

Dome Osteotomy of the Proximal Tibia for Genu Varum Treated With a New Fixation Device

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ABSTRACT: An innovative uniplanar–bilateral external fixator was designed, developed, and implemented for barrel-vault osteotomy of the proximal tibia. Eighteen cases of medial compartmental osteoarthritis of the knee with genu varum and one case of tibia vara were treated with dome osteotomy fixed with this new fixator to meet patient expectations regarding pain relief, early recovery with ability to squat, dependency periods, avoiding serious complications, convenience, and economic conditions. All cases achieved the desired degree of bony correction except for one case with 5° undercorrection due to preoperative posterolateral corner laxity. Plaster immobilization was not required during the treatment period, and all osteotomies united within 6-10 weeks with no major complications. Superficial pin tract infection occurred in

three cases. All patients returned to their activities of daily living by postoperative week 2. The Knee Society Score was 75-100 with average function/knee scores of 88.89/96.32 by the end of 2 months. Patients maintained these scores up to 2-year follow-up. This new fixator is compact and economical, with excellent patient compliance. It provides a stable fixation for the osteotomy and permits early joint mobilization, full weight bearing, and early return to activities of daily living. The fixator has the ability to alter correction in the early postoperative period to achieve a precise correction of the deformity. It qualifies as a safe device for this procedure, produces reliable and reproducible results, as well as satisfies patient expectations.

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INTRODUCTION

In a developing country with a majority of the population from the middle and lower socioeconomic strata, providing treatment options comparable to those available in developed countries (ie, joint replacement) is difficult. In patients with arthritis, expectations from treatment for painful arthritic knee are pain relief, rapid functional recovery for return to an independent lifestyle and activities of daily living, prevention of serious complications and permanent damage to the knee, convenience, and reasonable economic costs. Keeping these expectations in mind, medial compartmental osteoarthritis with genu varum is best treated with dome osteotomy for realignment of the tibia.

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Dome osteotomy offers several advantages. The osteotomy is performed in the broad cancellous metaphyseal region of the tibia. Its large surface area decreases the probability of nonunion. A small midline incision is made (minimally invasive to not pose problems for future surgeries) to permit a higher degree of correction. The incision involves no metaphyseal bone removal and causes no truncation, restoring the normal structure of the upper end tibia with no alteration of tibial slope and lesser incidence of patella infera. These qualities pose fewer problems for a future total knee replacement. Because the osteotomy is superior to the tuberosity, the tibial tuberosity can be anteriorized, resulting in a Maquet effect to decompress the patellofemoral joint.

Internal fixation of the osteotomy prevents the surgeon's ability to make postoperative alterations in correction if necessary. It also requires plaster immobilization in the early postoperative period and delays full weight bearing on the operated side. The residual implants could pose

difficulties in potential future joint replacement. These disadvantages are averted by the use of external fixation for the osteotomy.

Various fixators have been used for fixation of dome osteotomy⁶ of the upper end of the tibia. Unilateral fixators provide limited stability with challenges in maintaining the precise correction and do not permit early full weight bearing for the patient.^{4,13}

The Charnley fixator^{1,5} provides good stability, but results in either under- or overcorrection of deformity due to the mandatory parallel placement of the pins. (The proximal and distal pin may not be passed precisely at the angle of correction required, thus resulting in an under/overcorrection with a Charnley clamp.) Additionally, altering the correction in the postoperative period is not possible with the Charnley fixator, which may adversely affect the postoperative results.

The Ilizarov fixator is widely used due to its advantages of multiplanar stability and versatility to correct deformities in any plane.^{3,7} However, the device is bulky, not patient-friendly, and social acceptance of the device can be an issue.^{2,12} Many complications have been reported with the Ilizarov fixator, therefore the surgeon must be experienced with its use.^{2,12} Patients cannot wear their routine attire and social adjustments are necessary.

To overcome these problems as posed by the previously mentioned fixators and to meet the expectations of patients undergoing this procedure, a fixator known as Kodkani's Dome Stabilizer (presently manufactured personally by the author, Pranjali S. Kodkani), was created. It has a uniplanar-bilateral frame and provides a stable fixation for the dome osteotomy. The stabilizer is compact and has good patient compliance. It also gives the surgeon liberty to alter correction postoperatively if required. The application, functioning mechanism, and maintenance of the fixator are convenient for both surgeon and patient. The device produced reliable and reproducible results in the study conducted. The fixator achieved and maintained the desired degree of correction postoperatively with a good rate of union stresses. The fixator qualifies as a safe device, as its use for the dome osteotomy resulted in no major complications. It allowed early mobilization, early full weight bearing, and early return to activities of daily living as expected by the patients. The fixator used for this procedure caused no hindrance in the patients' daily activities and required no additional modifications in lifestyle. Patients experienced comfortable recoveries without complaints. The fixator's simple structure, along with the minimal inventory required for its application, makes it an economical device. Patients' early functional recovery and independence also contribute to the fixator's economic viability.

MATERIALS AND METHODS

A total of 19 patients (3 men and 16 women) were included in this study. Eighteen patients with medial compartmental osteoarthritis with genu varum and 1 patient with adolescent tibia vara were treated with dome osteotomy fixed with Kodkani's Dome Stabilizer. Patient age ranged from 16-68 years (mean: 54.5 years) and weight ranged from 36-76 kg (mean: 57.4 kg). Written informed consent was obtained from all patients opting for this treatment modality. Preoperative assessment of all patients included a detailed history, Knee Society Score, and a thorough examination including gait analysis. Following plain weight-bearing radiographs of both knees (anteroposterior and lateral views), a standing alignment view of both limbs was taken. Varus, valgus stress views, and Merchant views were also obtained. All required angles (lateral distal femoral, medial proximal tibial, joint line congruence, and hip-knee-ankle [HKA])⁹ with reference to the mechanical axis were calculated. The angle of correction required was calculated on the bipedal weight-bearing alignment view. The required angle was such that, postoperatively, the mechanical axis would pass just lateral to the lateral tibial eminence.

The author performed all surgeries. Patients were carefully observed from the day of surgery—daily for the first week and then weekly, with radiographs of the knee taken every 3 weeks until the fixator was removed. Patients continued follow-up every month for the next 6 months, and then 6-month to annual follow-up was maintained. Mean follow-up was 2 years (range: 1.6-2.7 years).

Specifications and Application

Kodkani's Dome Stabilizer is made of steel, with each fixator clamp having two blocks: sliding block and swivel block (Figure 1). The sliding block slides over the threaded rod and has two locking bolts on either side, which help lock the swivel block. The swivel block swivels over the sliding block and is held in place by a rivet. The swivel block's tunnels accommodate different sizes of Denham pins. The Denham pin is fixed with the bolt on the top and does not impair the swiveling of the clamp. Only the locking bolts on either side of the sliding block can lock the swiveling. When tightened, the locking bolts hold onto the rivet of the swivel block, thus preventing it from swiveling. This does not interfere with the sliding mechanism. The assembly of the Kodkani Dome Stabilizer consists of four clamps, two threaded rods with nuts, and two Denham pins.

Unlike the Charnley clamps, the Kodkani Dome Stabilizer accommodates both Denham pins, even if they are angulated to each other. This is important to achieve and maintain the precise degree of correction required. The ability of sliding these swivel clamps over the threaded rods with the

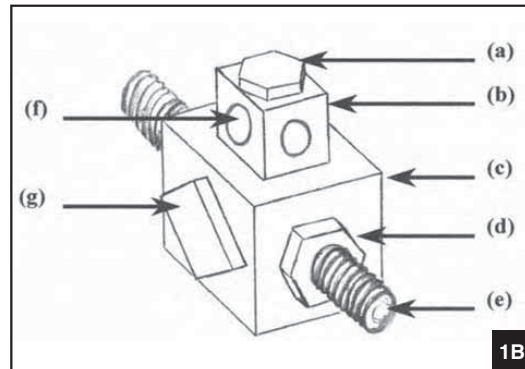
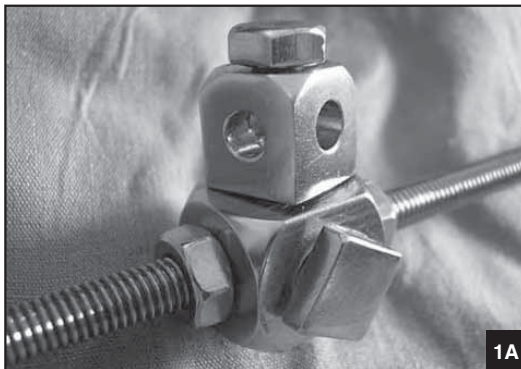


Figure 1. Photograph of the fixator clamp (A). Diagram of the fixator clamp and its parts (B): a) bolt for holding Steinmann/Denham pin; b) swivel block; c) sliding block; d) nut on threaded rod; e) threaded rod; f) tunnel for Denham/Steinmann pin; and g) locking bolt.

help of nuts permits postoperative alteration of correction if required.

Surgical Procedure

All patients were operated under spinal anesthesia with adequate sterile precautions. A tourniquet was applied to the thigh during surgery.

Fibular osteotomy with 1-cm excision of fibula was performed at the junction of the upper-middle third or middle-lower third of the fibula, depending on the degree of deformity. For deformity corrections $>10^\circ$, the fibula was excised at the junction of the upper-middle third to prevent resistance in alteration of correction by the interosseous membrane and overlapping of the fibula. In the remaining cases, excision was performed at the lower-middle third junction.

The proximal Denham pin was passed parallel to the tibial plateau 5 mm below the subchondral bone. It was passed percutaneously from lateral to medial in the middle thirds of the plateau under fluoroscopic guidance (Figure 2).

The distal pin was passed 1 inch below the tibial tuberosity at the calculated degree of correction required for each individual patient. The dome osteotomy was performed just above the tibial tuberosity through a 1- to 1.5-inch midline incision centering over the tuberosity. The proximal tibia was exposed in the parapatellar region in a subperiosteal manner through this mini, midline incision and adequate exposure was provided for the osteotomy. The osteotomy was performed by making multiple drill holes in the shape of a dome above the tuberosity using a curved guide placed in the retropatellar region. The osteotomy was completed using a narrow 5-mm osteotome to join the drill holes. The distal fragment was then rotated under the proximal fragment with a valgus force until both pins were parallel to each other, producing the desired degree of correction.

The fixator was applied on both sides and fixed to the

pins with the bolt over the swivel block. Nuts over the threaded rods were tightened to keep the two pins compressed against each other with lateral compression more than medial compression. The correction achieved was confirmed with a bovie cord from the center of the hip to the center of the talus, after which the fixator was fixed to a static position by additionally tightening the locking bolts on the sliding block.

The excised fibula was cut vertically into two to three parts to form 1-cm slivers that were then grafted from the posterior to anterior border of truncation (Figure 3). This graft consolidated and remodeled in the postoperative period. Following remodeling of the graft, the truncation, which is inevitably created laterally by sliding of the osteotomy, gets obliterated. This results in the upper end of the tibia achieving a near normal shape once again. Thus, it avoids the difficulties otherwise caused by a truncation during joint replacement surgery.

The distal pin was passed posterior to the proximal pin in the coronal plane and translated anteriorly by 0.50-1 cm during fixation to produce the Maquet effect. Rotational correction was achieved by passing the distal pin at an angle to the proximal pin in the horizontal plane and fixing them parallel to each other. The Maquet effect was obtained and internal rotation of the distal fragment was performed in cases with complaints of patellofemoral pain and lateral compression syndrome to decompress the patellofemoral joint. The time required for surgery was 45-90 minutes (mean: 60 minutes) with minimal postoperative blood loss.

Immediately postoperative, the limb was kept elevated and rest with ankle pumps and toe movements was encouraged. Exercises, including range of movement of the knee, static quadriceps, straight leg raising, and hip abductors, were encouraged to begin the day after surgery. By postoperative day 3, weight-bearing alignment views of the limb were taken and the degree of correction was

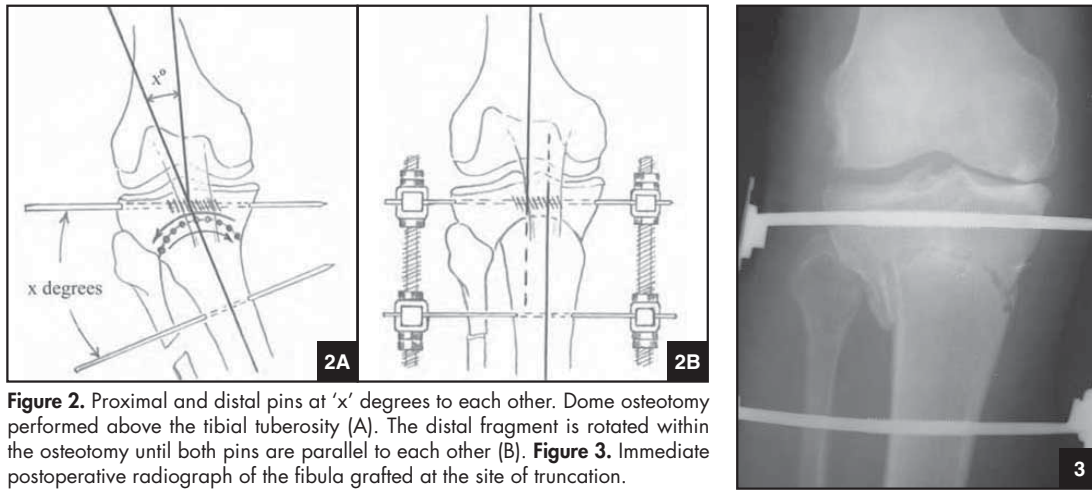


Figure 2. Proximal and distal pins at 'x' degrees to each other. Dome osteotomy performed above the tibial tuberosity (A). The distal fragment is rotated within the osteotomy until both pins are parallel to each other (B). **Figure 3.** Immediate postoperative radiograph of the fibula grafted at the site of truncation.

assessed. In cases showing opening of the medial joint line in the preoperative valgus stress view, medial joint line opening was sought on the postoperative alignment view. In cases without medial joint line opening, the mechanical axis passing lateral to the lateral tibial eminence was aimed for. Five patients required alteration in correction in the immediate postoperative stage. If adequate correction had not been achieved, an injectable analgesic was given and alteration in correction was performed.

Alteration in Correction

All swivel blocks were unlocked, with locking bolts kept loose. Distraction was performed on the appropriate side to disimpact at the osteotomy site and simultaneously alter the angulation to achieve the required degree of correction. The alteration of angular correction was assessed by measuring the intermalleolar distance and by placing a goniometer over the knee. Once the calculated intermalleolar distance/HKA angle was achieved, each side was simultaneously compressed to reimpact at the osteotomy site. The frame was then made static by locking the clamps with the locking bolts (Figure 4).

By postoperative day 7, all patients could walk while partially bearing weight and gradually increased to full weight bearing, depending on patient comfort level. Patients were encouraged to return to their activities of daily living by postoperative week 2, by which time the sutures had been removed.

Weight-bearing radiographs were taken every 3 weeks to confirm position of the osteotomy with regards to correction and union. Union was assessed by continuity of trabeculae across the osteotomy, absence of radiolucent zones, and sclerosis at the osteotomy and consolidating bone graft. The position of the pins was also assessed for migration. Once union of the osteotomy was confirmed (postoperative

week 6-8), the locking bolts were loosened and the compression of the clamps was released to determine whether any mobility remained at the osteotomy site. The fixator was kept dynamized for 3-6 days, after which it was removed if the patient had reported no new complications and radiographs revealed a good union of the osteotomy with no alteration in previous correction achieved (Figure 5). Throughout this period, the patient was kept under oral antibiotic cover (broad spectrum antibiotic, ie, cephalosporin) with lactobacillus supplement and pin tract dressings with Feracrilum gel (Seggard gel) applied at least three times daily.

RESULTS

The results were assessed with regards to the mechanical axis alignment and Knee Society Score confirming the reliability, reproducibility, and safety of the procedure. A series of questions was used to assess patient compliance with the fixator: 1) Do you have any problems in your day-to-day activities due to the procedure? 2) Do you face any problems due to the fixator on the knee? 3) Do you mind if the fixator is kept for longer (ie, if time worn exceeds planned length of time)?

Mechanical axis alignment results are shown in Table 1. The average preoperative varus was 191.1° HKA, with a maximum HKA angle of 204° . The desired degree of correction was achieved within 3° in all cases (Figure 6). An accurate correction was determined to be 2° - 3° of variation from the desired degree of correction, considering the possibility of a radiographic technical error.⁸ One patient had a residual 5° undercorrection due to preoperative posterolateral capsular complex laxity. An average of 173.1° HKA valgus was achieved, with valgus alignment achieved in all knees. All osteotomies united within 6-10 weeks.

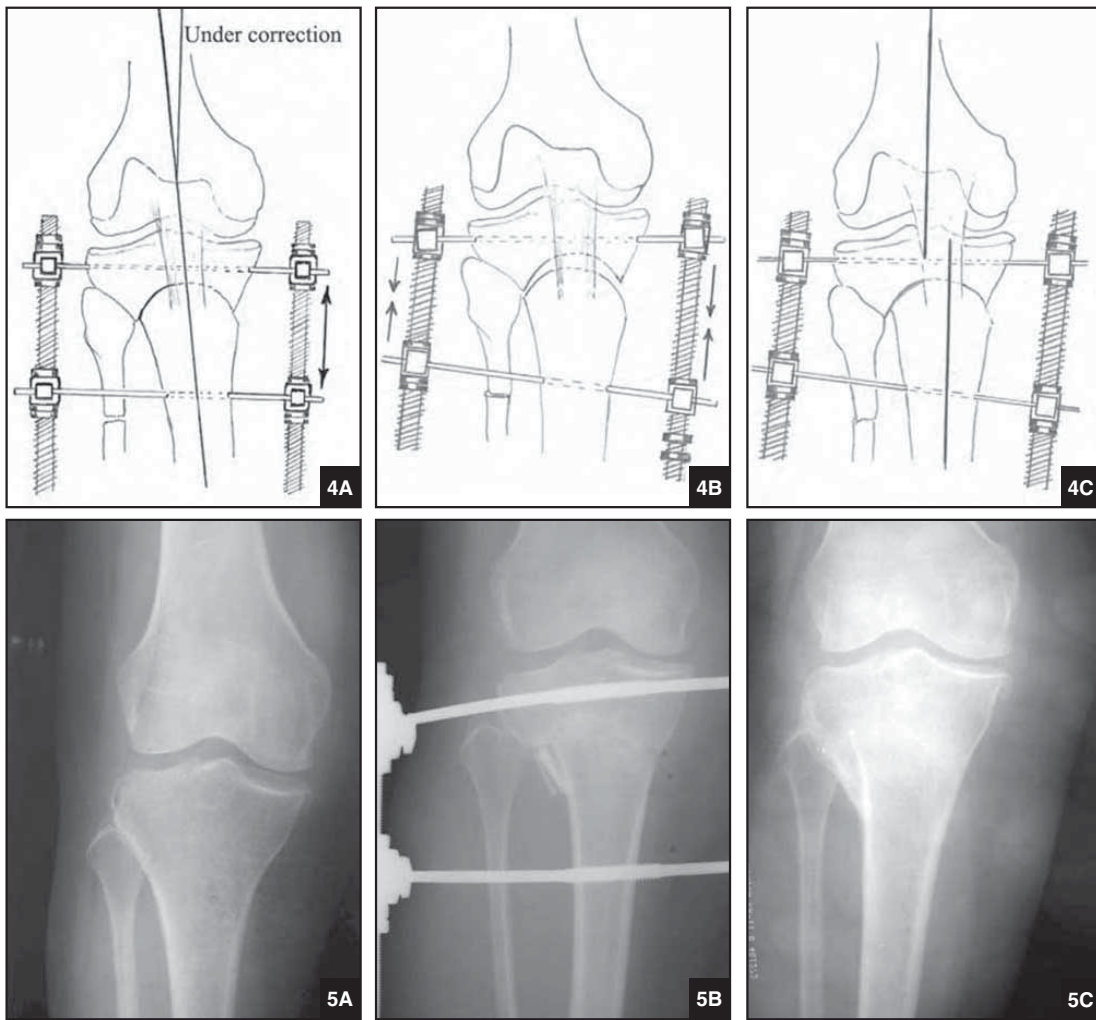


Figure 4. Undercorrection (assessed postoperatively) is corrected by first distracting the appropriate side until the desired degree of correction/HKA angle is achieved (A). Compression is performed on either side simultaneously to reimpact the osteotomy (B). Final alignment achieved (C). **Figure 5.** Radiographs taken preoperatively (A), immediately following the operation (B), and at final follow-up (C).

Knee Society Scores are shown in Table 2. All patients had a full active range of movement at the knee by postoperative day 2, and were full weight bearing by postoperative day 10 with a decrease in joint pain. Two weeks after surgery, patients were able to climb stairs without support, sit cross-legged, return to activities of daily living, and wear routine attire (Figure 7). All patients with medial compartmental osteoarthritis experienced pain relief while walking as well as climbing stairs. This was evident by their increased walking distance. No quadriceps wasting occurred in any patient. The Knee Society

Scores thus improved due to improvement in alignment, increased walking distance and stair climbing ability, and reduced level of pain. Due to the overcorrection, lower knee scores were achieved in some patients, producing “good” (75-85) results in four patients, and “excellent” (85-100) results in the remaining patients. Knee function score, however, was “excellent” in all patients except for one. Knee Society Score of all patients reached an average of 88.89 knee score and 96.32 function score by the end of 2 months and was maintained throughout follow-up.

The piece of fibula grafted at the truncation site at the

TABLE 1

PATIENT CHARACTERISTICS

Case No./Sex/Age (y)	Weight (kg)	Hip-Knee-Ankle Angle (°)			
		Preoperative	Immediate Postoperative	After Postoperative Readjustment	Last Follow-Up
1/F/60	59	188	168	172	174
2/F/50	55	184	178	175	176
3/F/56	60	194	175	175	177
4/F/50	52	190	175	175	177
5/F/62	50	204	175	175	180
6/F/65	62	186	170	174	174
7/M/58	74	189	170	175	175
8/F/57	63	198	175	175	175
9/M/45	76	190	174	174	174
10/F/59	58	187	170	170	171
11/F/54	56	188	171	171	172
12/F/52	52	195	174	174	176
13/F/56	62	192	173	173	175
14/F/57	54	187	172	172	174
15/F/55	56	184	172	172	173
16/F/55	56	189	171	171	173
17/M/60	54	192	176	171	172
18/F/68	57	200	170	170	172
19/F/17	36	194	175	175	178

upper end of the tibia consolidated with the osteotomy site by 6 months and remodeled to give the upper end of the tibia its near normal shape by 1 year.

The consistency in results obtained with regards to alignment and Knee Society Scores confirms the reliability and reproducibility of this procedure. Questions posed to the patients to assess their compliance revealed that the fixator did not create any problems in their daily living. They were comfortable and could wear their routine attire with the fixator. All patients were questioned regarding the level of inconvenience they experienced due to the fixator and their overall satisfaction with the results. Patient satisfaction was assessed based on the extent of subjective pain relief, reflected by their improvement in walking distance, ability to climb and descend stairs, and ability to carry out activities of daily living painlessly without any hindrance caused by the fixator or the procedure. The only minor problem encountered in some patients was that the medial ends of the pins sometimes touched the opposite knee. Also, the required regular pin tract dressings were cumbersome for some patients. Otherwise, patient compliance was good.

Regarding complications, superficial pin tract infection was noted around the upper pin tract in three cases with broadening of the upper lateral skin tract. This was secondary to increased mobility of the skin at this site due to its proximity to the joint. Migration of the proximal pin towards the osteotomy site was observed in one case due to the pin's close placement to the osteotomy. Five patients reported pain over the shin and ankle while walking during the first 3 weeks after surgery, after which the pain subsided. No patient experienced postoperative neurological deficit. The fixator used for this procedure was found to be a safe device, as no major intra- or postoperative complications occurred. All fixators were removed at the end of 8 weeks except for two cases in which it was removed 10 weeks postoperatively because radiographic union had not been confirmed. No patient required plaster immobilization. No mechanical problems were encountered due to the fixator.

DISCUSSION

Dome osteotomy of the proximal end tibia was the

preferred osteotomy at this site due to its distinct advantages. It permits the correction of severe deformities with the flexibility of choosing postoperative alteration in correction if necessary. The patellofemoral joint can be decompressed simultaneously. It does not require resection of the tibia and does not result in shortening of the limb. A small midline incision also proves to be advantageous. External fixation of the osteotomy allows early mobilization of the knee and avoids complications of plaster immobilization.^{10,11}

Previously reported series of high tibial osteotomy fixed with uniplanar fixators or Ilizarov's model experienced high rates of complications. Minor complications included pin tract infections and knee stiffness. Major complications were chronic osteomyelitis of the tibia, cellulitis, and reflex sympathetic dystrophy. Problems with union, such as delayed union and non-union,^{12,13} also occurred. Although the Ilizarov fixator has shown excellent results with regards to accuracy in achieving and maintaining the correction, the uniplanar fixators have resulted in a large percentage of over- or undercorrection and relatively low "excellent" outcomes.

The use of the Charnley fixator for dome osteotomy has also had its share of complications including major pin tract infections, requiring removal of the fixator and casting, nonunion, delayed union, peroneal nerve palsy, and thrombophlebitis. Maintenance of overcorrection is necessary for a successful outcome of the osteotomy, and an undercorrection will decrease functional outcome of the knee. Nineteen percent of cases failed to achieve a valgus correction with use of the Charnley fixator.⁵

A new fixator has been developed, which is economical, safe, patient compliant, and provides reproducible and reliable results. This new fixator gives the advantages of an external fixator in providing a stable fixation for the osteotomy and thus allowing early joint mobilization, early full

TABLE 2

COMPARATIVE KNEE SOCIETY SCORES OF ALL PATIENTS

Case No.	Knee Score/Function Score	
	Preoperative	Postoperative
1	50/50	92/100
2	51/50	85/90
3	40/40	95/100
4	40/50	85/100
5	20/50	75/80
6	40/40	94/100
7	60/60	92/90
8	50/90	97/100
9	50/90	94/100
10	50/50	85/100
11	50/50	83/100
12	40/50	95/100
13	40/40	87/100
14	60/60	89/90
15	71/80	91/100
16	60/80	91/100
17	60/70	83/90
18	30/50	76/90
19	80/100	100/100

weight bearing, and early return to activities of daily living (Table 3). No quantitative comparisons were made with the use of other fixators in this study. The dome osteotomy has good inherent stability in the anteroposterior plane owing

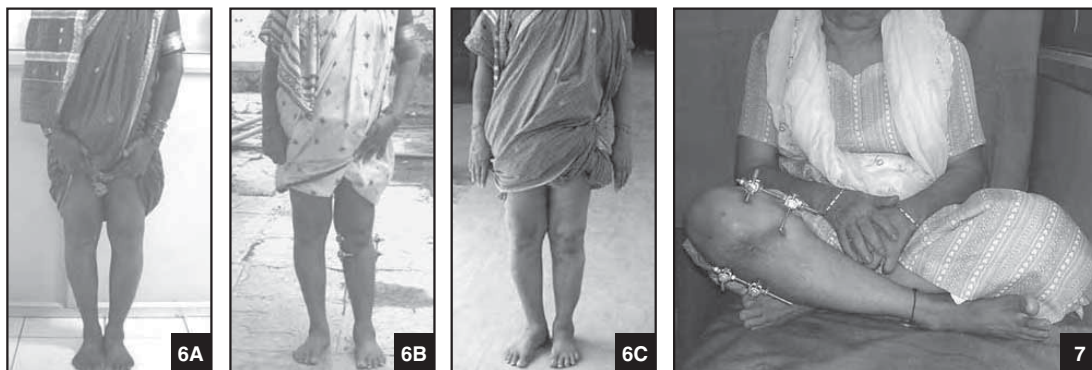


Figure 6. Preoperative alignment (A), early postoperative alignment (B), and alignment at final follow-up (C). **Figure 7.** Sitting cross-legged in the early postoperative period.

TABLE 3

COMPARISON OF FIXATORS USED FOR DOME OSTEOTOMY

Fixator	Stability	Ability to Alter Correction Postoperatively	Precision in Correction	Postoperative Excellent/Good Results (KSS) (%)	Major Complications	Immediate Range of Knee Movement	Full Weight Bearing	Size	Ability to Wear Routine Aftire	Cost
Ilizarov	Multiplanar	Possible	Excellent	≤90	+	Restricted	Early	Large and bulky	Not possible	Expensive
Orthofix	Unilateral	Possible	Good–excellent	61	+	Full	Delayed	Large	Not possible	Expensive
Charnley	Uniplanar–bilateral	Not possible	Fair	89	+	Full	Early	Small	Possible	Economical
Kodkani's Dome Stabilizer	Uniplanar–bilateral	Possible	Excellent	100	–	Full	Early	Small	Possible	Economical

Abbreviation: KSS = Knee Society Score

to the broad metaphyseal region and the confining nature of the osteotomy. The fixator's bilateral frame provides mediolateral stability, with additional stability provided by compression at the osteotomy. Aside from the fixator and the structure of the osteotomy, which provide the majority of stability, the soft tissues around the osteotomy add to its stability, similar to the stabilization of the knee by its surrounding soft tissues. The soft tissues that contribute to stability are the patellar tendon anteriorly, the medial collateral ligament medially, and the popliteus and gastrocnemius posteriorly. The fixator's small size enhances social acceptability, patient compliance, and patient convenience. It allows immediate postoperative correction alteration in the mediolateral plane without anesthesia or surgery. The fixator used for this procedure provides consistent reproducible results with reliability, safety, and efficacy. The total surgical time required is well within the permitted single tourniquet time. Its economic viability also adds to its significance.

The problems encountered with the fixator used for this osteotomy are minor and can be overcome with adequate precautions. The advantages offered by the device outweigh any problems it presents, and it therefore serves as an excellent modality of fixation for dome osteotomy of the proximal end of the tibia.

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