

Geometric Total Knee Arthroplasty

A TWO-YEAR FOLLOW-UP STUDY

BY MATTHEW D. SKOLNICK, M.D.*, MARK B. COVENTRY, M.D.*, AND
DUANE M. ILSTRUP, M.S.*, ROCHESTER, MINNESOTA

From the Mayo Clinic and Mayo Foundation, Rochester

ABSTRACT: In a study of our experience with the first 119 geometric arthroplasties of the knee done at the Mayo Clinic, reported after a minimum follow-up period of two years, we noted that relief of pain was the primary goal in 84 per cent of the cases and this was achieved in the majority. The average total motion was relatively unchanged but it became more useful postoperatively.

From April 1971 through June 1972, 119 knees were operated on and the geometric total knee prosthesis was inserted. The results of these arthroplasties have been analyzed in the same way as the results of polycentric arthroplasties done during a similar period⁶. Follow-up visits were carried out eight weeks after the operation, when the patient was interviewed and examined and roentgenograms were made. One year after operation, a special postoperative data sheet was completed subsequent to interview, examination, and roentgenographic studies. At two years, when most patients returned for the interview, examination, and roentgenographic studies, the two-year follow-up form was completed. The one-year and two-year data sheets were then compared with the preoperative data sheet. A few patients did not return for the two-year follow-up; in several instances the patient as well as the home physician was contacted by telephone. One patient died and eight were lost to follow-up between the first and second years.

This study was undertaken to determine, in light of our continuing experience with geometric total knee arthroplasty: (1) whether selection of patients for operation was correct; (2) whether technical surgical aspects had changed and were influencing the results; and (3) whether any design problems in the prostheses were emerging. We evaluated all complications and attempted to find their cause. Furthermore, we attempted to determine whether the goals of the patient and orthopaedist were realized two years or more after geometric total knee arthroplasty.

Material

Of the 119 arthroplasties, 43 per cent were unilateral (Table I). Thirty-four (38 per cent) of the patients were men and fifty-five (62 per cent) were women, with an age range of from twenty-five to eighty-four years (mean, sixty-one years). Fifty-three per cent of the knees had rheumatoid involvement and 41 per cent were osteoarthritic. In 48 per

cent, the total knee arthroplasty followed previous surgery on the knee. A large majority had had one or more intra-articular injections of steroids. Relief of pain was the primary goal of surgery in 84 per cent of the cases. The goal was to increase the range of motion in 5 per cent and to correct deformity in 11 per cent.

TABLE I
DEMOGRAPHIC DATA ON ONE HUNDRED AND NINETEEN KNEES

		Knees	
		No.	Per cent
Side			
Right	25	51	43
Left	26		
Right of bilateral	32	68	57
Left of bilateral	36		
Diagnosis			
Rheumatoid arthritis	63	63	53
Osteoarthritis	49	49	41
Post-traumatic state	6	6	5
Other (psoriatic arthritis)	1	1	1
Primary goal of operation			
Relieve pain	100	100	84
Increase motion	6	6	5
Correct deformity	13	13	11

Technique

The surgical technique previously described¹⁻⁴ was followed with few alterations. Cheilectomy of the femur, tibia, and patella was done in all knees. Synovectomy was done on knees with severely hypertrophic synovium and more commonly on rheumatoid knees. Patellectomy and capsular reconstruction were done infrequently (Table II).

Preparation of Bone Bed

The surface of the proximal part of the tibia should be made as flat and congruous as possible to provide maximum contact between the tibial component and bone and to prevent bending of the component at the connecting bridge during seating of the prosthesis, which can produce a distraction force on at least a portion of the prosthesis-cement or cement-bone interface. In addition, the slots for receiving the flanges of the tibial component should be as small as is compatible with a snug fit and ease of insertion, in order to reduce the amount of cement used and to give maximum prosthesis-to-bone contact.

Axial Alignment

The most critical factor preventing loosening appears

S&N EXHIBIT 1029
S&N v. BSI
IPR2013-00629

* 200 First Street, S.W., Rochester, Minnesota 55901. Please address reprint requests to Dr. Skolnick, c/o Section of Publications.

to be axial alignment. A new guide which was developed¹ has made this aspect of the operation more precise. Generally, the optimum tibiofemoral-shaft angle is between zero and 7 degrees of valgus. Preoperative varus must be corrected to the valgus range of 5 to 7 degrees, and preoperative valgus should be corrected so that it is closer to zero degrees. This realignment results in a more symmetrical distribution of compressive weight-bearing stresses over a larger surface. Fatigue failure of the underlying bone and therefore disruption of the cement-bone interface are minimized. In addition, balancing the knee in zero to 7 degrees of valgus reduces the tendency toward lateral subluxation of the tibia, which is present in so many knees with degenerative disease and preoperative varus alignment. Thus, shear stresses at the cement-bone interface are reduced.

The entire problem of loosening is the subject of an ongoing investigational project in the biomechanical research laboratory of this clinic⁵.

In the presence of congenital or acquired malalignment of the femur or tibia (after osteotomy or fracture), roentgenograms should be made of the entire limb in the weight-bearing position and total axial alignment should be determined.

Positioning of Tibial Component

The tibial prosthesis should be seated perpendicular to the shaft of the tibia. Tilting of the prosthesis will result in transmission of shearing forces to the cement-bone interface. Most commonly the component is erroneously tilted anteriorly; if tilted medially, the tendency of the tibial component to subluxate laterally is increased. The anterior connecting bridge of the tibial component should be placed just anterior to the attachment of the anterior cruciate ligament. Placement farther anteriorly will limit flexion and increase stress on the posterior part of the prosthesis. Placement farther posteriorly will limit extension and increase stress on the anterior part of the prosthesis.

Testing Motion before Cementing

The full range of motion of the knee should be carefully observed before cementing the prosthesis. Any tendency to levering of the tibial component from its bed should be corrected by anteroposterior repositioning prior to fixation to bone. Extension should stop as a result of posterior constraint by normal soft tissue and not as a result of impingement of the tibial component against the femur. The height of the anterior aspect of the tibial prosthesis has been reduced in a new design (Mark III) in order to prevent this impingement and its potentiating effect on loosening.

Position for Cementing

Uneven pressures may be exerted on the tibial component during cementing if the knee is extended during the setting of the cement. The tibial component, therefore, should be cemented with the knee near 90 degrees of flex-

ion and with the surgeon holding it firmly in place with finger pressure.

Intraoperative Data

Of thirty-nine cultures of 119 knees made at operation (Table II), seven (18 per cent) were positive. *Staphylococcus epidermidis* and streptococci were the most common organisms. None of the patients with positive cultures became infected subsequently. Our program now calls for routine culture at operation for all patients undergoing knee surgery.

TABLE II
SURGICAL DATA ON ONE HUNDRED AND NINETEEN KNEES

	Knees	
	No.	Per cent
Cultures (39)		
Negative	32	82
Positive	7	18
<i>Staphylococcus epidermidis</i>	2	
Streptococcus	3	
Anaerobic	1	
Mixed	1	
Adjunctive procedures		
Synovectomy	4	3
Reefing medial capsule	2	2
Patellectomy	1	1
Posterior capsulotomy	1	1
Repair subluxating patella	1	1
Graft non-union of tibial plateau	1	1

There was one intraoperative fracture, the medial tibial plateau in a patient whose tibial prosthesis subsequently loosened.

Postoperative Management

The postoperative management is relatively simple. We no longer use a Thomas splint with a Pearson attachment to gain motion, as this was a factitious cause of occasional peroneal palsy (see Early Complications), but have the patient sit on the edge of the bed to exercise the knee. This begins about three days after operation, when the bulky cotton Robert Jones dressing with a posterior plaster slab is removed. A long elastic stocking is helpful at this stage if there is much swelling. Active exercise is encouraged both at the patient's bed and in the Department of Physical Medicine. No passive stress is applied unless 80 to 90 degrees of flexion has not been obtained within ten to fourteen days after operation. At that time, if there is continued improvement nothing is done, but if the improvement in flexion has reached a plateau then manipulation is carried out. Manipulation under anesthesia was performed³ to gain further motion seven to fourteen days after operation at least once in 30 per cent of the knees. It is now done less often, since experience showed that if improvement is steady it will normally continue.

Early Complications

Wound healing was considered abnormal when the entire incision failed to heal by primary intention by the

twelfth postoperative day. Some manifestation of abnormal healing was noted in 21.8 per cent of the knees. Of seven knees (5.9 per cent) with superficial infection, two required open drainage in addition to antibiotics. All infections, as well as four peroneal-nerve palsies (3.4 per cent), eventually resolved completely. One patient had a fatal cerebrovascular accident one week after operation.

Late Complications

Follow-up of 110 of the 119 knees was continued for at least two years. One patient died and eight were lost to follow-up; 102 were re-examined. In the remaining eight instances a telephone interview was conducted, all patients having been examined at one year, and the two-year roentgenograms were sent to us for review.

In contrast to polycentric arthroplasty, the components of the geometric prosthesis fit intimately, and imprecise apposition of the components is not possible.

Dislocation occurred in one case of advanced rheumatoid arthritis with absence of the cruciate ligaments. This patient is able to voluntarily displace the tibia posteriorly and medially by contracting the hamstring muscles with the knee partly flexed. He had no pain, walked, climbed stairs, and denied disability.

Two deep infections (1.8 per cent) developed. One patient with rheumatoid arthritis had not had previous surgery and had no history of oral or intra-articular steroid therapy. After operation, she had persistent sterile drainage (no positive cultures could be obtained) with delayed wound healing. Subsequently she underwent arthrodesis, at which time microscopic examination of synovial tissue revealed non-inflammatory fibrosis. Cultures of the tissue were negative. Suction-irrigation and systemic antibiotics were not employed. The second patient had rheumatoid arthritis and a history of three previous operations, the most recent having been insertion of a tibial-plateau prosthesis. She had received oral doses of steroids but these had been discontinued six months before arthroplasty. Surgical cultures were negative but drainage from the wound after operation grew *Staphylococcus epidermidis*. The wound responded to local care without systemic antibiotic treatment. One year later, because of persistent pain, arthrodesis was performed after cultures of aspirate revealed *Staphylococcus aureus*. The infection resolved with suction-irrigation and systemic antibiotic therapy, but consolidation of the arthrodesis was delayed.

In thirteen knees (11.8 per cent) the tibial component appeared loose on roentgenograms. In ten, loosening was confirmed by reoperation; in the other three, symptoms were mild and were not directly traceable to the apparent loosening. All ten cases of loosening were in osteoarthritic patients, which indicates more severe demands biomechanically in this group than in the rheumatoid patients. Uncorrected varus alignment of the knee was thought to be the primary cause of loosening in eight knees. One patient had had a previous osteotomy (open wedge upper tibial) and a thin, inadequate medial tibial buttress was the

result. In addition, the knee was left in mild varus after the arthroplasty and she subsequently injured the knee in a fall. This patient represents an error in selection, in that extreme loss of bone of the medial tibial condyle, coupled with severe instability, is an indication for a more constrained type of knee arthroplasty. Another patient had residual cement posteriorly which blocked flexion and caused loosening as a result of repeated impact on flexion. In the remaining three knees there was no readily apparent reason for loosening. Additional factors contributing to loosening were: (1) excessively large components leading to imperfect seating on bone in three knees, and (2) inadequate bone medially leading to overstress of the medial tibial plateau in two knees. For such knees smaller components are now available. Seven knees had the original (Mark I) tibial components and six had tibial components with an additional flange anteriorly (Mark II). It is not known whether the absence of this flange contributed significantly to loosening of the prostheses. No knee in this series had the Mark III tibial design with straight sidewalls and thus more prosthesis-to-tibia contact (Fig. 1).

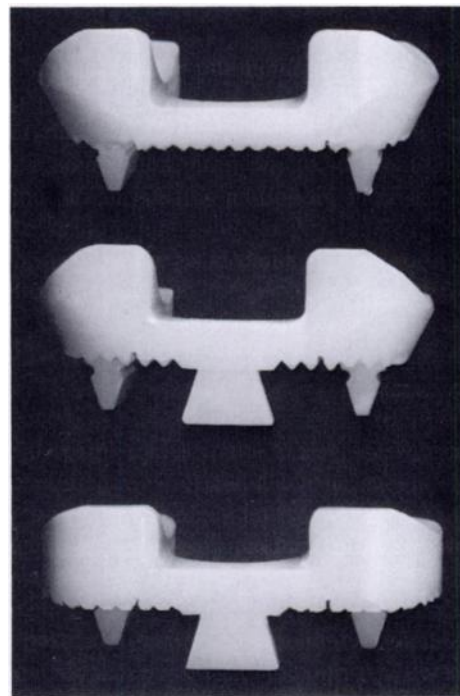


FIG. 1

Top — Mark I, middle — Mark II, and bottom — Mark III.

Lucent lines were noted at the tibial cement-bone interface in all cases of loosening and in about 80 per cent of the remaining knees with geometric arthroplasty. Some lucency could be seen between cement and bone or between prosthesis and cement in certain areas and on certain roentgenographic projections. The significance of the radiolucency in these latter cases is difficult to determine. In general, lucent lines are ominous when they appear generalized all around one component of the prosthesis two to three months after operation; when they pro-

gressively increase in width; when they are poorly marginated; and when they are more than one to two millimeters wide.

No fatigue fractures were encountered. Traction was used successfully for a traumatic supracondylar fracture in one knee.

Fragmentation of methacrylate with loosening of the tibial component and increasing medial laxity developed in one knee. Re-exploration was planned, probably with insertion of a constrained prosthesis.

One patient died after amputation above the knee for arteriosclerotic peripheral vascular disease with gangrene more than one year after arthroplasty. The knee itself was intact and otherwise functioning well.

Reoperation

The ten knees in which the prostheses loosened required a total of fifteen further operations. Six had one revision with replacement of the tibial components and realignment of the knee (one of these subsequently had a partial patellectomy and excision of a neuroma that caused persistent pain). One underwent re-exploration for persistent flexion contracture and residual varus and was found to have a loose tibial component. Both components were replaced, and the patient subsequently had a supracondylar osteotomy to correct the varus. One knee had a lax lateral ligament in addition to a loose tibial component and arthrodesis was necessary. In one knee a Herbert prosthesis was inserted, which subsequently fractured. Arthrodesis was attempted but had not consolidated to date.

Pain and decreased motion necessitated lysis of adhesions and patellectomy in one knee (with no relief) and arthrodesis in another.

A femoral component was replaced to correct a flexion contracture in one knee; in another, a loose marker wire was removed. At the time of writing the marker wires are embedded within the polyethylene tibial components and should no longer cause this complication. Increasing valgus instability in one knee did not respond to reefing of the medial capsule.

TABLE III

REOPERATION (ONE HUNDRED AND TEN KNEES)

Reason	No. of Knees	No. of Procedures
Loosening	10	15
Deep infection	2	2
Pain and decreased motion	2	2
Flexion contracture	1	1
Loose marker wire	1	1
Increasing valgus deformity	1	1
Total	17	22
(15.5 per cent of 110 knees)		

Thus, a total of twenty-two reoperations were performed on seventeen knees (Table III). Eleven knees still had geometric arthroplasties at the time of writing and the other six had undergone arthrodesis.

Results

Whereas pain was significant in 106 of 110 knees (96 per cent) before operation, little or no pain was present in eighty-two of eighty-nine (92 per cent) at two-year follow-up (Table IV). Twenty-one of the 110 knees were

TABLE IV
PAIN (ONE HUNDRED AND TEN KNEES)

	Knees			
	Before Operation		After Operation	
	No.	Per cent	No.	Per cent
None	2	4	51	92
Mild	2		31	
Moderate	42	96	7	8
Severe	64		0	
Total	110	100	89	100
Excluded			21	

excluded from tabulation for the following reasons: six knees were in four patients who had died; four had had an arthrodesis; four had undergone exploration recently; three were scheduled for reoperation; one had had a recent supracondylar fracture; and in three the amount of pain was not recorded. Relief of pain in rheumatoid and osteoarthritic knees was comparable. Rheumatoid knees more commonly were very painful before operation with mild pain afterward; osteoarthritic knees more commonly were moderately painful before operation with no pain subsequently.

TABLE V

WALKING WITH AIDS (ONE HUNDRED AND TEN KNEES)

Aid	Knees			
	Before Operation		After Operation	
	No.	Per cent	No.	Per cent
None	16	15	42	49
Cane or crutch	36	80	20	50
Two canes or crutches	40		13	
Walker	12		10	
Unable to walk	6	5	1	1
Total	110	100	86	100
Excluded			24*	

* Three additional unrecorded knees.

Significantly greater independence in this series of patients was reflected by the decrease in use of ambulatory aids (Table V) and the increase in distance walked (Table VI). In 15 per cent of the knees the patients required no walking aids preoperatively, whereas postoperatively 49 per cent needed no aids. In five per cent of the knees the patients had been unable to walk at all before operation, compared with 1 per cent postoperatively. Improvement in the use of aids was equally significant ($p < 0.001$) for patients with rheumatoid and osteoarthritic knees, although the former were consistently more disabled. Distance walked increased significantly ($p < 0.001$) for the entire group, although the increase in the patients with rheumatoid knees was not statistically significant.

The average postoperative range of motion in knees for which it was recorded was from 7 to 87 degrees of flexion, an arc of 80 degrees of total motion. Patients who had died or had undergone reoperation were not included. These figures represent an increase of 7 degrees of extension, a decrease of 9 degrees of flexion, and a decrease of 2 degrees of total motion. Of these changes in motion, only the increase in extension was statistically significant ($p < 0.001$). Both rheumatoid and osteoarthritic knees gained a significant amount of extension (8 and 10 degrees, respectively); in each of these groups, changes in flexion and total motion were not statistically significant. In general, knees with limited motion before operation gained motion, whereas the more mobile knees lost motion.

Satisfaction with the results was expressed by 93 per cent of the patients.

TABLE VI
WALKING — DISTANCE POSSIBLE (ONE HUNDRED AND TEN KNEES)

Distance	Knees			
	Before Operation		After Operation	
	No.	Per cent	No.	Per cent
Unlimited	7	6	32	39
4 to 6 blocks	12	83	11	58
2 to 3 blocks	33		17	
Indoors	46		20	
Bed to chair	10	11	2	3
Unable to bear weight	2		1	
Total	110	100	83	100
Excluded			27*	

* Six additional unrecorded knees.

Discussion

The major indication for geometric arthroplasty is disabling pain in the knee (84 per cent of our patients). Other goals are overcoming stiffness and deformity. Virtually any degree of flexion contracture can be corrected with arthroplasty. However, in knees with a contracture of more than 45 degrees of flexion before operation, persistent quadriceps lag may prevent full active extension. Severe varus and valgus deformity similarly can be corrected by operation, although medial instability associated with severe valgus may preclude an optimum result. Extreme osteoporosis, loss of bone, severe ligament laxity, and lack of a quadriceps mechanism are the only current contraindications to geometric arthroplasty. How-

ever, a history of recent infection or a neuropathic (Charcot) knee precludes any type of replacement arthroplasty.

Emerging from this study, as well as from continued experience, is the fact that the geometric units are versatile and probably adaptable to more patients with degenerative, rheumatoid, and traumatic arthritis than any current knee prosthesis with which we are familiar. A simple resurfacing of the joint, such as might be required for a rheumatoid arthritis patient with no bone loss and good ligaments but with pain due to rheumatoid disease that has destroyed hyaline cartilage, can be done with other types of prostheses. It can also be done with the geometric prosthesis which actually removes no more bone than any of the other models. And in the case of the knee that is somewhat unstable, the geometric prosthesis provides some built-in stability. When there is excessive bone loss (preventing anchoring of the tibial unit) or excessive instability and when a failed prosthesis of any type needs salvage, a constrained prosthesis of a joined or hinged type is indicated.

It is difficult to evaluate the effect of the inherent stability (constraint) of the geometric device on loosening of the tibial component. It seems logical that the greater the stability (constraint) of the prosthesis, the greater would be the transmission of forces to the cement-bone interface. Critical examination of the failures in this series, however, indicates that a significant technical error occurred in almost every case. As noted previously, loosening was found only in patients who had degenerative gonarthrosis — those who, as a group, have greater stress on their knees than do rheumatoid patients.

Instability of the knee and dislocation of the prosthesis were not significant problems. Laxity of capsular and ligamentous structures is taken up by the so-called spacer effect of the components (thicker tibial components are available when necessary to ensure adequate postoperative stability).

Similarly, fatigue or traumatic fracture of supporting bone was uncommon. The medullary cavities of the femur and tibia are violated to only a small degree and in such a way as to minimize stress concentration, particularly at the medial tibial plateau.

A number of advantages accrued relative to geometric total knee arthroplasty in this series of cases: there was significant relief of pain; many patients were suitable for this procedure when unconstrained arthroplasty, such as polycentric arthroplasty, was contraindicated⁶; and the procedure provided a high degree of stability in knees that were relatively lax before operation.

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