperative fixed flexion deformity or the extension lag. CPM can be recommended as a safe and effective modality to achieve more rapid and more successful postoperative rehabilitation after knee arthroplasty.

In 1876 Hugh Owen Thomas *(1)* stated that "a combination of enforced, uninterrupted and prolonged rest" was necessary for successful wound healing. Immobilisation, however, results in contracture of muscles and joint capsule, proliferation of intracapsular connective tissue, the formation of intra-articular adhesions and cartilage degeneration *(2,3)*. The traditional postoperative management of the patient with a total knee arthroplasty has been to immobilise the knee for a period of time using bulky Robert Jones dressings with or without plaster reinforcement *(4–7)* or a cylinder cast *(8,9)*. Range of motion exercises are sometimes not started until the 14th postoperative day *(5)*.

Constant movement contradicts the principles of immobilisation, elevation and rest which historically have been thought to promote wound healing; but, even in the nineteenth century there were those who believed that prudent and methodical movement aided wound healing *(10)*. By 1979, Salter was able to conclude from his studies on immature rabbits that continuous movement, albeit passive movement, had no detrimental effects on wound healing and indeed resulted in stronger wounds with a greater concentration of collagen *(11)*. However, the clinical situation in man may not be comparable to that in the rabbit. Knee flexion in the early postoperative period increases the tension across the wound *(12)* and recent reports have suggested that CPM adversely affects wound healing after knee arthroplasty *(13)*.

The goal of postoperative rehabilitation after arthroplasty is the early return of joint function and in the knee there is a close correlation between the range of motion and the functional abilities and, hence, in the overall success of the arthroplasty *(14)*. CPM has been used to restore movement in the early postoperative period when active exercises may be difficult. Although it has been demonstrated that CPM can result in a greater range of knee flexion in the early postoperative phase, these studies have not been controlled randomised trials and have not differentiated between patients with rheumatoid arthritis and those with osteoarthritis *(13,15,16)*.

This study was performed to determine the effect of postoperative CPM on the range of knee flexion, the fixed flexion deformity, the extension lag after knee arthroplasty and on wound healing. Unlike previous studies, this study was confined to patients undergoing total knee arthroplasty and patients with rheumatoid arthritis and those with osteoarthritis were considered separately.

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Methods and materials

A randomised controlled trial was undertaken in 56 patients undergoing primary total condylar knee arthroplasty. Of the patients, 20 suffered from rheumatoid arthritis and 36 patients had osteoarthritis. The mean age of the patients was 69 years (range 36–85 years), 23 were male and 33 female. All patients received a Kinematic total condylar knee prosthesis. Preoperatively, the patients were assessed and matched for the presence of factors that might adversely affect wound healing such as diabetes, corticosteroid therapy and peripheral vascular disease, for their age, type of arthritis and presence of any previous scars around the knee. Haematological assessment included a full blood count and serum urea and creatinine estimations. All results were within acceptable limits adjusted for the age of the patient. The preoperative extensor lag, fixed flexion deformity and range of knee flexion were measured with a goniometer.

A standard operative protocol was designed which included a three-dose regimen of prophylactic antibiotics, a medial parapatellar approach to the knee and the use of gentamicin-containing cement. The wounds were closed in layers with interrupted nylon mattress sutures for the skin. Two wound drains were used with one placed within the joint cavity and one in the subcutaneous fat. The knee was wrapped in wool and a crêpe bandage applied.

Patients were randomly assigned to one of two groups: one group received immediate postoperative CPM while the second group was immobilised in a splint. CPM (Fig. 1) was used for the first 7 postoperative days. Patients used the machine for 20 h/day for 3 days and then for 16 h/day for 4 days. A CPM regimen was designed which limited early postoperative knee flexion when the wound is most vulnerable to disruption. The initial range of motion was 0–40° and this was increased each day by 10° up to 90° on the 6th day. The apparatus was removed on the 7th day. Twice daily the CPM machine was removed and full extension exercises were performed under the supervision of the physiotherapist.

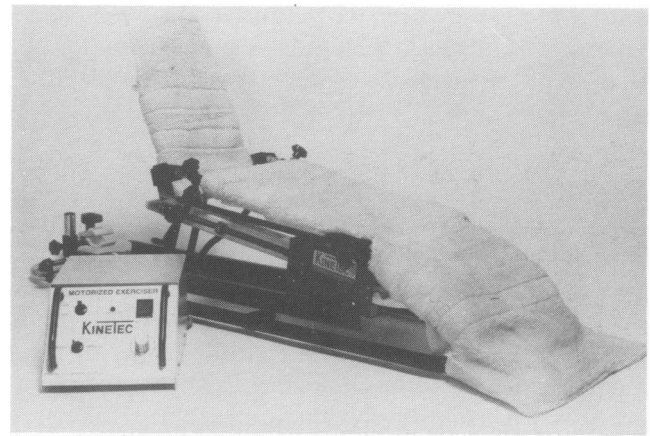

Figure 1. The CPM machine used in this study.

Weight bearing was begun on the 3rd day, but no active knee flexion was allowed until the 7th day (Table I).

Patients on the immobilisation regimen wore a splint over the bandages for 7 days. Straight leg raising exercises were performed twice daily. Weight bearing started on the 3rd postoperative day, but no active knee flexion was allowed until the 7th postoperative day as in the CPM group.

All wounds were inspected regularly throughout the postoperative period. Failure of primary wound healing was considered to be present if aseptic wound dehiscence occurred, if an aseptic wound discharge continued after the 5th postoperative day or if infection confirmed by positive wound swab culture was present. The range of motion was recorded on the 7th, 10th and 14th day. All patients were reviewed at 6 weeks, 3, 6 and 12 months. The wounds were inspected and the range of motion measurements were made.

The statistical analysis was performed in association with the statistical services unit of the University of Sheffield. Further calculations were performed using a microcomputer and the Stat View 512+ statistical analysis program. Statistical analysis included paired *t* tests for within patient analyses of the range of motion. Two

Table I. Postoperative continuous passive motion protocol

Day	*Protocol*
0	CPM applied in recovery with adequate analgesia and sedation. Range 0–40°
1	Range 0–40°. CPM used 20 h Straight leg raising exercises for two periods of 1 h
2	Range 0–50°. CPM used 20 h. Straight leg raising exercises Bandages removed, wound inspected and dressings changed
3	Range 0–60°. CPM used 20 h. Straight leg raising exercises Patient allowed to mobilise in a knee extension splint
4	Range 0–70°. CPM used 16 h. Straight leg raising exercises
5	Range 0–80°. CPM used 16 h. Straight leg raising exercises
6	Range 0–90°. CPM used 16 h. Straight leg raising exercises
7	CPM stopped. Active knee flexion exercises started

sample t tests were used for the analysis between patient groups. Contingency table analysis was used for the analysis of the incidence of wound healing problems.

Results

This study contained 56 patients: 26 received CPM and 30 were immobilised. Superficial infection occurred in three cases, but none of these were in the CPM group. Although the incidence was marginally higher in rheumatoid patients and in immobilised patients the differences were not statistically significant (Table II). Delayed wound healing, usually minor, occurred in eight cases; two were in the CPM group and six in the immobilised group. Again, although the incidence was higher in rheumatoid patients and immobilised patients, the differences were not statistically significant (Table II). All of the patients eventually achieved successful wound healing and there were no cases of deep wound infection. The one complication of CPM was the development of buttock pressure sores in two patients early in the study; subsequently, extra nursing vigilance prevented this problem.

The duration of postoperative hospital inpatient stay was determined by the range of motion and functional ability. Patients were discharged when mobile with at least 70° of knee flexion. The mean length of hospital stay was 15 days for the CPM group and 20 days for the immobilised group ($P<0.01$). This reduction in the inpatient hospital stay for the CPM group was obtained in patients suffering from both rheumatoid arthritis and osteoarthritis.

The fixed flexion deformity was not significantly different between the CPM and immobilised groups at any time during the postoperative period. The fixed flexion deformity decreased from a mean of 4° at 7 days to mean 1° at 6 months (Table III). There was no increase in the early postoperative extension lag after the use of CPM. After 7 days the overall mean extension lag was 7°. By 6 months this had diminished to a mean of 1° and it remained at this level at the 12-month review.

The range of knee flexion achieved with CPM was significantly greater than with immobilisation throughout the early and the late postoperative periods. The ultimate range of knee flexion measured at 12 months was 10° greater in the CPM group (Table III). No patient underwent manipulation under anaesthesia to improve the range of flexion.

The effect of CPM was further analysed by studying the group of 36 patients with osteoarthritis. Of these 36 patients, 16 received CPM while 20 were immobilised. The ultimate range of knee flexion at 12 months was 105° for those patients receiving CPM, but only 93° for those

Table II. Incidence of wound healing problems in the different groups of patients receiving CPM and immobilisation

Arthritis	*No.*	*Delayed healing*	*Superficial infection*	*Deep infection*
Continuous passive motion				
Osteoarthritis	16	2	0	0
Rheumatoid arthritis	10	0	0	0
Immobilisation				
Osteoarthritis	20	4	1	0
Rheumatoid arthritis	10	2	2	0
Total	56	8 (14%)	3 (5%)	0

Table III. Fixed flexion deformity, extension lag and flexion for the immobilised group and the CPM group

Measurement/ Protocol	*No.*	*Day 7*	*Day 10*	*Day 14*	*6 Weeks*	*3 Months*	*6 Months*	*1 Year*
Fixed flexion								
Immobilised	30	3.1	4.4	2.1	1.8	1.2	1.0	0.4
CPM	26	4.2	4.5	3.0	3.4	2.9	1.2	1.7
Extension lag								
Immobilised	30	7.2	2.9	5.5	0.5	0.9	0.5	0.4
CPM	26	7.5	4.7	3.9	2.0	1.4	1.3	0.1
Flexion								
Immobilised								
Osteoarthritis	20	45	52	60	70	89	92	93
Rheumatoid	10	64	76	82	95	105	96	101
Mean	30	51	60	67	78	94	93	96
CPM								
Osteoarthritis	16	68	75	77	86	98	101	105
Rheumatoid	10	68	71	74	92	101	107	107
Mean	26	68	73	76	88	99	103	106
Total	56	59	66	71	82	97	98	100

who were immobilised ($P < 0.05$). The use of CPM after total condylar knee arthroplasty in osteoarthritic patients resulted in a significant increase in both the early and late range of knee flexion (Table III). Similarly, in rheumatoid patients the use of CPM resulted in an increased range of knee flexion compared with immobilisation. The final range of flexion was increased from 101° to 107° as measured at 12 months (Table III).

The effect of CPM used in patients with osteoarthritis compared with rheumatoid arthritis was studied further. In the CPM group of 26 patients, 16 had osteoarthritis and 10 had rheumatoid arthritis. The mean knee flexion achieved in the osteoarthritic patients at 14 days was 77°, at 6 months 101° and at 12 months 105°. In rheumatoid arthritis patients the mean knee flexion at similar stages was 74°, 107° and 107°. There was no significant difference between the two groups of patients. Thus, after total condylar knee arthroplasty, CPM has a similar beneficial effect on the range of knee flexion in rheumatoid and osteoarthritic patients (Table III).

Discussion

Salter and Ogilvie-Harris *(17)* concluded from their animal studies that CPM had no adverse effect on wound healing. Unfortunately, although enormous skin flaps can be raised in the rabbit, the anatomy of the cutaneous circulation in man is very different and, in clinical practice, skin necrosis is an ever present hazard *(18)*. Failure of primary wound healing and superficial infection may both progress to deep infection with dire consequences for the patient *(19)*. Hence, CPM can only be recommended for knee arthroplasty patients if there is no deleterious effect on wound healing.

For this study, a conservative CPM regimen was designed which specifically limited flexion in the first few postoperative days in order to obtain the maximum effect upon joint mobility while minimising the potentially adverse effect of knee flexion on wound healing. No significant difference in the incidence of infection or failed primary wound healing was demonstrated between the two groups. This is in contrast to the results of a more aggressive regimen discussed by Goletz and Henry *(13)*. Thus, if used in a controlled manner, CPM does not increase the clinical incidence of wound healing problems.

Postoperative rehabilitation after a knee arthroplasty is concerned with the early return of joint function, which in the knee joint correlates well with the overall range of knee flexion *(14)*. For the swing phase of normal gait 65–70° of knee flexion are required, for ascending and descending stairs 90° and 100° respectively, and 105° for rising easily from a low chair *(20,21)*. Postoperatively, manipulation under anaesthesia has been used to gain additional knee flexion. The complications of this procedure include supracondylar fracture, patella tendon avulsion *(5)*, wound dehiscence, haemarthrosis *(21)* or death due to anaesthetic complications *(22)*. Fox and Poss *(21)* evaluated the results of manipulation and found that the ultimate range of knee flexion was no different for those patients who were manipulated compared with those who were not manipulated. CPM has been used after knee arthroplasty to restore movement, particularly in the first few postoperative days when patients are reluctant to perform active exercises. In this situation, CPM has also been demonstrated to improve the clearance of blood from the joint *(23)* and to reduce the requirement for analgesia *(13)*. However, CPM does not significantly reduce the incidence of deep vein thrombosis *(16)*. CPM is most effective in improving the range of knee motion when its use is limited to the first 7 postoperative days *(24)*. In this study, after total condylar knee arthroplasty, the use of CPM resulted in a significant increase in the range of early knee flexion compared with that present in immobilised patients. This finding in itself is not surprising and has been reported previously *(15)*. However, in this study, this significant difference in knee flexion had been maintained at the 12 month review. This effect was noted for both osteoarthritic patients and rheumatoid arthritis patients. The 10° increase in the range of knee flexion is significant not only statistically but also functionally, in that it allows the patient to achieve additional activities such as descending stairs or rising from a low chair more easily.

The CPM regimen used included a cycle of motion producing full extension and, in addition, twice daily quadriceps exercises were performed. This prevented the development of a fixed flexion deformity or an extensor lag in those patients who received the CPM regimen compared with those who were immobilised in extension.

Those patients who received the CPM regimen postoperatively regained functional knee flexion more rapidly than those who were immobilised. This benefit did not occur at the expense of wound healing problems and thus resulted in an earlier discharge from hospital for both rheumatoid and osteoarthritic patients in this group. A conservative CPM regimen can therefore be recommended as a safe and effective means of achieving more rapid and more successful postoperative rehabilitation after knee arthroplasty in both rheumatoid and osteoarthritic patients.

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