ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

An innovative Biological Lock Step Plate for Medial Open Wedge High Tibial Osteotomy.

Prof. Dr.Jagdish J Patwa, Dr. Malkesh D Shah, Dr.Keyur B Patel, Dr.Neel H Patel, Dr.Maulik R Jhaveri, Dr.Parth B Patel

- Department of Orthopaedics, Dhiraj Hospital, S.B.K.S.M.I.R.C., Sumandeep Vidyapeeth deemed University, Vadodara, Gujarat, India

Manuscript Info

Manuscript History:

Received: 18 August 2015
Final Accepted: 22 September 2015
Published Online: October 2015

Key words:

Medial compartment arthrosis, medial open wedge high tibial osteotomy, Biological lock step plate, Osteoarthritis knee.

Corresponding Author

Prof. Dr.Jagdish J Patwa
Professor & Unit Head
Department of Orthopaedics,
Dhiraj Hospital,
S.B.K.S.M.I.R.C.,
Sumandeep Vidyapeeth deemed University,
Vadodara, Gujarat,
India

Abstract

Background: In medial compartment osteoarthritis of knee, changing the axis of weight bearing by doing medial open wedge osteotomy such that, the mechanical axis passes through the Fujisawa point after surgery giving long term result that articular surface on medial side regenerates $1^1/_2$ times within 1-2 years, which may delay or obviate total knee replacement. After observing all complications of various implants, we have innovated a Biological Lock Step Plate for medial open wedge high tibial osteotomy, having excellent result and an advantage of early mobilisation.

Material & Method: Seventy knees of 66 patients with Medial compartment Osteoarthritis knee operated using Biological lock step plate and autologous cancellous bone graft (M:F – 28:38; average age 49.29 ± 4.85 years [range 39-59 years]).Preoperative & postoperative radiographs and knee society scores were obtained, with average follow-up of 36.43 ± 15.02 months (2-5 years).

Results: The average preoperative knee society scores were 59.11 ± 8.59 and 72.43 ± 9.66, respectively, compared with the postoperative averages of 93.17 ± 11.44 and 91.71 ± 8.19, respectively. Most knees 62 were excellent, 2 good, 2 fair and 4 poor rating. Patients were relieved of pain and started with partial weight bearing walking on 4th postoperative day and had resume their duties after 2 months without any activity restrictions.

Conclusions: We recommend the use of our Biological lock step plate for Medial open wedge osteotomy, an ideal method for tackling Medial compartment Osteoarthritis knee in early age group, as it has 88.57% excellent result with relatively less complication rate (11.4%).

INTRODUCTION

In younger age group of Asians having habit of floor sitting with god gifted 3^0 varus of proximal tibia is the main cause for Medial Compartment Osteoarthritis (MCOA) knee [19, 30 and 40]. Changing the line of weight bearing, by performing medial open wedge osteotomy in such a way that, the mechanical axis should pass through the Fujisawa point after surgery, resulting in articular cartilage regeneration [14, 24, 26 and 40].

After observing the complications of this procedure with routinely used implants, we used our Biological Lock Step Plate for medial open wedge high tibial osteotomy (MOWHTO) [2, 3, 16, 17, 32 and 40].

The Aim and Objective of the study, is to analyse the clinical and functional outcomes of our Biological lock step plate in MOWHTO and to compare it with other studies.

Materials and Methods:

Our implant – Biological Lock Step Plate.

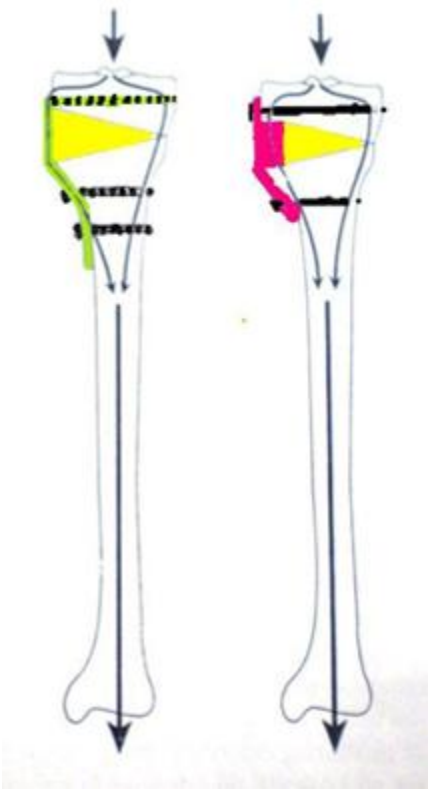


Figure 1. Axial forces exerting shear stress on the plate without step at the site of opening wedge leading to loading of screws and with the step at the site of opening wedge preventing loading of screws and transmitting axial force in a direct line.

Why Open Wedge Osteotomy With Biological Lock-Step Plate?

1. Axial forces exert high shear stress on the screw at the site of wedge (fig. 1) [2, 28, 29, 40, 43, 45 and 48].
2. Step plate used to allow transmission of the axial forces in a direct line (fig. 1) [1, 28, 29 and 45].
3. Screws are protected from loading by the step in the plate (fig. 1) [2, 28, 29 and 45].
4. Early mobilization (within 3 weeks post-op) [2, 43 and 48].
5. Because of lock plate even in osteoporosis it will catch the osteotomy perfectly & implant failure is very rare [1, 2, 28, 29, 40, 43, 45 and 48].

Advantages:

a) MOWHTO using our lock step plate and with the modification of the technique, is the answer to medial compartment arthrosis if patient selection is proper [2, 9-11, 40 and 48].

b) One might delay/obviate the need for replacement [24].

Description of Our Biological Lock Step Plate

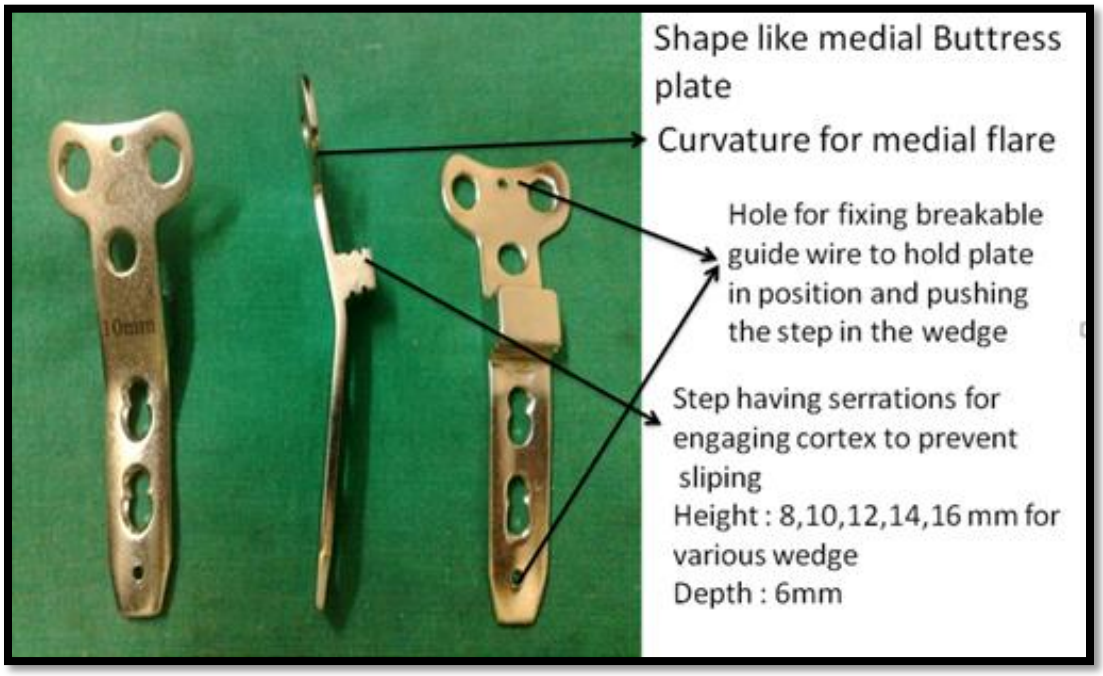


Figure 32a: Description of plate design, shape and Step

Figure 2b: Description of screws and holes

Wedges for opening out osteotomy on medial side by pushing it in osteotomy at anterior and posterior cortex along with close-up view indicating the markings of wedge height.

Preoperative planning [37, 40]

- Mechanical axis.
- To decide for osteotomy – Mal Alignment test is must.
- Identify source of mal-alignment using MAT.
- Decide whether femoral and / or tibial osteotomy is needed.
- Identify level of CORA[34].
- Choose type of osteotomy [23].
- Determine type of correction.
- Determine magnitude of correction (Fig.3) [14].
  (Rough measurement 1 degree = 1mm wedge height)

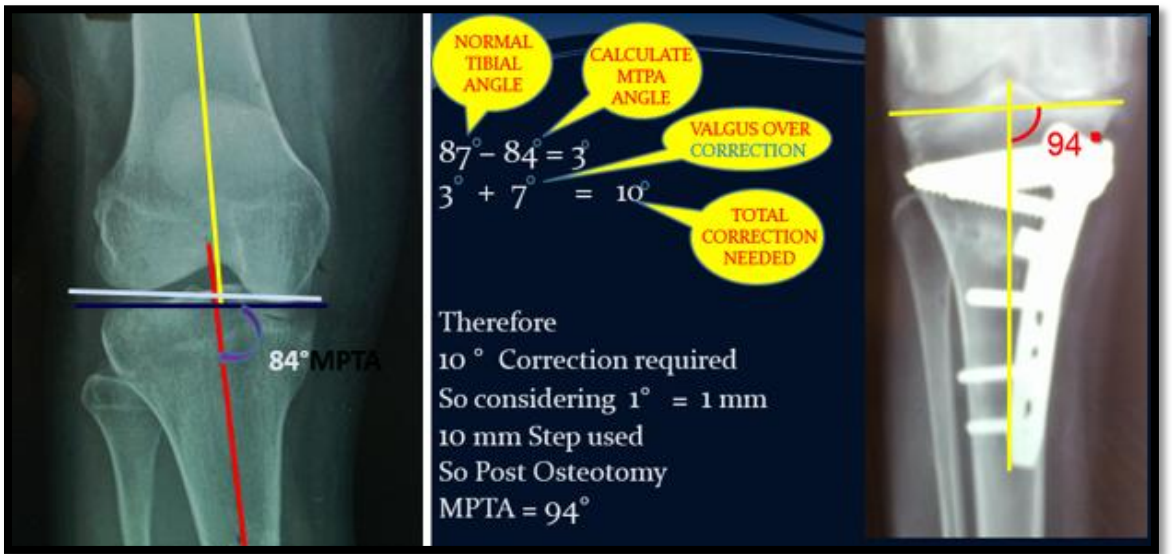


Figure 3 Pre-operative rough measurements, calculations and fixation according to calculations.

Procedure:

- Procedure done under IITV and radiolucent fracture table.
- Take medial incision, raise pes anserinus & elevate the periosteum.
- Put the zig parallel to medial articular surface and pass a guide wire from medial to lateral, 3.5 cm below the medial articular surface or summit of medial flare, towards the tip of the head of fibula and cut only 2/3rd portion of the tibia and go just above the tibial tuberosity and do osteotomy parallel to guide wire.
- Put anterior and posterior wedge and maintain the wedge with lamina spreader.
- Open out the wedge and maintain it with self-holding spreader.
- Negotiate the plate in such a way that step remains within the wedge and hold the plate with breakable k-wire (Fig. 4).

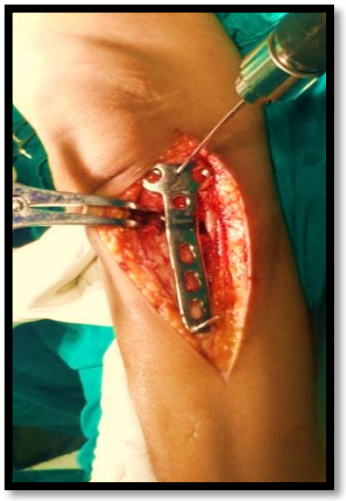
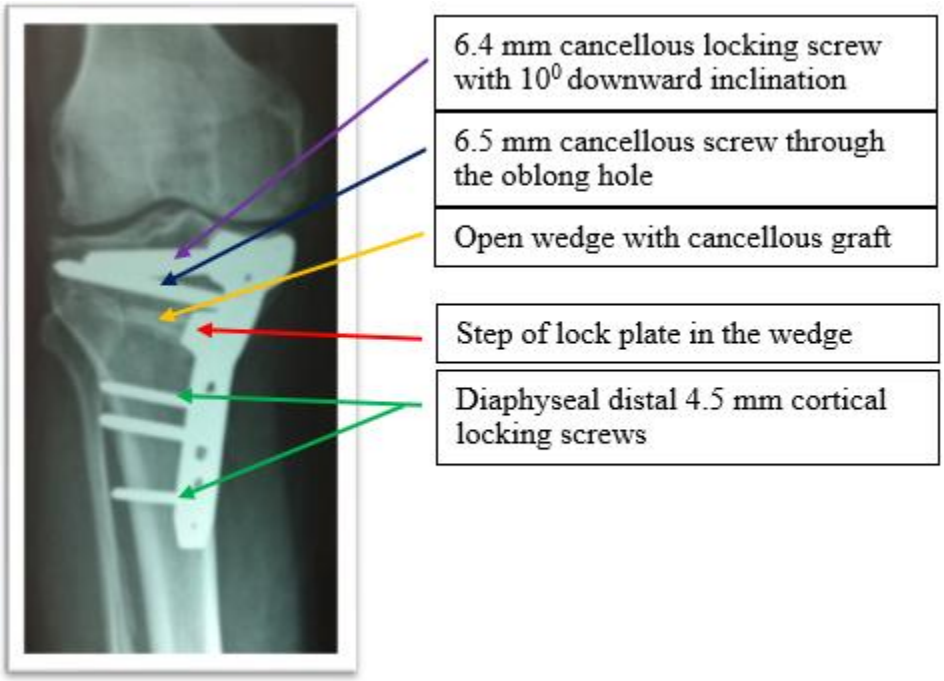


Figure 4 Placement of Lock Step Plate in the opening wedge held with self holding spreader and holding with breakable k-wire.

- When wedge is more than 10 mm always do a cancellous bone grafting fitted with simple cortical screws or cortical locking screws (we have done autogenous cancellous bone grafting in all cases).
- Proximal to step, there are two holes in transverse portion of plate having two cancellous locking screws, which are arranged in such a way that after putting the sleeve, it will go with 10^0 inclination downward from the articular surface and third adjustable hole given for cancellous screw, so the whole construct is so solid that even in osteoporotic bone chances of implant failure is very less.
- Distal to Step, minimum 3 cortical locking or simple screws as per the need are fixed bicortically using drill sleeves in a similar fashion as above and using the combiholes provided (Fig. 5).

Figure 5: final fixation



Post-operative Regime: All the patients were started with Quadriceps and range of motion exercises on first day after surgery to obtain knee motion. Mobilization with partial weight bearing at 4th post-operative day followed by stick walking on 4th week and full weight bearing walking on 6th week post-operatively. All patients were followed up at 1 month, $1^1/_2$ month, 2 months, $2^1/_2$ months, 3 months, 4 months, 6 months, 9 months, 12 months and followed up regularly every 3 monthly.

Results:

Table 1: Various Averages

SR. NO.	TYPES OF AVERAGES	AVERAGES
1	MEAN AVERAGE AGE	49.29 YEARS
2	AVERAGE PRE-OP MPTA	84.74^0
3	AVERAGE POST-OP MPTA	94.74^0
4	AVERAGE CLINICAL UNION	2.26 MONTHS
5	AVERAGE RADIOLOGICAL UNION	3.47 MONTHS
6	AVERAGE FOLLOW/UP	36.43 MONTHS
7	AVERAGE PRE-OP KSS (CLINICAL)	59.11
8	AVERAGE POST-OP KSS (CLINICAL)	93.17
9	AVERGAE PRE-OP KSS (FUNCTONAL)	72.43
10	AVERGAE POST-OP (FUNCTIONAL)	91.71

[All the averages at a glance, describing final outcome.]

Seventy knees of 66 patients with age group ranging from 39-59 years with mean average age of 49.29 ± 4.85 years, subjectively rated their 70 preoperative knee as poor. The average preoperative knee society scores were 59.11 ± 8.59 and 72.43 ± 9.66, respectively, compared with the postoperative averages of 93.17 ± 11.44 and 91.71 ± 8.19, respectively. With mean average follow up of 36.43 ± 15.02 months postoperatively, most knees 62 were rated as excellent, with 2 good, 2 fair and 4 poor rating. Patients were relieved of pain and were started with partial weight bearing walking on 4th postoperative day in most cases and had resume their duties after 2 months. The Medial proximal tibial angle pre-operatively was measured with mean of 84.74, which was corrected to a mean of 94.74 at the final follow-up.

Table 2: Results

GRADE	TOTAL MEDIAL OPEN WEDGE OSTEOTOMY
EXCELLENT (80-100)	62
GOOD(70-79)	2
FAIR(60-69)	2
POOR(<60)	4
TOTAL	**70**

[We achieved 88.57% excellent result, poor result in 5.7% because of 2 intra-articular extension of osteotomy, one lateral compartment syndrome and one due to lack of physiotherapy. In 2 cases our score was excellent, despite superficial and deep late infection.]

Discussion:

Asians and Middle East countries having habit of floor sitting, squatting etc. are among the leading cause of increasing incidence of MCOA Knee. In 1962, Jean Debeyre published his experience with MOWHTO, beginning in 1951. The theoretical advantages of an open wedge osteotomy over closed wedge includes restoration of anatomy with addition of bone to the diseased medial side, the ability to achieve a predictable correction in the coronal and sagittal planes, the ability to intra-operatively adjust the correction, the requirement for only a single bone cut, better preservation of the bone stock, avoids injuries to the peroneal nerve and proximal tibiofibular joint and relative ease of combining this technique with other procedures as well as appears to allow easier conversion to knee replacement [4, 5, 46 and 47].

Limitations of total knee arthroplasty and its complications with the cost factor, can be avoided by MOWHTO in properly selected cases, which may delay or obviate the need for total knee arthroplasty [9, 20, 24, 35, 39 and 47].

Prof. Koshino et al[25] using angled blade plate for MCOA got satisfactory results of 110 excellent and 55 good knees out of 176 knees with an average of 5.5 years follow-up. Prof. Koshino's study[49], have the longest follow-up of 15-28 years in the world. After seeing his work at ASAMI annual conference 2009, Jaslok and after having personal discussion with Prof. Koshino regarding the procedure, we started confidently doing cases with our plate. Even though our follow-up is short with mean average of around 36.43 ± 15.02 months, we achieved 91.43% (64 excellent to good out of 70 knees), which is equivalent to Hernigou et al[18], having 90 % good result at the end of 5 years. According to Patrick J. DeMeo et al[39], MOWHTO produces good results in midterm, with 95% excellent to good, only 5% fair ratings after 2 years post-operatively and 70% survivorship at the end of 8 years.

Bone graft & Radiological Union:

Table 3: Radiological Union

TIME (MONTH)	NO. OF OSTEOTOMY
3	30
4	37
5	3
TOTAL	**70**

[67 cases got radiological union within 4 months duration.]

Autogenous bone graft always gives good result as per speed of healing is concerned and so we have done autogenous iliac crest cancellous graft[46] in all cases and achieved average radiological union of 3.47 months, which is almost similar to Prof. Koshino et al[25] and Chaturong Pornrattanamaneewong et al[5], Whereas Brosset et al[48], achieved union at 4.5 months without bone graft. According to Nicholas et al[31], Autograft bone filled osteotomies has lowest rates of delayed union/non-union. As per Chae DJ[4], the MOWHTO using autologous tricortical bone graft and T-plate fixation may be technically demanding procedure associated with moderate rate (18.8%) of complications, which can be minimized with proper pre-operative planning, adequate intra-operative precautions and few modifications to avoid technical error. According to article no. 12 by Alex Staubli, in book "Osteotomies around the Knee", several reports in literature describes the interposition of the autogenous material, (generally one or more bicortical iliac graft) or insertion of homogenous or heterogeneous bone substitutes in MOWHTO definitely helps in stability and rapid healing [40].

Autologous Iliac Bone grafts are considered to be gold standard [18, 46]. The use of the bone grafts in filling gaps increases mechanical stability and enhance bone healing [2]. All our cases were grafted with cancellous bone graft irrespective of the angle of deformity and so healing of osteotomy is very fast as wedge is supporting the medial cortex, we promoted early weight bearing and allowed all patients to walk on 4th day post-operatively and full weight bearing walking at 6th week post-operatively. According to Frank R Noyas et al[13], the use of an autologous iliac crest bone graft in addition to a progressive rehabilitation program successfully prevented non-union, change in the tibial slope and knee arthrofibrosis in MOWHTO.

In F. Gouin et al[12] series, bone union period of 2.6 months when autologous cancellous bone graft was used and 5.8 months in cases where biphasic macro porous calcium phosphate ceramic wedge (BMCaPh) was used. Moreover Iliac crest pain disappeared rapidly and union was early with autologous tricortical graft whereas, significantly more pain 3 months after surgery and prolonged union time was observed with BMCaPh as a bone substitute. Prof. Koshino et al[50] series, suggested use of 2 porous hydroxyapatite (HA) wedges along with bone graft inserted into the opened osteotomy, followed by fixation with two plates gave satisfactory results with no collapse or subsidence at the osteotomy site after mean follow-up of 6.6 years. When tomofix plate is used, chronos wedge is essential and at times chronos wedge may not fuse properly with patient's cancellous bone, while we are using cancellous bone graft from patient himself, so healing is better and faster in post-operative period. Even though AO Foundation, in their book "Osteotomies around the knee" mention that upto 13 mm wedge does not require bone grafting when modified tomofix plate is used, while many other references suggest that when autogenous graft is used osteotomy unites early and that is why we can allow early weight bearing [12].

Fujisawa point:

Table 4 Medial Proximal Tibial Angle

ANGLE (DEGREE)	NUMBER OF KNEES	
	PRE OPERATIVELY	POST OPERATIVELY
81-83^0	34	0
84-86^0	20	0
87-89^0	16	0
90-92^0	0	3
93-95^0	0	47
96-98^0	0	19
99-101^0	0	1
TOTAL	**70**	**70**

[After correction by open wedge osteotomy by our designed biological lock step plate, almost in all case mechanical axis passing from fujisawa point except one where because of smaller diameter of tibial articular surface, over correction done in one case who had developed lateral compartment syndrome.]

Fujisawa et al[14], concluded in their work that corrected axis should run through the lateral 30% - 40% of the tibial plateau such that post-operative mechanical axis runs laterally through the tibial plateau, at 62% of its entire width, measured from medial side [2]. Selection of wedge is as such that after surgery mechanical axis among all our patients passes through the Fujisawa point.

Implant design:

Our Biological lock step plate has been designed to achieve optimal stability without the interference of bone healing. The principle of the locking compression plate system (LCP) meets our requirements. The locking head screws provide a stable fixation without compression between plate and bone. Our plate is rigid as it is made up of single piece of metal block and step of 8mm with serrations which prevents slippage of medial cortex giving rigidity as well as stability to avoid complications of implant failure.

Although Tomofix plate provides biomechanically stable fixation, it is too large or too long for Asian population, as a result there is post-operative discomfort and local irritation and no purchase of D-hole [32, 44]. Short spacer plates such as Puddu plate, Aescula, etc. have low incidence of local irritation, but several authors have reported on high risk of plate related complications [16].

Overall length of our plate is 10cm and T-arm is slightly curved and is 3.6cm. Proximally in curved portion upto the step, the thickness is 2.5 mm while from the step towards distally it is 3 mm. Proximal two holes are of 6.4 mm with 10^0 downward inclination and locking type, while third hole is proximal to step and has adjustable angled hole, so we can pass cancellous screw in a desired direction. The three holes in distal portion below the step are dual combi holes which match with the 4.5 locking as well as 4.5 cortical screw. With the use of spacer we can maintain the appropriate interspace between the plate and the bone. The three proximal screws are angled and that is why it catches the proximal portion easily and 10^0 inclination produces compression at lateral cortex and avoid penetration of articular surface confidently. Third proximal hole is adjustable, so crossing of screw will further add to the rigidity.

As per the biomechanical study of Gunter Spahn and Ralf Witting[17], three implants C-plate, Puddu plate and Tomofix were tested, which suggested that C-plate with mobile spacer had better stability under maximal axial force. Biological Lock Step Plate used in our study has better stability than C-plate, as spacer in C-plate is movable which increases the risk of breakage of plate at the site of the level of the spacer due to axial loading. Another biomechanical study was conducted by Seung-Beom Han et al[44] between - plate without a metal block, Anatomical Locking Metal Block Plate (OhtoFix), Aescula Plate. The use of metal block resulted in consistently higher fixation strength and improved load bearing capabilities compared to the one without a metal block, as well as least opening gap displacement was observed with the same. The addition of a metal block provided increased primary mechanical stability compared to other plates which can be used for augmentation of mechanical strength in case of large amount of correction. With the use of metal block the ultimate failure load exceeded the ultimate failure load of the Tomofix plate. The construct with new anatomical locking metal block plates with a 10 mm metal block resisted more than 3 times and twice the amount of loading cycles when compared to the short metal block plates and the new plate without a metal block. According to Agneskirchner JD et al[1], construct with a long rigid locking plate resisted more loading cycles than the short metal block plates. Moreover, it provides stable fixation for early weight bearing. Unlike these spacer plates or plates with moveable metal bock, our plate is having fixed 6 mm step of various sizes according to the requirement of the wedge and plate is made up of single piece and the step also has serrations which prevent it from slipping off the medial cortex and provides rigidity. Thus, our plate have 100% stability with locking screws and is rigidly catching open wedge even in osteoporotic bone and allows early weight bearing.

Complications:

Overall rate of complication in our study is 11.4%. Superficial infection after giving antibiotic as per culture report came under control without impairing healing. Delayed deep infection were because of Haematogenous spread due to renal pathology for which we did drainage, debridement treated with continuous irrigation and negative suction following which it came under control. Because of Intra-articular extension of osteotomy, union was delayed up to 5 months. Because of less tibial diameter, less than 57 mm, our rough calculation leads to over correction and that is why we suggest that rough calculation is only to be considered when tibial diameter is around 57 mm. If it is less then it will lead to over correction and if it is more than it will lead to under correction. In such situation calculation is to be made by Pythagoras theorem. After performing the osteotomy, wedges are to be pushed one by one,

gradually and safely pushing the wedge inside and opening of the medial wedge space, so lateral cortex should be preserved as lateral 10 mm space acts as a hinge.

Based on our experience, an OWHTO has many advantages over a closed wedge high tibial osteotomy. As suggested by Miller et al[3], the complications are relatively less than the close wedge osteotomy and we confirmed it in our study with our plate.

Among the complications[3, 16] like haematoma, failure of implant, deep vein thrombosis, paresis of peroneal nerve, vessel injury, pseudo arthrosis of tibial osteotomy, pseudo arthrosis of fibula, necrosis of tibial head, Sudecks syndrome, compartment syndrome, failure of osteosynthesis with or without loss of correction etc., we came across only two infections, one over correction, three cases of extension of osteotomy in lateral cortex and two intra-articular extension of osteotomy which had delayed union.

According to Esenkaya I[11], overall results are good, but rate of complications are very high - breakage of lateral cortex in 25%, osteotomy extension in tibial plateau 8.6%, DVT 3.4%. As compared to this study in our study, we have only three cases of extension of osteotomy in lateral cortex while opening out the wedge. But, as our direction of osteotomy is from medial to lateral, towards the head of fibula, the extension usually goes into syndesmosis, so there may not be any displacement. Our proximal 2 screws having downward inclination and having 3rd cancellous screw in the centre of the proximal portion of the plate, we can adjust the screw in such a way that lateral extension of osteotomy gets compressed in between the plate and the cancellous screw. This study having 3.4% DVT, fortunately we have not encountered any case of DVT in our study as physiotherapy started immediately as soon as pain subsides and we are making patient to walk partial weight bearing with walker on 4th day post-operatively. Also we didn't come across delayed healing of wound. All wounds healed well. All the osteotomies healed well in time, except 2 osteotomies, which were extended intra-articularly, were delayed for healing after 4 months.

According to Maximum Golavakha et al[29] and Seung-Beom Han et al[44], even with tomofix, the shear stress leading to pulling out of the screws was among the complications leading to implant failure, because there is no wedge to distribute the weight in the center. And stress & strain appears directly over the screw, which leads to its loosening. While in our plate, we have used step of 6mm with locking screws. So we haven't come across any case of implant failure, even in osteoporotic bone.

As far as our information is concerned most of the surgeon including Japanese they are using Tomofix plate with chronos wedge, but none of the studies of AO foundation book have mentioned regarding the use of wedges. The disadvantage of using the chronos wedge at times prevents union or delayed union at the site of osteotomy, which secondarily likely to give rise to implant failure. Second most important finding in AO foundation book is that they are using only one bicortical screw in the distal portion of the plate and the other screws are Unicortical, which is likely to produce implant failure in Osteoporotic bone. So when a step is made from a single piece metal block along with plate, definitely avoids such implant failure and as we are putting only 3 screws in distal fragment, distal portion considering the bone morphology of and Asian, the overall length is decreased to 10 cm so we put all screws bicortical to increase rigidity and stability. As far the cost factor is concerned the cost of Tomofix plate is almost three times more than our plate. And over and above the cost of chronos wedge which is to be put separately, so overall cost of implant is very high.

According to Gunter Spahn[16 and 17], MOWHTO treated with Puddu plate, the rate of complication was 43.6% and that with C-plate was 16.7%. Whereas, the rate of complication in our study was 11.4%.

KNEE SOCIETY SCORE (KSS):

Table 5 Knee Society Score (Clinical & Functional)

NUMBER OF CASES				
SCORE	**PRE-OP**		**POST-OP**	
	CLINICAL	**FUNCTIONAL**	**CLINICAL**	**FUNCTIONAL**
0-10	0	0	00	00
11-20	0	0	00	00
21-30	0	0	00	00
31-40	0	0	00	00
41-50	10	2	00	00
51-60	32	2	00	04
61-70	21	42	02	02

71-80	07	14	10	02
81-90	00	10	30	8
91-100	00	00	28	54
TOTAL	**70**	**70**	**70**	**70**

[Almost all cases improved in clinical and functional criteria of knee society score, but 4 poor cases had knee society score less than 60, because of complications.]

In comparison with other studies, as far as postoperative knee society score is concerned, it has negligible difference having similar average follow-up with over all good results.

Table 6 Comparison of KNEE SOCIETY SCORE of various opening wedge high tibial osteotomies.

Various Studies	No. of Knees	Average Age in years	Knee Society Score				Mean follow-up period	Any augmentation
			Clinical		Functional			
			Pre-op	Post-op	Pre-op	Post-op		
Su Chan Lee et al[47]	37	53	52.19± 11.48	92.49± 5.10	52.84± 6.23	89.05±5. 53	15.6 months	Aescula open wedge plate and an allogenic bone graft
Koshino et al[49]	75	59.6± 6.7	37±20	87±19	38±16	80±19	19±3 years	Koshino blade plate
T. Brosset et al[48]	51	53±7. 5	69±15. 5	90±7.4	84±15. 5	95±8.9	24 months	Locking plate(Tomofix) without filling
Koshino et al[50]	21	66.6	60.2±5. 3	94.3±7. 3	48.1±1 0.4	93.1±9.8	78.6 months	Tomofix with porous hydroxyapatite
R. Takeuchi et al[43]	57	69	50.9±1 2.3	91.7±6. 9	59.3±1 3.1	94.1±8.8	40 months	Tomofix with bone substitutes
F. Gouin et al[12] 1. BMCaPh 2. Autograft	22 BMCa Ph 18 AUTO	51	62.4	82	70	86	45±21 months	BMCaPh ceramic wedges vs Autologous tricortical graft
Our study	70	49.29 ±4.85	59.11± 8.59	93.17± 11.44	72.49± 9.66	91.71±8. 19	36±15.02 months	Anatomical Lock Step Plate with Autologous cancellous bone graft

Limitations of the study:

Limitations of this study is that we haven't confirmed our findings arthroscopically as affordability of our patients is main issue at our institute.

Conclusion:

Compared with TKA, High tibial osteotomy has advantages such as simplified technique, a lower surgical cost and a lack of limitations in the flexion motion after surgery (achieving wider range of motion). As per Asian customs and Middle East rituals, these populations can perform floor sitting, squatting and kneeling, cross leg sitting, able to play out door games, etc. after MOWHTO with our plate which is a significant advantage over TKA.

Despite of whatever may be the angle of correction we have done cancellous autogenous bone grafting in all cases and the area of grafted wedge is protected completely by medial side small step underneath medial cortex, supporting medial cortex and that is why post-operative collapse inspite of early weight bearing on 3rd day with walker and full weight bearing after six weeks never leads to collapse or recurrence of deformity.

As per Prof. Koshino's study, it is shown that after MOWHTO within one and half year in young patients with unloaded medial compartment, the thickness of articular surface becomes one and half times than the normal and remains highly active and that is why TKR can be delayed or obviated without any activity restrictions. It is an ideal method for tackling Medial Compartmental syndrome in early age group. We recommend the use of our Innovative Biological lock step plate with autogenous cancellous bone graft for MOWHTO, as it is effective in obtaining desired correction angle with 88.57% excellent result and relatively 7.14% rate of complication.

Case 1: Patient had bilateral medial compartment arthrosis, operated first on left side and within 3 months period patient was fully satisfied, so decided to undergo same procedure on right side.
Preoperative radiographs showing bilateral AP view (fig. 6a).

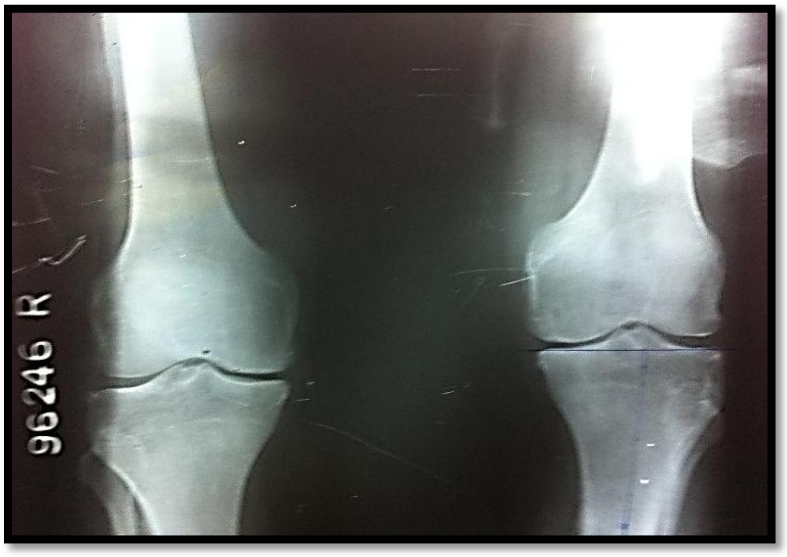


Figure 6a: Bilateral knee Anteroposterior view standing

Final follow-up radiographs of bilateral knee AP view at the end of 4 years (fig. 6b).

Figure 6b: Final Follow-up X-ray of Bilateral Knee AP view at the end of 4 years.

Final follow-up clinical photographs at the end of 4 years with active full range of movements and increased standing time and walking freely with walking distance of 5km (fig. 6c, fig. 6d and fig. 6e).

Figure 6c Standing time increased and deformity corrected

Figure 6d: sitting cross legged without pain

Figure 6e full active pain free range of movements

References

1. Agneskirchner JD, Freiling D, Hurschler C, Lobenhoffer P. Primary stability of four different implants for opening wedge high tibial osteotomy. Knee Surg Sports Traumatol Arthrosc. 2006;14:291–300.[PubMed]
2. Brinkman JM, Lobenhoffer P, Agneskirchner JD, Staubli AE, Wymenga AB, van Heerwaarden RJ. Osteotomies around the knee: patient selection, stability of fixation and bone healing in high tibial osteotomies. J Bone Joint Surg Br. 2008 Dec; 90(12):1548-57. doi: 10.1302/0301-620X.90B12.21198.
3. Bruce S. Miller, M.D., M.S., Brian Downie, M.S., E. Barry McDonough, M.D., Edward M. Wojtys, M.D. Complications after Medial Opening Wedge High Tibial Osteotomy. Arthroscopy: The Journal of Arthroscopic & Related Surgery - Volume 25, Issue 6, June 2009, Pages 639–646.
4. Chae DJ, Shetty GM, Wang KH, Montalban AS Jr, Kim JI, Nha KW. Early complications of medial opening wedge high tibial osteotomy using autologous tricortical iliac bone graft and T-plate fixation. Knee. 2011 Aug; 18(4):278-84. doi: 10.1016/j.knee.2010.05.009. Epub 2010 Aug 30.
5. Chaturong Pornrattanamaneewong, Surin Numkanisorn, Keerati Chareancholvanich, and Thossart Harnroongroj, MD. A retrospective analysis of medial opening wedge high tibial osteotomy for varus osteoarthritic knee. Indian J Orthop. 2012 Jul-Aug; 46(4): 455–461: doi: 10.4103/0019-5413.98833.
6. Craig M. Rodner, Douglas J. Adams, Vilmaris Diaz-Doran, Janet P. Tate, Stephen A. Santangelo, Augustus D. Mazzocca, and Robert A. Arciero. Medial Opening Wedge Tibial Osteotomy and the Sagittal Plane: The Effect of Increasing Tibial Slope on Tibiofemoral Contact Pressur. Am J Sports Med September 2006 34 1431-1441.
7. Dae-Hee Leea, b, Seoung-Bum Hanb,Kwang-Jun Ohc, Jun Seop Leed,Jae-Ho Kwona,Jong-In Kima, Smarajit Patnaika,Gautam M. Shettya, Kyung-Wook Nha; The weight-bearing scanogram technique provides better coronal limb alignment than the navigation technique in open high tibial osteotomy ; The Knee, Volume 21, Issue 2, March 2014, Pages 451–455
8. Davide Edoardo Bonasia, Federico Dettoni, Gabriele Sito, Davide Blonna, Antongiulio Marmotti, Matteo Bruzzone, Filippo Castoldi and Roberto Rossi; The American Journal of Sports Medicine; Medial Opening Wedge High Tibial Osteotomy for Medial Compartment Overload/Arthritis in the Varus Knee: Prognostic Factors ; Am J Sports Med 2014 42: 690 originally published online January 21, 2014; DOI: 10.1177/0363546513516577
9. Devgan A; Marya KM; Kundu ZS; Sangwan SS; Siwach RC. Medial opening wedge high tibial osteotomy for osteoarthritis of knee: long-term results in 50 knees. The Medical Journal of Malaysia [Med J Malaysia] 2003 Mar; Vol. 58 (1), pp. 62-8.
10. Esenkaya I, Fixation of proximal tibia medial opening wedge osteotomy using plates with wedges. Acta Orthop Traumatol Turc. 2005; 39(3):211-23.
11. Esenkaya I. Proximal tibia medial open-wedge osteotomy using plates with wedges: early results in 58 cases. Source: Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal Of The ESSKA [Knee Surg Sports Traumatol Arthrosc] 2006 Oct; Vol. 14 (10), pp. 955-61. Date of Electronic Publication: 2006 Mar 28.
12. F. Gouin , F. Yaouanc,D. Waast, B. Melchior, J. Delecrin,N. Passuti; Open wedge high tibial osteotomies: Calcium-phosphate ceramic spacer versus autologous bonegraft; Orthopaedics & Traumatology: Surgery & Research, Volume 96, Issue 6, October 2010,Pages 637-645; doi:10.1016/j.otsr.2010.03.022
13. Frank R. Noyes, Md, William Mayfield, Md, Sue D. Barber-Westin*,Jay C. Albright, Md, And Timothy P. Heckmann, Pt . Opening wedge high tibial osteotomy - An operative technique and rehabilitation program to decrease complications and promote early union and function. Am J Sports Med August 2006 Vol. 34 No. 8 1262-1273
14. Fujisawa Y, Masuhara K, Shiomi S. The effect of high tibial osteotomy on osteoarthritis of the knee.Orthop Clin North Am. 1970; 10:585–608. [PubMed]
15. G.S.E. Dowd , H.S. Somayaji,M. Uthukuri. High tibial osteotomy for medial compartment osteoarthritis. The Knee; Volume 13, Issue 2, March 2006, Pages 87–92;doi:10.1016/j.knee.2005.08.002
16. Gunter Spahn. Complications in high tibial (medial opening wedge) osteotomy. Archives of Orthopaedic and Trauma Surgery - December 2004, Volume 124, Issue 10, pp 649-653, Date: 30 Sep 2003
17. Gunter Spahn, Ralf Wittig. Primary stability of various implants in tibial opening wedge osteotomy: a biomechanical study. Journal of Orthopaedic Science, December 2002, Volume 7, Issue 6, pp 683-687

18. Hernigou P, Medevielle D, Debeyre J, Goutallier D. Proximal tibial osteotomy for osteoarthritis with varus deformity. A ten to thirteen-year follow-up study. (PMID: 3818700). The Journal of Bone and Joint Surgery. American Volume [1987, 69(3):332-354]
19. Jens Dominik Agneskirchner, M.D., Christof Hurschler, Ph.D., Christiane D. Wrann, D.V.M., Philipp Lobenhoffer, M.D. The Effects of Valgus Medial Opening Wedge High Tibial Osteotomy on Articular Cartilage Pressure of the Knee: A Biomechanical Study. Arthroscopy: The Journal of Arthroscopic & Related Surgery - Volume 23, Issue 8, August 2007, Pages 852–861
20. John M. Wright, MD, Heber C. Crockett, MD, Daniel P. Slawski, MD, Mike W. Madsen, MD, and Russell E. Windsor, MD. High Tibial Osteotomy. J Am Acad Orthop Surg 2005;13:279-289
21. John N. Insall, MD, Lawrence D. Dorr, MD, Richard D. Scott, MD, and W. Norman Scott, MD. Rationale of the Knee Society Clinical Rating System. Clin Orthop. 1989 Nov ;(248):13-14. PMID: 2805470)
22. Jung WH, Takeuchi R, Chun CW, Lee JS, Ha JH, Kim JH, Jeong JH. Second-look arthroscopic assessment of cartilage regeneration after medial opening-wedge high tibial osteotomy. Arthroscopy. 2014 Jan;30(1)
23. Keppler P, Suger G, Kinzl L, Strecker W. Osteotomies in malalignments of the lower extremities.Chirurg. 2002 Oct; 73(10):982-9.
24. Kim SJ, Mahajan RH, Park KY, Kim TE, Lee DH, Choi WJ. Biplanar medial open wedge high tibial osteotomy for medial compartment osteoarthritis of the Knee: a novel technique and follow-up. Oper Tech Orthop. 2007; 17(1):29–37.
25. Koshino T, Morii T, Wada J, Saito H, Ozawa N, Noyori K. High tibial osteotomy with fixation by a blade plate for medial compartment osteoarthritis of the knee. Orthop Clin North Am. 1989;20:227–243.[PubMed]
26. Koshino T, Wada S, Ara Y, Saito T. Regeneration of degenerated articular cartilage after high tibial valgus osteotomy for medial compartmental osteoarthritis of the knee. Knee. 2003 Sep; 10(3):229-36.
27. Laprade RF, Spiridonov SI, Nystrom LM, Jansson KS. Prospective outcomes of young and middle - aged adult's with medial compartment osteoarthritis treated with a proximal tibial opening wedge osteotomy. Arthroscopy.2012bMar;28(3):354-64.
28. Maas S; Diffo Kaze A; Pape D. Static and Dynamic Differences in Fixation Stability between a Spacer Plate and a Small Stature Plate Fixator Used for High Tibial Osteotomies: A Biomechanical Bone Composite Study. ISRN Orthopedics [ISRN Orthop] 2013 Sep 23; Vol. 2013, pp. 387620. Date of Electronic Publication: 20130923 (Print Publication: 2013).
29. Maxim L Golovakha, Weniamin Orljanski, Karl-Peter Benedetto, Sergey Panchenko, Philippe Büchler, Philipp Henle, and Emin Aghayev . Comparison of theoretical fixation stability of three devices employed in medial opening wedge high tibial osteotomy: a finite element analysis. BMC Musculoskelet Disord. 2014; 15: 230. doi: 10.1186/1471-2474-15-230
30. Mündermann A, Dyrby CO, D'Lima DD, Colwell CW Jr, Andriacchi TP. In vivo knee loading characteristics during activities of daily living as measured by an instrumented total knee replacement. J Orthop Res. 2008 Sep; 26(9):1167-72. doi: 10.1002/jor.20655.
31. Nicholas J. Lash, Julian A. Feller, Lachlan M. Batty, Jason Wasiak, Anneka K. Richmond, Bone Grafts and Bone Substitutes for Opening-Wedge Osteotomies of the Knee: A Systematic Review ; Arthroscopy: The Journal of Arthroscopic & Related Surgery; Volume 31, Issue 4, April 2015, Pages 720–730
32. Niemeyer P, Schmal H, Hauschild O, von Heyden J, Sudkamp NP, Kostler W. Open-wedge osteotomy using an internal plate fixator in patients with medial-compartment gonarthritis and varus malalignment: 3-year results with regard to preoperative arthroscopic and radiographic findings. Arthroscopy.2010; 26:1607–1616. [PubMed]
33. Paley D. Principles of deformity correction, page no.480
34. Paley D, Herzenberg JE, Tetsworth K, McKie J, Bhave A. Deformity planning for frontal and sagittal plane corrective osteotomies. Orthop Clin North Am. 1994; 25:425–465. [PubMed]
35. Paley D, Maar DC, Herzenberg JE. New concepts in high tibial osteotomy for medial compartment osteoarthritis. Orthop Clin North Am. 1994; 25:483–498.
36. Paley D, Tetsworth K. Mechanical axis deviation of the lower limbs. Preoperative planning of uniapical angular deformities of the tibia or femur. Clin Orthop Relat Res. 1992 Jul ;(280):48-64.

37. Pape D, Rupp S. Preoperative planning for high tibial osteotomies. Oper Tech Orthop. 2007; 17:2–11.
38. Patond KR, Lokhande AV. Medial open wedge high tibial osteotomy in medial compartment osteoarthrosis of the knee. Natl Med J India. 1993 May-Jun; 6(3):104-8.
39. Patrick J. DeMeo, MD*†, Eric M. Johnson, MD†, Peter P. Chiang, MD‡,Angela M. Flamm, MS† and Mark C. Miller, PhD. Midterm Follow-up of Opening-Wedge High Tibial Osteotomy. Published online before print July 1, 2010, doi:10.1177/0363546510371371Am J Sports Med October 2010vol. 38 no. 10 2077-2084
40. Philipp Lobenhoffer, Ronald J van Heerwaarden, Alex E Staubli, Rolad P Jacob. Osteotomies around the Knee. Indications – Planning – Surgical Techniques using Plate Fixators. 2008 by AO foundation.
41. Pornrattanamaneewong C, Harnroongroj T, Chareancholvanich K. Loss of correction after medial opening wedge high tibial osteotomy: a comparison of locking plates without bone grafts and non-locking compression plates with bone grafts. J Med Assoc Thai. 2012 Sep; 95 Suppl 9:S21-8.
42. Prix R. Opening – wedge osteotomy of the proximal tibia. ActaChirOrthopTraumatolCech.2005; 72(5):308-12.
43. Ryohei Takeuchi, M.D., Hiroyuki Ishikawa, M.D., Masato Aratake, M.D., Haruhiko Bito, M.D., Izumi Saito, M.D., Ken Kumagai, M.D., Yasuhsi Akamatsu, M.D., Tomoyuki Saito, M.D. Medial Opening Wedge High Tibial Osteotomy With Early Full Weight Bearing. Arthroscopy: The Journal of Arthroscopic & Related Surgery;Volume 25, Issue 1, January 2009, Pages 46–53
44. Seung-Beom Han, MD, Ji-Hoon Bae, MD, Sung-Jae Lee, MD, Tae-Gon Jung, MD,3 Kang-Hee Kim, MD, Jae Ho Kwon, MD, and Kyung Wook Nha, MD. Biomechanical Properties of a New Anatomical Locking Metal Block Plate for Opening Wedge High Tibial Osteotomy: Uniplane Osteotomy. Knee Surg Relat Res. 2014 Sep; 26(3): 155–161.doi: 10.5792/ksrr.2014.26.3.155
45. Stoffel K, Dieter U, Stachowiak G, Gächter A, Kuster MS. Biomechanical testing of the LCP--how can stability in locked internal fixators be controlled? Injury. 2003 Nov; 34 Suppl 2:B11-9.
46. Stuart J. Warden Hayden G. Morris Kay M. Crossley Peter D. Brukner Kim L. Bennell. Delayed and non-union following opening wedge high tibial osteotomy: surgeons' results from 182 complete cases. Knee surgery sports & traumatology arthroscopy – February 2005 -
47. Su Chan Lee, Kwang Am Jung, Chang Hyun Nam, Soong Hyun, Soong Hyun Jung and Seung Hyun Hwang. The Short-term Follow-up Results of Open Wedge High Tibial Osteotomy with using an Aescula Open Wedge Plate and an Allogenic Bone Graft: The Minimum 1-year Follow-up Results. ClinOrthop Surg. 2010 Mar; 2(1): 47-54.
48. T. Brosset, G. Pasquier, H. Migaud, F. Gougeon. Opening wedge high tibial osteotomy performed without filling the defect but with locking plate fixation (TomoFix™) and early weight-bearing: Prospective evaluation of bone union, precision and maintenance of correction in 51 cases. Orthopaedics & Traumatology: Surgery & ResearchVolume 97, Issue 7, November 2011, Pages 705–711; doi:10.1016/j.otsr.2011.06.011
49. Tomihisa Koshino, Takuji Yoshida, Yuki Ara, Izumi Saito, Tomoyuki Saito. Fifteen to twenty-eight years' follow-up results of high tibial valgus osteotomy for osteoarthritic knee. The Knee: Volume 11, Issue 6, December 2004, Pages 439–444
50. Tomihisa Koshino, MD, PhD; Tomoo Murase, MD, PhD; Tomoyuki Saito, MD, PhD.Medial Opening-Wedge High Tibial Osteotomy with Use of Porous Hydroxyapatite to Treat Medial Compartment Osteoarthritis of the Knee. J Bone Joint Surg Am, 2003 Jan; 85 (1): 78 -85. http://dx.doi.org/
51. Woon-Hwa Jung, Ryohei Takeuchi, Chung-Woo Chun, Jung-Su Lee, Jae-Heon Jeong. Comparison of Results of Medial Opening-Wedge High Tibial Osteotomy With and Without Subchondral Drilling; Arthroscopy: The Journal of Arthroscopic & Related Surgery; Volume 31, Issue 4, April 2015, Pages 673–679; doi:10.1016/j.arthro.2014.11.035.