

# Review article: Knee flexion after total knee arthroplasty

KY Chiu, TP Ng, WM Tang, WP Yau

Division of Joint Replacement Surgery, Department of Orthopaedic Surgery, The University of Hong Kong, Queen Mary Hospital, Pokfulam, Hong Kong

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## ABSTRACT

Many factors affect or predict the flexion range achieved after total knee arthroplasty. While the knees that have good preoperative flexion have better final flexion, knees with good preoperative flexion do lose some flexion whereas those with poor preoperative flexion can gain flexion. Although studies of different prosthetic designs have produced conflicting results, recent studies appear to favour posterior cruciate ligament (PCL)—substituting over PCL-retaining prostheses. Several factors related to surgical techniques have been found to be important. These include the tightness of the retained posterior cruciate ligament, the elevation of the joint line, increased patellar thickness, and a trapezoidal flexion gap. Vigorous rehabilitation after surgery appears useful, while continuous passive motion has not been found to be effective. Obesity and previous surgery are poor prognostic factors; certain cultural factors, such as the Japanese style of sitting, offer ‘unintentional’ passive flexion and result in patients with better range. If the flexion after surgery is unsatisfactory, manipulation under anaesthesia within 3 months of the total knee arthroplasty can be beneficial.

**Key words:** flexion; range of motion; total knee arthroplasty

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## INTRODUCTION

Range of motion is an important measure of outcome of total knee arthroplasty (TKA), and is an important part of most knee scoring systems. It has been demonstrated that a 67° of knee flexion is needed for the swing phase of the gait, 83° to climb stairs, 90° to descend stairs, and 93° to rise from a chair.<sup>1,2</sup> The minimum flexion of the knee necessary for usual daily living is generally agreed to be 90°. <sup>3</sup> It has been shown that the amount of knee flexion significantly influences the total Hospital for Special Surgery Knee Score, the stair climbing score, and the walking ability score.<sup>4</sup>

While patients hope that their knee range will improve after a TKA, this may not happen. A large review of TKAs of different designs performed before the end of 1985 found that 46% of patients could not flex their knees beyond 90° after the surgery.<sup>5</sup> Even in the recent literature, reports exist of loss of average knee flexion after TKA.<sup>6,7</sup>

What should an orthopaedic surgeon tell a patient about the likely range of knee flexion after TKA? Most published series report a final flexion between 100° and 115° (Table 1). Questions such as: ‘When can one expect more flexion after TKA and when should one expect less?’, ‘What can be done to maximise the flexion range?’, and ‘What can be done if the postoperative range is not good?’ are all important. The objective of this paper is to review the literature regarding factors

**Table 1**  
Literature review results for flexion range following total knee replacement

Authors (year)	No. of patients/knees	Follow-up period (years)	Type of prosthesis inserted (manufacturer)	Degree of flexion—mean (range)	
				Preoperative	Final
Insall et al. (1982)	91/118	2–4	Insall-Burstein (Zimmer)	95°	115° (60°–140°)
Insall et al. (1983)	79/100	5–9	Total condylar	87° (3°–150°)	98° (75°–125°)
Figgie III et al. (1986)	101/116	2.5–5	Insall-Burstein (Zimmer)	Not available	101° (30°–135°)
Ranawat and Boachie-Adjei (1988)	87/112	8–11	Total condylar	Not available	95° (70°–120°)
Rosenberg et al. (1990)	122/132	3–6	Miller-Galante (Zimmer)	101° (15°–140°)	105° (45°–140°)
Ryu et al. (1993)	60/90	2–7.5	Miller-Galante I (Zimmer)	111° (75°–140°)	110° (60°–130°)
Ranawat et al. (1997)	96/125	4–6	PFC posterior-stabilised (Johnson & Johnson)	107° (60°–135°)	111° (75°–135°)
Shurman et al. (1998)	138/164	2	Insall-Burstein II (Zimmer)	105°	110°
Schai et al. (1998)	122/155	>10	PFC PCL-retaining (Johnson & Johnson)	Not available	113° (85°–135°)
Li et al. (1999)	78/94	8–12	Insall-Burstein II (Zimmer)	88° (10°–120°)	100° (30°–130°)
Ewald et al. (1999)	–/306	10–14	Kinematic PCL-retaining (Howmedica)	107°	104°
Kaper et al. (1999)	–/119	5–8	SAL mobile-bearing PCL-retaining (Sulzer)	110°	111°
Callaghan et al. (2000)	64/86	9–12	LCS rotating platform (Depuy)	110° (45°–140°)	102° (15°–120°)

that could affect or predict the range of motion achieved after TKA.

## FACTORS THAT HAVE BEEN EVALUATED

### Predictive value of preoperative range of motion

The preoperative range of motion is known to be an important factor that influences the range of motion after TKA. Knees that have good preoperative flexion have better flexion postoperatively than those with poor preoperative flexion. Menke et al.<sup>8</sup> assessed the range of motion in 90 patients who had total condylar knee replacements 5 to 6 years prior. The subjects' postoperative flexion range showed a significant

correlation with their preoperative range. Another study of patients given cruciate-retaining TKAs for severe osteoarthritis found that when the preoperative flexion was less than 90°, the final flexion after TKA was 88°, which was significantly less than the final flexion of 103° observed in patients whose preoperative flexion were 90° or more.<sup>9</sup>

A report involving 257 patients with a minimum 12-month follow-up period divided patients into 3 groups: those with preoperative flexion of less than 90°, 90° to 105°, and greater than 105°.<sup>10</sup> The authors found no significant difference between the groups as regards the average final flexion ranges; all patients tended to move towards a middle range. This concurs with the findings of several other studies,<sup>11–15</sup> which show that those knees with good preoperative flexion

**Table 2**  
**Changes in flexion range following total knee replacement**

Authors (year)	No. of patients/ knees	Follow-up period (years)	Type of prosthesis inserted	Preoperative flexion	Change in flexion
Ritter and Stringer (1979)	90/145	>1	Mixed*	<75°	+16°
				76°–95°	+5°
				>95°	–8°
Shurman et al. (1985)	55/71	>2	Total condylar	<100°	+11°
				>100°	–11°
Parsley et al. (1992)	252/313	1–2	Mixed†	<75°	+16°
				75°–95°	+7°
				>95°	–6°
Shurman et al. (1998)	138/164	>2	Insall-Burstein II	≤109°	+15°
				>109°	–4°

\* Two-thirds were total condylar

† All were cruciate-retaining

tend to lose flexion, while those with poor preoperative flexion gain flexion after TKA (Table 2).

#### Effect of associated disease or trauma on outcome

Early reports suggested that knee flexion increases after TKA if the diagnosis is rheumatoid arthritis (RA) but decreases if the diagnosis is osteoarthritis (OA). For example, Ritter and Stringer<sup>11</sup> evaluated 145 consecutive TKAs in which 6 TKA designs were used, with two-thirds being total condylar knee prostheses. They found that the knee flexion range increased by 2° in RA patients, a non-statistically significant difference. On the other hand, for patients with a diagnosis of OA, the knee flexion range significantly decreased by 4°. A more recent study that reviewed cruciate-sacrificing, meniscal-bearing TKAs found a mean loss of flexion in OA patients of about 3°, and a mean gain in RA patients of about 5°.<sup>14</sup>

A 1998 study of 164 Insall-Burstein posterior-stabilised (IB; Zimmer, Indiana, US) TKAs evaluated the factors that affect postoperative knee flexion.<sup>15</sup> For the knees that had a preoperative flexion arc of more than 78°, the mean postoperative flexion was 100° if the diagnosis was RA, septic arthritis, or avascular necrosis. For patients with a diagnosis of OA, trauma or gout, the mean postoperative flexion was even better at 120°. For the knees that had preoperative flexion of

more than 109°, flexion decreased by 2° after surgery if the diagnosis was OA, trauma or gout, whereas if the diagnosis was RA, septic arthritis or avascular necrosis, the flexion decreased by 15° after surgery. The data from this study are difficult to interpret because several diagnoses were grouped together. However, because OA and RA are the predominant knee diseases, one could infer that the OA patients do better than the RA group when the knee are not too stiff, i.e. more than 78° of flexion, before surgery.

#### Effect of prosthesis type on outcome

The early total condylar designs had limited flexion range because the posterior femoral flange engaged the posterior aspect of the tibial component at about 95° of flexion.<sup>16,17</sup>

By saving the PCL, femoral rollback is preserved. This step, together with modification of the prosthetic geometry, provides greater posterior clearance and permits more flexion motion. Femoral rollback can also be achieved by substituting the PCL with a posterior-stabilised design with a tibial post (the femoral cam mechanism). A meta-analysis of 130 studies reporting patient outcomes after TKA<sup>18</sup> found that the mean range of motion was 99° (range, 84°–113°) after a PCL-sacrificing TKA, 107° (range, 65°–123°) after PCL-retaining knee surgery, and 103° (range, 85°–115°) after PCL-substituting knee surgery. However, no adjust-

ment was made for the preoperative range of motion each patient had.

Some studies have failed to show better knee flexion with the retention or substitution of the PCL. One study compared the range of motion after total condylar knee or posterior-stabilised total condylar knee surgery.<sup>19</sup> While the mean final flexion was 11° better in the patients with posterior-stabilised total condylar knees, this group also had better preoperative flexion. The authors felt that the difference in final flexion was not related to the design of the prosthesis. Likewise, Hirsch et al.<sup>20</sup> reported that the final knee flexion was more or less the same whether the PCL was sacrificed or retained. Using the same prosthetic design (Press Fit Condylar; Johnson & Johnson, Indiana, US), the flexion obtained was 103° after PCL-sacrificing TKA, compared with 104° after PCL-retaining TKA.

Several studies have compared the knee flexion after PCL-retaining and PCL-substituting TKA. A study published in 1991 reported on 30 patients who had bilateral TKAs performed.<sup>21</sup> A PCL-retaining prosthesis (in 3 different designs) was implanted in one side, and a PCL-substituting prosthesis was implanted in the other side. The preoperative flexion was 101° in the PCL-retaining side, and 98° in the PCL-substituting side; the postoperative values were 111° in the PCL-retaining side, and 113° in the PCL-substituting side. Hirsch et al.<sup>20</sup> studied 242 TKA patients who were divided into 3 treatment groups. Press fit concylar (PFC) TKA was inserted in groups one and 2, with the PCL sacrificed in group one and retained in group 2. For group 3 patients, the PCL was substituted with an IB TKA. The postoperative flexion range of group 3 patients was 112°, which was significantly better than the respective figures for group one and group 2 patients (103° and 104°, respectively). In a study published in 1998, 20 patients who had PFC PCL-retaining knee surgery were compared with 20 patients who had PFC PCL-substituting knee operations.<sup>22</sup> Before surgery, the mean knee flexion was 118° for the PCL-retaining knees, and 108° for the PCL-substituting knees. After surgery, in active weightbearing mode, the postoperative knee flexion was 113° for the PCL-substituting knees, significantly more than that (103°) achieved in those with PCL-retained knees. Hence, it appears that PCL-substituting TKA gives better flexion.

Modifications to the designs of TKA may help to improve knee flexion. A Japanese study compared 31 Kyoto University (KU) prostheses with 31 total condylar prostheses in patients who had RA.<sup>23</sup> The KU prosthesis has a cruciate-substituting design, with a unique ball-and-socket coupling in the centre of the

posterior portion of the femorotibial articulation. Unlike the usual post-cam design, the ball is from the femoral side and the socket is on the tibial side. The posterior part of the tibial articular surface is flattened. These features allow femoral rollback and femorotibial contact posteriorly, thus improving the posterior clearance when the knee is flexed. Before TKA, the knee flexion in the study participants averaged 116° in the total condylar group, and 117° in the KU group. After TKA, the final knee flexion was reduced to an average of 94° in the total condylar group, and increased to 120° in the KU group. Using the same prosthetic geometry, but making the femoral component out of alumina ceramic, Akagi et al.<sup>24</sup> prospectively evaluated 182 knees for 4 to 9 years. The mean preoperative flexion in participants was 119° while the postoperative flexion was 124°. The study authors called it 'bisurface total knee replacement', and considered it important in improving the flexion range.

Whether or not mobile-bearing TKA improves knee flexion is not conclusive. The effects of preserving and sacrificing the PCL when using a Low Contact Stress (LCS) [Depuy, Leeds, UK] mobile-bearing knee system have been studied.<sup>25</sup> A total of 261 rotating platform (PCL-sacrificing) and 521 meniscal-bearing (PCL-retaining) knee operations were conducted. One year after surgery, the mean flexion range was 115° for the cruciate-retaining knees, and 105° for the cruciate-sacrificing knees. However, the PCL-sacrificing rotating platform prostheses were used in the difficult cases with poorer preoperative flexion of 95°, compared with 105° flexion for the PCL-retaining meniscal-bearing knee group.

### **Flexion range after TKA is affected by the surgical techniques**

Surgical techniques are undoubtedly important. Many studies have tried to determine factors related to surgical techniques that affect the range of motion after a TKA.

Computer models had been used to study the effects of simulated placements of TKA components on knee flexion. Using a 3-dimensional model of the PCL-retaining TKA, projections have been made of posterior displacement of the tibial component by 5 mm, anterior displacement of the femoral component by 2.5 mm, and posterior slope of the tibial component by 10°, resulting in less strain in the PCL with knee flexion.<sup>26</sup> The maximum knee flexion was increased by 5%, 15%, and 30%, respectively. On the other hand, anterior displacement of the tibial component by 5 mm, posterior displacement of the femoral component by 2.5 mm, and anterior slope of the tibial component by

10° decreased the maximum knee flexion by 10%, 10%, and 25%, respectively. Piazza et al.<sup>27</sup> found in another computer model that a posterior tibial slope did not produce the same beneficial effects in PCL-substituting TKA. With 5° of posterior tilt, the knee had to flex 18° before the tibial post interacted with the femoral ram. In other words, a posterior tibial tilt made it more difficult for the post-cam mechanism to start functioning, and could thus affect the knee flexion after TKA.

Tightness of the retained PCL was considered a possible factor leading to unsatisfactory postoperative flexion. Ritter et al.<sup>28</sup> reported that it was possible to balance the excessively tight PCL by subperiosteally recessing the tibial attachment. The knee flexion achieved was 114° for the PCL-balanced knee and 107° for the standard knees. Although a conforming polyethylene insert theoretically resists rollback in a cruciate-retaining knee, it has been reported that a good range of motion can also be achieved after balancing the PCL.<sup>29</sup> When 2 groups of PFC TKA were compared, one with a curved insert and one with a flatter insert, no difference in the change of knee range was found between the 2 groups.

Several clinical studies have also shown that elevation of the joint line and increased patellar thickness lead to poor knee flexion after TKA. Shoji et al.<sup>30</sup> studied 231 primary TKAs in which 4 different prostheses were used and the PCL was retained in fewer than 20% of the knees. These investigators found that if the patellar thickness was increased by 20% after surgery, as many as 74% of knees could not flex more than 100°, whereas only 3% could not do so if the increase in patellar thickness was under 20%. Likewise, if the joint line was elevated by 10 mm or less, 32% of knees could flex beyond 120°, while only 7% of knees could do so if the joint line was raised by more than 10 mm. A review of 90 Miller-Galante I (MG I) [Zimmer, Indiana, US) TKAs in 60 patients showed that the joint line was elevated by an average of only 2.1 mm in the good-flexion group, and it was 5.7 mm in the poor-flexion group.<sup>31</sup> While the preoperative patellar thickness was 19.5 mm in the good-flexion group and 18.8 mm in the poor-flexion group, the thickness after TKA was reversed, with 18.7 mm in the good-flexion group, and 21.4 mm in the poor-flexion group.

The ability to obtain a rectangular flexion gap has been shown to be important. Laskin<sup>32</sup> conducted a study in 1995 to compare 2 groups of knees. For patients in the first group, equal resection of the posterior femoral condyles combined with a 90° tibial resection resulted in a trapezoidal flexion gap. For patients in the second group, the femoral resections were externally rotated by an average of 3° to give a

rectangular flexion gap. The same cruciate-retaining prosthesis (Genesis; Smith and Nephew, Tennessee, US) was used in all knees. In the first group (92 knees), the average preoperative flexion was 120°, which fell to 100° postoperatively. In the second group (96 knees), the average preoperative flexion was 115°, which dropped slightly to 112° postoperatively.

Scott and Siliski<sup>33</sup> have reported on the use of a V-Y quadricepsplasty to improve knee flexion in patients with stiff knees. An inverted 'V' incision was made in the quadriceps tendon and the lateral limb of the 'V' was carried from the apex laterally and distally along the insertion of the vastus lateralis muscle, with care taken to preserve the lateral superior geniculate artery. During wound closure, the medial limb was advanced and sutured, and the lateral limb was left open to accomplish an effective lengthening. While the average preoperative knee flexion was only 26° (range, 15°–40°), the final flexion angle was 75° (range, 45°–100°).

It has also been suggested that wound closure be performed on the knee with flexion from 90° to 110°. The idea suggested by Emerson et al.<sup>34</sup> was that loss of flexion occurs due to the relative shortening of the extensor mechanism, together with the skin tightness, if the wound was closed with the knee extended. In their study, it was found that the flexion range of the flexion-closure group surpassed the preoperative flexion range by 2° six months postoperatively, whereas the extension-closure group had 4° less flexion compared with their preoperative flexion. However, others have not been able to demonstrate any difference in the early postoperative parameters, or the 2- to 3-month follow-up data between knees closed in full extension or in flexion.<sup>35</sup>

Lee et al.<sup>36</sup> have reported on the final range of motion by looking at intra-operative flexion against gravity (by flexing the hip to 90° after capsular closure). They studied 364 primary cruciate-retaining TKA. The knees were subjected to 6 days of continuous passive motion (CPM). The authors found that 97% of knees had a flexion at 2 years within 10° more or less of the intra-operative range.

### **Role of continuous passive motion in rehabilitation**

While a poor flexion range before the operation is considered to be predictive of less flexion after TKA, it is possible to achieve good knee flexion with a vigorous motion protocol. In a study performed by Mullen,<sup>37</sup> patients were given passive motion of the knee by therapists of 90° after 5 days, followed by active flexion and extension exercises for 5 minutes per hour. Quadriceps strengthening exercises were

added on 13 patients with less than 90° of flexion prior to operation, and the regimen continued for as long as 6 months. The average flexion increased from 48° preoperatively to 103° after 2 to 5 years.

Whether CPM is beneficial to the range of motion after TKA is not decided. It has been reported that none of 137 patients who were subjected to CPM after TKA required manipulation for poor initial flexion, while 21% of 129 patients who did not have CPM required manipulation of the knee.<sup>38</sup> However, several authors have reported no long-term difference in the range of motion after TKA with CPM.<sup>39–41</sup> Other series have found a difference in the range of motion only in the early postoperative period but not after 3 months.<sup>42–44</sup>

Jordan et al.<sup>45</sup> reported on the use of an 'early flexion routine' to achieve maximum early knee flexion. The CPM was begun in the recovery room, with the range set from 70° to 120° of motion. Extension was advanced by 20° on the first postoperative day, followed by full extension on the second postoperative day. 50 knees were subjected to this method, while 50 others knees were allocated to a control group, for which CPM started on the second postoperative day with 0° to 40° of motion and progressing as tolerated, by 10° increments. An LCS meniscal-bearing prosthesis was implanted in every knee. The range of motion at one year was 120° in the early-flexion group, and 111° in the control group. This approach has been tested by a randomised prospective study.<sup>46</sup> For the early-flexion group the range was set from 70° to 100° in the recovery room, 40° to 100° on the first postoperative day, and 0° to 100° as pain was tolerated. For the control group, CPM was started on the first postoperative day with 0° to 30° of motion, and progressing as tolerated in 10°–15° increments. No significant difference was found between the 2 treatment groups after 4 weeks.

In another prospective, randomised study, patients were allocated into 3 treatment groups: no CPM (group 1), CPM from 0° to 50° and increased as tolerated (group 2), and CPM from 70° to 110° (group 3).<sup>47</sup> The CPM was initiated in the recovery room, and was used for a maximum of 24 hours in groups 2 and 3. Assessments before the operation, at 6 weeks, 23 weeks, 26 weeks, and 52 weeks postoperatively did not show any difference in the average knee flexion capacity among the 3 groups. Consequently, the authors did not support the use of short-term CPM after TKA.

### **Cultural differences can affect postoperative flexion**

In Japan, full squatting with the knees to the floor is commonly practised every day because of the sitting

environment. Good flexion after TKA with a flat posterior tibial surface to allow rollback and rotation at flexion has been reported by Shoji et al.<sup>48</sup> They also used dedicated instrumentation for controlled soft tissue—balancing with the knee in flexion and extension. Vigorous rehabilitation lasted for 4 weeks, and more than half of the knees required manipulation to improve flexion range. The investigators studied 50 knees, of which 35 were associated with RA, and 15 with OA. The preoperative flexion of patients was 121°, and the flexion range was 127° after a mean follow-up of 2 years. Full squatting was possible in 6 patients. In a subsequent paper, the same group of authors reported the results of 227 knees in 152 patients with RA.<sup>49</sup> After follow-up from 2 to 4 years, 14 patients were able to squat fully. Further evaluation of those patients who could squat fully found that more than half were no longer able to squat after 8 years.<sup>50</sup> The main reasons for this were ankle pain on squatting, and no opportunity to squat because of change to a western life style. The 'unintentional' passive flexion exercise imparted by the Japanese sitting-style appears to be important in achieving and maintaining full knee flexion after TKA.

### **Factors that adversely affect postoperative flexion range**

Obesity is associated with poor flexion range after TKA. Shoji et al.<sup>30</sup> studied 192 patients who underwent primary TKA; 186 patients had OA and 45 had RA, and 4 different prostheses were used. Patients were divided into 3 groups according to their postoperative knee flexion. In the group of patients with a flexion of more than 120°, only 7% were obese. In contrast, in the group of patients who had flexion between 100° and 120°, 28% were obese. In the group of patients with flexion of 100° or less, as many as 78% were obese.

A history of prior knee surgery can also adversely affect the flexion range after TKA. Katz et al.<sup>51</sup> reported a reduced range of motion after 21 porous-coated anatomic (PCA; Howmedica, New Jersey, US) TKA were performed for failed high tibial osteotomy, compared with 21 primary TKA for OA. Another study compared the results of 42 TKA performed following high tibial osteotomy with 41 following primary TKA.<sup>52</sup> The preoperative flexion range was 101° for the osteotomy group and 97° for the control group, respectively. After follow-up for 2 to 4 years, the knee flexion remained unchanged in the osteotomy group, while it was increased to 115° in the control group. Stiehl et al.<sup>25</sup> studied 782 LCS mobile-bearing TKA. The preoperative flexion were 100° and 99° for the knees with and without prior history of surgery, respectively.

After 2 years, the knees without prior surgery gained an average flexion of  $4^\circ$ , which was significantly more than that gained in the knees subjected to prior surgery ( $1^\circ$ ). However, in another study conducted by Meding et al.,<sup>53</sup> no significant difference in knee flexion was found between the side with and without previous high tibial osteotomy in patients who had underwent bilateral TKA.

### What if the postoperative range is not good?

If the range of motion is suboptimal after TKA, one can consider performing manipulation under anaesthesia. Knees that had less than  $90^\circ$  of flexion 2 weeks after surgery have been manipulated in a study conducted by Fox and Poss,<sup>54</sup> giving a mean gain of flexion of  $37^\circ$ . However, only  $13^\circ$  gain in flexion remained after one year. Better outcomes are shown in more recent studies. In one, 47 knees that had failed to achieve more than  $80^\circ$  of flexion after intensive physiotherapy from 2 to 41 weeks after surgery were manipulated.<sup>55</sup> The mean gain of flexion was  $34^\circ$  at the time of the manipulation, and the mean gain remained similar ( $33^\circ$ ) one year later. Sustained gain in flexion appears possible even if the manipulation is performed relatively late after the arthroplasty. Some other researchers have found, however, that the results of manipulation under anaesthesia performed 3 months after the TKA are inferior to that performed earlier.<sup>56</sup>

### FACTORS THAT HAVE NOT BEEN EVALUATED

The above sections cover some factors affecting knee flexion after TKA that have been studied and reported. Apart from these, other factors could be considered to be important and have been commonly recommended. However, it could be difficult, if not impossible, for them to be evaluated in a scientific manner.

One of these factors is the need to pay attention to the clearance of any posterior femoral condylar remnants (Fig. 1). The latter, if not cleared, may obstruct knee flexion by causing impingement against the tibial liner posteriorly. One must be able to feel the recesses over the back of the distal femur until absence of bone ledge or residual bone chips, which could jam and block knee flexion, are assured.

Some surgeons prefer leaving the flexion gap a little bit lax to gain better knee flexion. However, there has not been any study to scientifically prove that such approach is warranted. In contrast, some other surgeons emphasise the importance of a tight flexion



**Figure 1** The distal femur is usually lifted up by the intramedullary guide to improve the view, and an osteotome is used to remove the possible obstruction.



**Figure 2** With attention being paid to all details, it is possible to get very good flexion range in the early postoperative period. In this particular patient, flexion up to  $130^\circ$  was achieved at 10 days after TKA.

gap, especially when one is putting in a mobile bearing knee, to reduce the risk of 'spinning-out'.

Another example is related to patient motivation, and the ability to tolerate the pain and discomfort during the rehabilitation period. A preoperative

education class may be helpful. After TKA, consideration needs to be given to all the possible measures for alleviating the pain and discomfort. To have a high chance of achieving good knee flexion at the end of the day, it is important to aim at getting good knee flexion in the early postoperative stage (Fig. 2).

### HOW SHOULD KNEE FLEXION BE MEASURED?

Direct comparison of the range of motion achieved in one study with that achieved in another may not be fair. The means by which the range of motion is

measured can be important. It has been well documented that visual assessment by a surgeon is not accurate. The routine use of a goniometer improves the accuracy of flexion measurement. Most surgeons now consider radiographic measurements. Whether the range of motion is measured in a weightbearing mode or in a passive manner can be important as well. Dennis et al.<sup>22</sup> measured the maximum knee flexion using video-fluoroscopy in active weightbearing mode by asking the patient to make a deep knee bend. This is considered to be the best currently available method for studying the knee flexion after TKA, and is used in most recent studies.

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