Supracondylar Osteotomy of the Femur with Use of Compression

Osteosynthesis with a Malleable Implant*

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Abstract

Background: **The goal of treatment of a valgus deformity of the knee that is secondary to osteoarthritis of the lateral compartment is to obtain axial correction of the malalignment of the extremity. Osteosynthesis of the osteotomized femur with use of internal fixation and a stiff implant has not been as successful as expected. We evaluated the accuracy and maintenance of correction and the stability of fixation with a malleable plate after a supracondylar osteotomy of the distal aspect of the femur that was performed to correct a valgus deformity of the knee.**

Methods: **We performed an incomplete oblique osteotomy of the distal aspect of the femur in nineteen patients (twenty-one knees) and stabilized the osteotomy site with a malleable semitubular plate, which was bent to form an angled plate, and lag-screws. Postoperatively, the patients were immediately encouraged to walk, with partial weight-bearing on the affected extremity. The mean age of the patients was fifty-seven years (range, thirty-nine to seventy-one years), and the mean duration of follow-up was five years (range, two to twelve years).**

Results: **In seventeen knees, the osteosynthesis withstood the mechanical loading that occurred during the postoperative functional rehabilitation program. Prolonged use of crutches or immobilization, or both, was necessary after the operation in three knees. The osteosynthesis failed in one knee. The loss of correction in eighteen knees, after bone-healing, averaged 1.7 degrees (range, 0 to 4 degrees).**

Conclusions: **Our method of achieving osteosynthesis is based on the concept that inherent endogenous stability mechanisms can be mobilized by circumferentially compressing the two cortical tubes with the cut ends congruently apposed to each other. We believe that our technique provides an alternative to osteosynthesis with use of a stiff implant such as a fixed-angle blade-plate device.**

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A supracondylar varus osteotomy of the femur can be performed to correct a valgus deformity that is secondary to osteoarthritis of the lateral compartment of the knee. The goal of treatment is to obtain axial correction without extensive dissection. The postoperative regimen should impose the least possible restriction on the lifestyle and daily activities of the patient.

Osteosynthesis provides a means for obtaining maximum stability of the osteotomized femur and achieving the goals of the osteotomy. Müller et al.[12], in 1970, introduced the revolutionary concept of obtaining stability at the osteotomy site with use of 90-degree double-angle and 95-degree condylar plates. This method was widely adopted on the basis of the concept that, with use of these stiff implants, early postoperative walking with partial weight-bearing could be instituted. However, despite rigid fixation of the osteotomy site, the cortical bone of the proximal segment often subsided into the cancellous bone of the distal segment when the patient was bearing weight, resulting in unwanted axial deviation[16]. This occurred frequently in osteoporotic bone or after repeated intraoperative impaction of the seating chisel, to obtain the desired correction, resulting in loose seating of the blade.

These concerns led some authors to avoid vigorous postoperative rehabilitation. Finkelstein et al.[4] immobilized the extremity in a cylinder cast for two weeks and prohibited weight-bearing for six weeks. McDermott et al.[9] permitted walking with graduated weight-bearing only when radiographs showed signs of consolidation. Healy et al.[5] stabilized the leg with a hinged fracture-brace and allowed only touch-down weight-bearing for six weeks.

Since 1984, an incomplete oblique supracondylar osteotomy with use of a malleable semitubular plate, bent to form an angled plate, has been performed at our hospital to achieve stabilization. Postoperatively, the patient is immediately allowed to walk with crutches while bearing partial weight on the affected extremity. We reviewed the results of this treatment to determine whether the osteosynthesis could withstand the forces generated during functional postoperative rehabilitation and whether the planned angle of correction could be achieved and maintained until there was bone-healing.

Materials and Methods

Between 1984 and 1996, we performed an oblique supracondylar osteotomy of the distal part of the femur

in twenty-one knees in nineteen patients (nine women and ten men). There were ten right knees and eleven left knees; two patients had bilateral involvement, and the second operation was performed more than six months after the first procedure. At the time of the index operation, the mean age was fifty-seven years (range, thirty-nine to seventy-one years). None of the patients were lost to follow-up.

Preoperatively, all patients complained of pain that was predominantly localized to the lateral side of the knee and was typically present when climbing stairs or walking on uneven ground. Two patients had to change their occupation, because of moderate or severe pain, from a physically demanding job involving manual labor to a sedentary job. All patients had to reduce their physical activity, and most patients used nonsteroidal anti-inflammatory medications to reduce the pain. Radiographs showed mild or moderate osteoarthritis of the lateral compartment of the knee, with narrowing of the lateral joint space, subchondral sclerosis, and few if any osteophytes. The mean tibiofemoral angle was 12 degrees (range, 10 to 16 degrees). The mean knee flexion was 148 degrees (range, 130 to 160 degrees); four patients had a slight extension deficit, and one patient had a 15-degree extension deficit (Table I).

The indications for the procedure included pain secondary to mild or moderate osteoarthritis and a valgus deformity with a tibiofemoral angle of up to 20 degrees. Patients also had to be able to comply with a program of partial weight-bearing with use of crutches. The degree of pain was determined by questioning the patients rather than by using a visual analog scale. Contraindications to the procedure included narrowing of the medial compartment of the knee, tibiofemoral subluxation, patellofemoral arthritis, valgus deformity due to obliquity of the tibial plateau, an extension deficit of more than 15 degrees, instability due to laxity of the medial collateral ligament, and severe osteoporosis.

Postoperatively, the functional outcome was evaluated with use of The Hospital for Special Surgery knee-rating scale[6]; this was the scale that was commonly used at the time that the senior author (F. H.) first performed the index procedure. The scale has a maximum of 100 points, with 30 points assigned to pain; 22 points, to function; 18 points, to range of motion; and 10 points each, to muscle strength, an extension deficit, and instability. Points are deducted for use of walking aids, an extension lag, and varus deformity. The overall score is categorized as a failure (less than 60 points), fair (60 to 69 points), good (70 to 84 points), or excellent (85 points or more). Subjective satisfaction with the outcome of the procedure was determined by asking the patients whether, given the same preoperative conditions, they would have the same operation again.

The effects of mechanical loading of the osteosynthesis were evaluated in relation to compliance with the postoperative regimen (the time at which the patient stopped using crutches and use of external immobilization). Compliance with the postoperative regimen was confirmed by the senior author, who observed all of the patients during physiotherapy, which was provided at the hospital. Observation of the patient's ability to bear partial weight, and the patient's description of his or her activities, were useful for estimating the effects of mechanical loading and also for monitoring and guiding the patient's progress. Patients were questioned about pain during weight-bearing, since pain can be considered a sign of instability.

The radiographs made immediately after the operation were compared with those made at eight weeks and one year postoperatively, in order to determine whether subsidence of the proximal cortex into the distal cancellous bone or signs of implant loosening were present. We evaluated whether there was any difference between the planned tibiofemoral angle of correction to 1 to 3 degrees of varus (depending on the height of the patient) and the final angle of correction after bone-healing. The planned correction was predetermined on a tracing of the preoperative radiograph. The final correction that was achieved after bone-healing was determined from the radiograph used for preoperative planning and the radiograph made one year after the operation, when the patients could walk without crutches or pain while bearing full weight on the affected leg. Use of these criteria ensured that the femur had healed and was stable at the time that the one-year follow-up radiograph was made. The anteroposterior radiograph that was used to determine the angle of correction was made with an eighteen-by-forty-three-centimeter x-ray cassette with the patient standing. The patella was carefully centered on the distal aspect of the femur between the two epicondyles, especially in patients who had an extension deficit. All of the preoperative and postoperative radiographic measurements were made by one individual who was unaware of the initial planned angle of correction. All of these measurements were estimated independently by another orthopaedic surgeon who did not participate in the study.

Operative Technique

The operation was performed without use of a tourniquet, through a medial skin incision that extended ten centimeters proximal to the medial epicondyle of the femur. The vastus medialis muscle was freed from the intermuscular septum, and periosteal branches from the superior medial genicular artery were ligated. The periosteum was incised longitudinally and retracted with Hohmann retractors to expose the cortex at the planned level of the osteotomy.

The level and direction of the osteotomy were determined with use of a small radiopaque triangular template that was available in several different angles. Image intensification was used to confirm the placement of the template, with care being taken to obtain a

TABLE
PREOPERATIVE

Case	Gender, Age at Op. *(yrs.)*	Occupation	Comorbid Conditions (Time Before Index Op.)	Pain	Nonop. Treatment of Pain*
1	F, 43	Nun	—	Mod.	—
	44		—	Mod.	—
2	M, 68	Forklift operator	Open reduct. and internal fixat. after fract. of tib. plateau (1 yr.)	Mod.	NSAIDs
3	F, 54	Farmer	Adipositas	Mod.	—
4	F, 58	Tailor	—	Mod.	NSAIDs
5	F, 68	Farmer	—	Mod.	NSAIDs
6	M, 50	Cook	Osteochon. dissecans; lat. meniscect. (20 yrs.)	Mod.	NSAIDs
7	M, 46	Office worker	Rupture of post. and med. cruciate ligs. (6 yrs.)	Mod.	—
8	M, 57	Park ranger, farmer	Removal of meniscal ganglion (35 yrs.)	Severe	—
9	F, 56	Farmer	—	Mod.	NSAIDs
	57		—	Mod.	NSAIDs
10	F, 59	Homemaker	Partial lat. meniscect. (1 yr.)	Severe	NSAIDs
11	M, 63	Bricklayer	Mild osteoporosis; partial lat. meniscect. (1 yr.)	Mod.	—
12	M, 51	Construction worker	Open reduct. and internal fixat. after fract. of lat. tib. plateau (1 yr.)	Mod.	NSAIDs
13	M, 59	Office worker	—	Mod.	NSAIDs
14	F, 71	Homemaker	Mild osteoporosis	Mod.	Intra-artic. cortisone
15	M, 51	Director	Fract. of dist. part of femur (41 yrs.)	Mod.	—
16	M, 65	Construction worker	Mild osteoporosis	Mild	NSAIDs
17	M, 64	Construction worker	Lat. meniscect. (23 yrs.); partial patellect. (15 yrs.)	Mod.	—
18	F, 51	Farmer	Mild osteoporosis; lat. meniscect. (23 yrs.)	Mod.	NSAIDs
19	F, 39	Farmer	Mild osteoporosis; osteot. after fract. (15 yrs.)	Mod.	NSAIDs

*NSAIDs = nonsteroidal anti-inflammatory drugs.

true anteroposterior image by centering the patella between the two epicondyles. The template corresponding to the size of the bone wedge to be removed was placed frontally over the femur with its tip pointing toward the lateral epicondyle, with care taken to ensure that the tip remained proximal to the joint surface. The template was rotated around its tip until the sides crossed the medial cortex at a point equidistant from the tip (Fig. 1-A). The point of entry for the plate was marked on the medial epicondyle with a Kirschner wire. The flexible target triangle was held against the curvature of the bone while the lines of the osteotomy were marked along the sides. The template was removed, and the osteotomy of the femur was performed along the markings, with care taken to leave the lateral cortex intact. After the bone wedge had been removed, a slight varus force was applied across the defect for a few minutes in order to slowly bend the lateral cortex without breaking it. On completion of the osteotomy, the medial cortices of the two segments of bone should be exactly apposed to each other.

Osteosynthesis was achieved with use of a six-hole semitubular steel AO plate (Stratec Medical, Oberdorf, Switzerland). One-half of the plate was beaten flat with a hammer; the implant then was bent through the third screw-hole to form an angled plate, with the flat portion forming the blade. The newly fashioned blade was driven into the condyle two centimeters distal and approximately parallel to the osteotomy line (Fig. 1-B). A cortical lag-screw was placed through the hole at the bend and was angled in an ascending and slightly posterior direction. The screw could pass through the plate into the thick lateral cortex in an oblique direction and obtained excellent purchase in the bone, thereby permit-

I
DATA

Activities Limited by Knee Deformity	Range of Motion *(degrees)*	Extension Deficit *(degrees)*	Radiographic Tibiofemoral Angle *(degrees)*	Knee-Rating Scale[6] *(points)*	
				Functional Score	Overall Score
Stair-climbing	150	0	10	16	67
Walking on uneven ground in fields	150	4	10	20	64
Mushroom-gathering in woods	150	0	11	20	68
Walking on uneven ground in fields, working on slope	120	15	10	14	63
Stair-climbing, skiing	150	0	—	16	66
Walking on uneven ground in fields	150	4	16	20	69
Stair-climbing, hill-climbing, skiing	145	5	12	18	61
Stair-climbing, skiing	145	0	11	18	68
Stair-climbing, milking cow, working on slope	140	0	16	15	60
Walking on uneven ground	140	0	12	16	65
Stair-climbing	145	0	13	16	66
Stair-climbing, standing in kitchen, swimming (breaststroke)	150	0	—	16	61
Walking downhill, hunting, skiing	145	0	11	14	65
Stair-climbing, kneeling, lifting heavy objects at work	130	0	12	16	64
Skiing, stair-climbing	145	5	13	15	56
Stair-climbing	150	0	13	10	57
Performing gymnastics, playing tennis	160	0	11	20	70
Stair-climbing, skiing, hiking	150	0	12	17	70
Stair-climbing, kneeling, hill-climbing	145	0	12	14	65
Stair-climbing, playing golf	150	0	12	14	65
Stair-climbing, working on slope	155	0	13	18	69

ting compression of the osteotomy site (Fig. 1-C). The plate was secured proximally with three cortical screws, which were inserted eccentrically; this placed the plate under tension and allowed it to conform to the shape of the bone, thereby further compressing the osteotomy site (Fig. 1-D). In five patients, the bone appeared less dense than expected and a second lag-screw with a washer was placed anterior to the plate to obtain more compression laterally and to prevent rotation of the device (Figs. 1-E, 2-A, and 2-B). We found use of the second screw to be advantageous in patients who had osteopenic bone.

Postoperative Regimen

Active range-of-motion exercises were started on the first postoperative day. The patients were allowed to get out of bed and were instructed to use crutches while bearing about twenty kilograms of weight on the involved extremity during walking. This degree of weight-bearing was maintained for eight weeks, during which time swimming or early return to a standing occupation were not permitted. Subsequently, if there was no evidence of subsidence at the site of the osteotomy or of loosening of the implant and there was no pain, full weight-bearing was permitted, even if there was little evidence of callus formation on the radiographs. There was usually no evidence of callus formation at eight weeks postoperatively.

Results

Function

The mean overall preoperative knee score, according to the scale of The Hospital for Special Surgery[6], was 65 points (range, 56 to 70 points) for the twenty-one knees. This score increased to a mean of 84 points (range, 61 to 100 points) at a mean of five years

(range, two to twelve years) postoperatively (Table II). Most of the increases were due to a reduction in pain compared with the preoperative status. Eleven knees were rated as having an excellent result; eight, a good result; and two, a fair result. One patient who had a fair rating had more pain during walking nine years after the operation (and after a long symptom-free period) than she had had preoperatively. The other patient who had a fair rating had a rapid decrease in function secondary to dementia six years after the operation. The osteosynthesized femur healed in twenty knees. One patient had failure of healing. His score was 80 points three years after a second osteosynthesis procedure.

One of the two patients who had had to change from a job involving manual labor to a sedentary occupation preoperatively returned to heavy farm labor thirteen months after the operation. The other patient was free of symptoms after the operation but preferred to continue driving a bus, for personal reasons.

Twelve patients had a high level of subjective satisfaction with the outcome. One additional patient was very satisfied with the result in one knee at twelve years postoperatively but was only moderately satisfied with the result in the other knee at eleven years. Four patients were moderately satisfied. One patient was dissatisfied eleven years after the procedure because of increasing pain during the two years prior to the latest evaluation. The remaining patient could not describe her degree of satisfaction because of dementia; however, her daughter stated that her mother had performed household tasks for many years after the operation and had never mentioned any problems related to the involved extremity. Eighteen patients stated that they would have the operation again given the same set of circumstances. No patient required conversion to a total knee replacement at the time of the latest follow-up evaluation.

Compliance with Postoperative Regimen

Fourteen patients stopped using crutches ten weeks or less after the procedure, after having been fully weight-bearing for a short period. An additional patient, who had been managed with a bilateral operation, stopped using crutches ten weeks after one operation and 1.5 years after the other. Two patients used crutches for twelve weeks, and the duration of use was not known for two patients.

Seventeen patients were treated without any form of external immobilization. The two remaining patients were managed with immobilization of the extremity in a cylinder cast for four and eight weeks as a precaution;

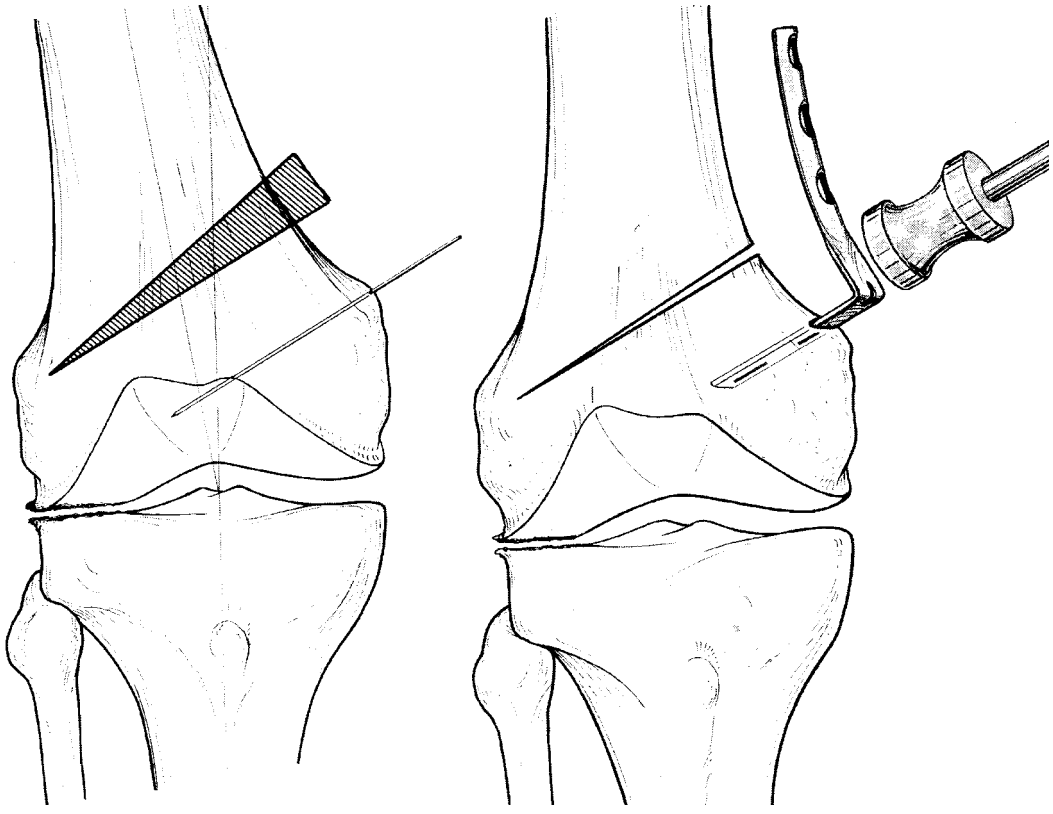

FIG. 1-A FIG. 1-B

Figs. 1-A through 1-E: Diagrams illustrating the operative technique.

Fig. 1-A: The sides of the template cross the medial cortex equidistant from the tip of the triangle.

Fig. 1-B: The semitubular plate is bent to form an angled plate and is driven into the medial condyle two centimeters distal and approximately parallel to the osteotomy line. Its tip lies anterosuperior to the intercondylar notch.

one of these patients had pain when bearing weight on the affected extremity, and the other patient was unable to comply with partial weight-bearing. A cast was preferred to a more functional brace because the cost of the latter would have been borne by the patient, whereas that of the former would not.

Pain As a Measure of Healing

Fifteen of the knees were not painful during weight-bearing. However, most patients reported a feeling of weakness in the involved extremity that lasted for about six months. Three knees were painful during weight-bearing, and one was immobilized for this reason. It was not clear whether the three remaining knees were painful during weight-bearing.

Radiographic Findings

Postoperatively, there was no subsidence in eighteen knees. One knee had slight subsidence on the medial side, with a negligible change in the angle between the tangent to the condyles and the longitudinal axis of the femur. One knee with a failed osteosynthesis had subsidence on the lateral side. In another knee, it was not possible to assess subsidence because the first postoperative radiograph could not be retrieved.

Nineteen knees had no signs of implant loosening, and two had loosening. In one of the latter two knees, the lag-screw crossing the osteotomy site broke without resulting in any loss of correction.

For eighteen knees, the mean difference between the planned correction of the longitudinal axis of the extremity and the final correction achieved after bone-healing was 1.7 degrees (range, 0 to 4 degrees). The interobserver difference was 0.04 degree for the mean difference and 0 degrees for the maximum difference. For two knees, the preoperative radiographs could not be retrieved; however, the follow-up radiographs showed no subsidence or loosening. The follow-up radiograph was not available for the remaining knee (Table II).

Complications

The patient in whom the osteosynthesis failed was a healthy fifty-seven-year-old farmer. She complained of increasing postoperative pain during weight-bearing, mainly on the lateral side of the knee. The pain was initially attributed to an excessively long screw, which was removed eight weeks after the operation. At that time, there were no radiographic signs of instability; however, the blade of the plate was less than two centimeters distal to the osteotomy site. The leg had not been immobilized, as the patient refused to wear a cast. Removal of the screw did not reduce pain during weight-bearing as much as had been expected. Four months after the operation, a progressive valgus deformity developed,

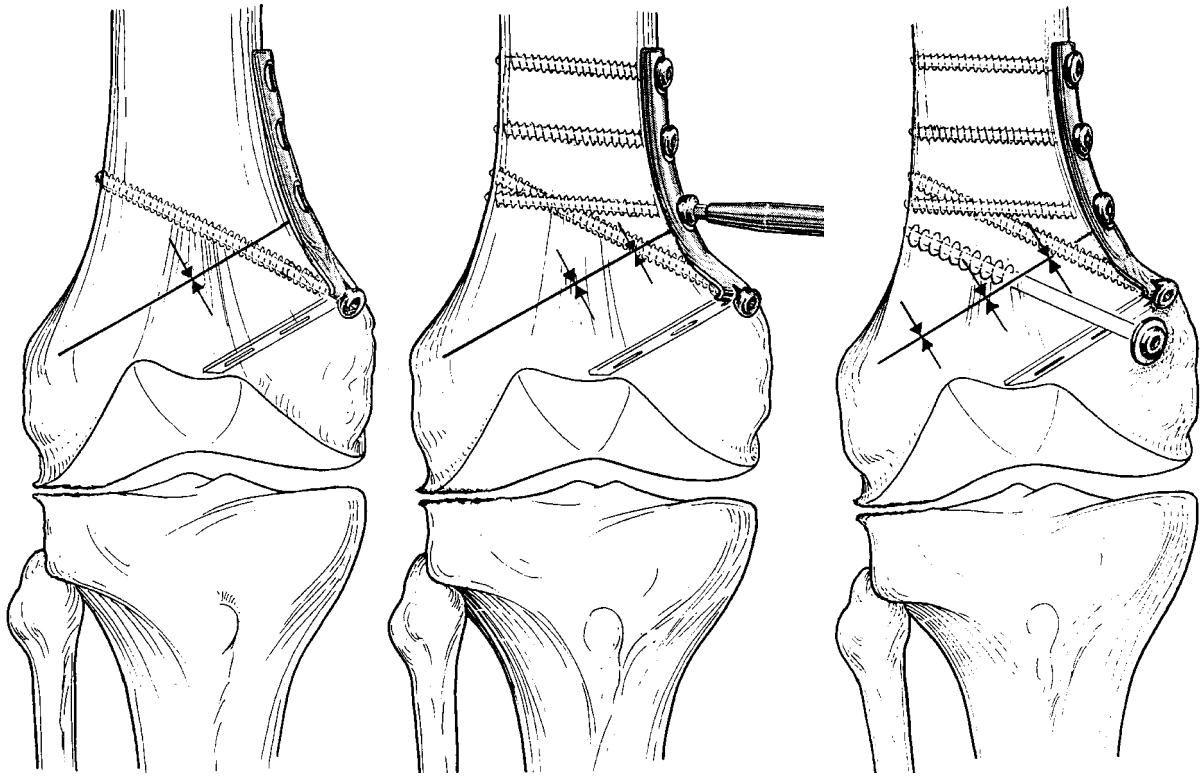

FIG. 1-C FIG. 1-D FIG. 1-E

Fig. 1-C: A cortical lag-screw through the hole at the bend tightly compresses the osteotomy site.
Fig. 1-D: The plate is secured proximally with three cortical screws inserted eccentrically. The screws place the plate under tension and model it exactly to the shape of the bone.
Fig. 1-E: A second lag-screw affords more compression laterally and secures against rotation.

TABLE
POSTOPERATIVE

Case	Early Data					
	Use of Crutches for >10 Wks.	Ext. Immobil.	Pain During Weight-Bearing	Subsidence	Implant Loosening	Planned/Final Angle of Correct. (Difference) *(degrees)*
1	No	No	No	No	No	8/11 (3)
	No	No	No	No	No	8/10 (2)
2	No	No	No	No	No	10/10 (0)
3	No	No	No	No	No	9/10 (1)
4	No	No	No	No	No	—
5	No	Yes, for 4 wks.	—	Yes	No	14/14 (0)
6	No	No	No	No	No	10/12 (2)
7	No	No	No	No	No	10/11 (1)
8	No	No	No	No	No	14/12 (2)
9	No	No	No	No	No	10/8 (2)
	Yes, for 1.5 yrs.	No	Yes	Yes	Yes	12/—
10	—	No	—	No	No	—
11	No	No	No	No	No	10/9 (1)
12	—	No	—	No	No	10/11 (1)
13	No	No	No	No	No	10/7 (3)
14	No	No	No	No	No	10/12 (2)
15	No	No	No	No	No	10/6 (4)
16	No	No	No	No	No	10/12 (2)
17	Yes, for 12 wks.	Yes, for 8 wks.	Yes	—	Yes	10/10 (0)
18	No	No	No	No	No	10/8 (2)
19	Yes, for 12 wks.	No	Yes	No	No	10/13 (3)

with subsidence of the proximal cortex into the distal cancellous bone on the lateral side and loosening of the screws. A second procedure was performed with use of a double-angled plate, without any intraoperative problems. The osteotomy site healed uneventfully, and the patient did well postoperatively.

Minor complications included two subcutaneous hematomas, noted on the second and third postoperative days, which resolved without treatment; one popliteal vein thrombosis, noted on the fourth postoperative day, which responded to a ten-week course of Coumadin (warfarin); and one superficial wound infection, noted on the fourth postoperative day, which resolved after use of antibiotics. None of these complications led to a longer period of rehabilitation.

Discussion

It is believed that the exogenous stability achieved with stiff implants can be enhanced by use of inherent endogenous stabilizing mechanisms of the body. Wagner[16] and, later, Miniaci et al.[11] tried to improve the congruence of the superimposed cortices by making the bone cut in a descending direction toward the condyle. Others attempted to keep the opposite cortex and the periosteum intact, by only bending it, so that it would act as a stabilizing hinge[1,3,7,15,16]. However, oblique and incomplete osteotomies have been used mainly for correction of varus deformity of the proximal aspect of the tibia[13,17]. The use of implants that are shorter and have a lower profile than the double-angle and condylar plates made it possible to plan a less extensive operation. Furthermore, smaller implants may not require removal. Weber and Wörsdörfer[18] and Wagner[16] used a malleable semitubular plate, which can easily be contoured to the bone, with one end trimmed to form a serrated edge that can be driven into the femoral condyle. However, low-profile implants have never been widely used because of concern that they would provide decreased stability compared with that afforded by stiff implants.

In seventeen of the twenty-one knees, the osteosynthesis accomplished with our method withstood the mechanical loads generated during functional postoperative rehabilitation. In three knees, the osteosynthesis was stable but required a prolonged period of partial weight-bearing or immobilization, or both. Osteosynthesis failed only in one knee (5 percent). In comparable

II
DATA

Latest Follow-up Data					
				Knee-Rating Scale[6] *(points)*	
Durat. of Follow-up *(yrs.)*	Level of Patient Satisfact.	Activities	Range of Motion *(degrees)*	Functional Score	Overall Score
12	High	Household chores and, rarely, stair-climbing	140	20	77
11	Med.		130	22	82
11	High	Gathering mushrooms in woods	150	22	85
11	Low	Walking inside of house only; avoided stair-climbing for prior 2 yrs.	120	15	62
11	High	Stair-climbing; stopped skiing 3 yrs. ago	150	22	100
8	—	Sitting in wheelchair only, probably due to rapid progression of dementia over last 2 yrs.	140	11	61
6	Med.	Skiing and bicycle-riding	145	22	85
5	High	Skiing	145	21	84
5	High	Farming, but milking cows avoided	145	19	82
4	High	Walking on uneven ground and stair-climbing	140	18	80
3	High	Walking for unlimited distance after 2nd osteosynthesis	135	18	80
3	High	Stair-climbing, but not able to perform breaststroke while swimming	145	20	85
3	Med.	Hunting and skiing	145	22	85
3	Med.	Stair-climbing, but kneeling and lifting heavy objects avoided	140	22	85
3	High	Skiing	135	20	82
2	High	Stair-climbing	145	22	85
2	High	Walking for unlimited distance, but not able to perform gymnastics	160	22	100
3	High	Skiing	145	22	85
2	High	Hill-climbing	150	22	100
2	Med.	Playing golf	150	21	81
2	High	Working on slope	155	22	100

studies in which stiff, angled implants were used, mechanical complications related to failure of fixation were reported in 4 to 16 percent of patients[1,2,4,5,9-11,14].

We believe that the advantage of our technique lies in the stability offered by the fixation, which is based on two factors. First, the descending direction of the osteotomy leads to complete circumferential abutment of the superimposed cortical segments because both surfaces have almost the same diameter. This degree of circumferential congruence cannot be achieved with a horizontal osteotomy (Fig. 3). In contrast to contact between the proximal cortex and the distal cancellous bone, circumferential contact between the two cortical surfaces at the osteotomy site renders subsidence with subsequent deviation of the axis much less likely. Second, the stability of an interrupted tubular structure can be reinstated by frictional forces when the two parts of the tube are sufficiently compressed onto each other. The entire contact area of the superimposed cortices is compressed by the lag-screws crossing the osteotomy site as well as by the screws placed eccentrically in the plate.

Another advantage of our technique is its potential to achieve the desired correction of the longitudinal axis of the extremity. The average deviation of 1.7 degrees between the planned and final angles of correction after bone-healing suggests that this technique allows the desired degree of correction to be achieved. Our available radiograph size (eighteen by forty-three centimeters) renders measurement of the longitudinal axis of the extremity more difficult than it is on a radiograph made with a thirty-six-inch (ninety-one-centimeter) cassette. However, by paying meticulous attention to details and ensuring that all radiographs and measurements were made with use of a standardized method, we were able to avoid errors due to the closely placed reference points.

There are two reasons why such accurate correction can be achieved with our technique. First, the intraoperative correction of the axis of the extremity is determined according to the size of the wedge of bone that is removed. With a malleable implant, the direction of the plate in the condyle has no impact on the extent of the correction because tightening of the screws will contour the plate to the bone rather than pulling the bone to the plate. Only a few approximated

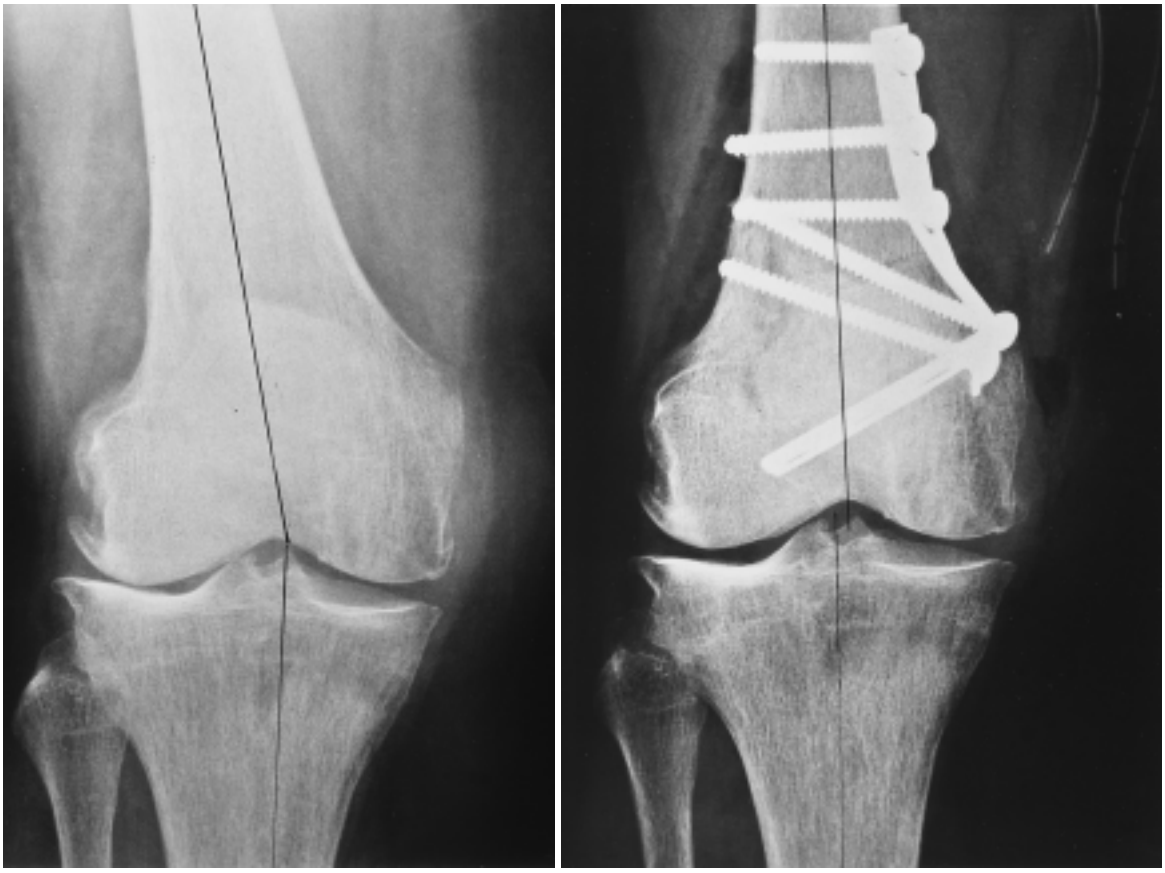

FIG. 2-A FIG. 2-B

Figs. 2-A and 2-B. Case 14. Radiographs of a patient who had a supracondylar varus osteotomy.
Fig. 2-A: Preoperative radiograph showing narrowing of the lateral compartment of the knee, osteophytes, and a valgus deformity.
Fig. 2-B: Postoperative radiograph showing the internal fixation and correction of the tibiofemoral angle.

reference points are required to achieve accurate correction. The degree of correction is not affected by the slope of the wedge of bone. In contrast, with a fixed-angle device, correction of the axis of the extremity is determined mainly by the direction in which the seating chisel is driven; the size of the wedge of bone that is removed plays a secondary role. With a fixed-angle device, subsidence of the cortices into one another is even exploited to make adjustments of the correction intraoperatively[9]. The use of stiff implants makes it necessary to determine several reference points, each introducing a potential source of error. It seems far simpler to accurately remove the planned wedge of bone than to maintain correct angulation in three planes while driving a seating chisel into the condyle of the femur. The second reason for the accuracy of the correction is that cortical tubes that abut each other in a congruent manner are less likely to subside into one another than are less precisely superimposed cortices. Therefore, deviation of the axis under load is less likely after an oblique osteotomy than it is after a horizontal osteotomy.

A difference of less than 2 degrees between the planned and final angles of correction of the axis of the extremity has been reported with use of stiff implants[8,9]. However, the maximum difference between the planned correction and the final result in comparable studies in which fixed-angle devices were used was more than the 4 degrees observed in our patients. McDermott et al.[9] performed a corrective osteotomy in twenty-three patients with use of guide-wires to seat the chisel parallel to the joint space for correct orientation of the 90-degree double-angle plate. Those authors reported 80 percent concordance between the planned and final angles of correction. However, the maximum difference between the planned and the final correction was twice the difference seen in our patients. Learmonth[8] used a special jig applied to the lower extremity to identify the longitudinal axis of the knee and reported a mean and maximum difference, between the planned correction and the final result, of 0.3 and 2 degrees, respectively, in twelve patients.

Maintenance of an intact lateral hinge is crucial for the success of our technique. It is therefore important to close the bone wedge slowly to allow the lateral cortex to bend. Although it was not always possible to avoid a fracture of the lateral cortex, the experience of the senior author has shown that the intact periosteum and joint ligaments are sufficient to maintain stability

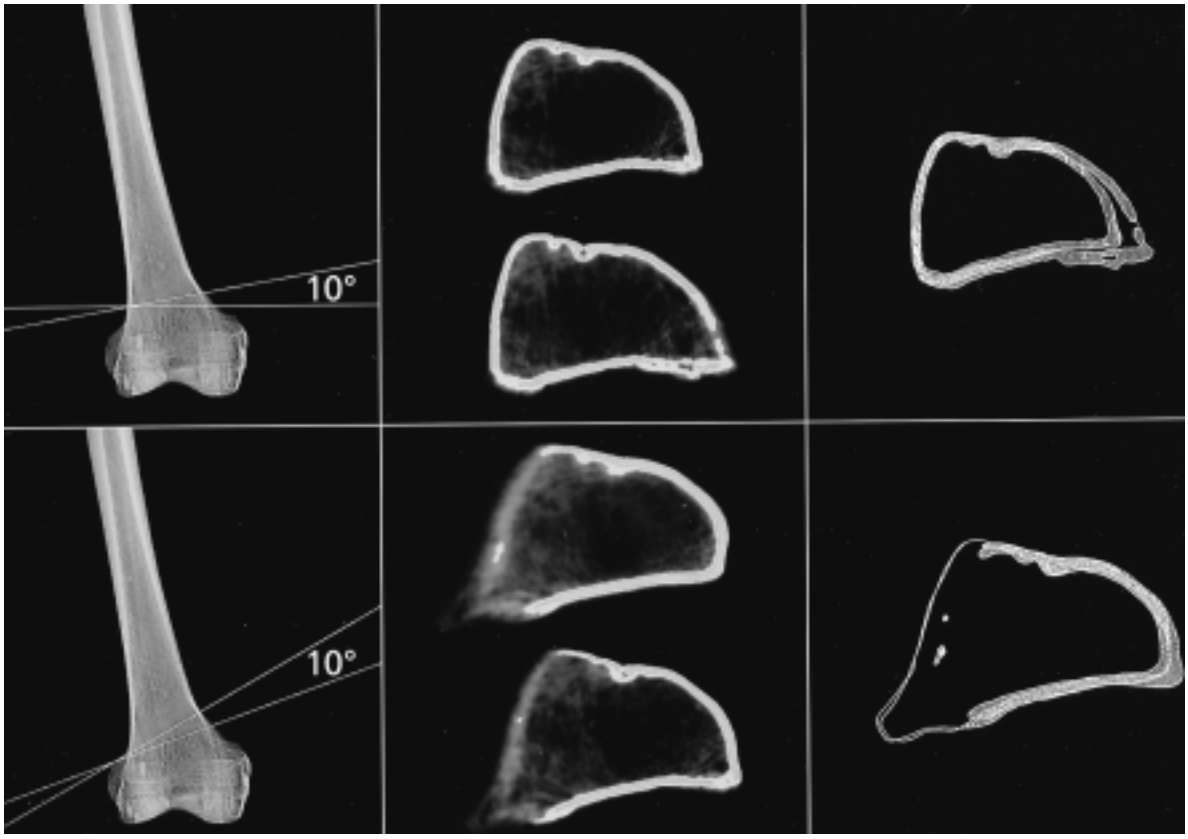

FIG. 3

From left to right: computerized tomographic scout view, computerized tomographic images (with emphasis of cortical bone) made at the level and in the direction of the straight lines, and superimposed images showing congruence of the cortices after a horizontal osteotomy (top set of images) and a descending osteotomy (bottom set of images). The top-right image shows that, after removal of a bone wedge of only 10 degrees, the cortical tubes are no longer superimposed medially. The weight-bearing function of the medial support must be taken over by the stiff implant, to avoid subsidence of the cortex into the soft cancellous bone during weight-bearing. In the bottom-right image, the cortices are seen to be still superimposed medially after removal of a wedge of 10 degrees.

in conjunction with the osteosynthesis. Furthermore, the intact lateral structures prevent rotational and translational malalignment until full stability has been restored by the osteosynthesis.

We believe that the operative technique that we have described provides an alternative to the conventional method of using a stiff implant for the correction of mild-to-moderate valgus deformity of the knee.

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