

Abstract of the PhD thesis

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**The radiological examination of the position of the tibial condyle and the patella
after combined and after closing-wedge high tibial osteotomy
Short- and mid-term results after combined high tibial osteotomy**

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Introduction

High tibial osteotomy is a well-established procedure for treatment of the varus osteoarthritic knee. High tibial osteotomy produces satisfactory clinical results in the short term, but this result deteriorates with time. (Insall 1984, Coventry 1993)

Valgus tibial osteotomy inevitably produces some transposition of the tibial condyle with respect to its bony axis. Scarring between the osteotomy site and the surrounding soft tissue are often seen after high tibial osteotomy and patella infera is not uncommon after osteotomy.

The greater the angle of correction obtained the greater the transposition. The greater the distance between the center of the deformity and the center of the correction, the greater the transposition.

The high tibial osteotomy is unlikely to give permanent relief, but may buy time, although most probably not more than 10 years and many patients who undergo high tibial osteotomy, require total knee replacement after osteotomy. (Insall 1984)

By avoiding considerable transposition of the tibial condyle by high tibial osteotomy, the possibility to revise a failed high tibial osteotomy to a successful total knee replacement can be preserved.

Taking Insall's opinion seriously into account, our aim was to develop an osteotomy type, which besides significant correction doesn't cause such extent of transposition at the tibial condyle which would endanger the success of the subsequent total knee replacement. It was an important aspect at the development of the osteotomy type to avoid the development of patella infera.

The correction achieved by closing wedge osteotomy above the tibial tubercle is limited. The opening wedge osteotomy performed above the tibial tubercle increases the pressure in the medial compartment of the knee. Considerable correction can be achieved by dome osteotomy, but after dome osteotomy, the transposition of the tibial condyle is considerable too.

We developed the combined osteotomy in 1993. After the first osteotomy made 2 cm distally to the joint line, a bone wedge is removed based laterally. Its tip ends at the center of the proximal osteotomy (half bone wedge). The distal part of the tibia is placed into the valgus position and the half bone wedge is placed into the gap opened medially.

At combined osteotomy, the center of the correction is the center of the tibial condyle, while at closing wedge osteotomy it is the medial cortex and so, with combined osteotomy, twice the correction can be achieved than with traditional closing wedge osteotomy.

The distance between the center of the correction of the combined osteotomy and the centre of deformity is not significant, so the explicit transposition of the tibial condyle is not expectable. Following the combined osteotomy the distance between the tibial tubercle and the joint line does not change, which reduces the danger of the development of patella infera.

We assume that the transposition of the tibial condyle and the shortening of the patellar ligament is smaller following the combined osteotomy than following the closing-wedge osteotomy, and we assume that the mid-term results of the combined osteotomy shall be good, outstanding beside the significant corrections.

The review of the literature

High tibial osteotomy has long been used as surgical treatment for medial osteoarthritis of the knee. Closing-wedge, dome, and opening-wedge osteotomies are widely used. Recently, opening-wedge tibial osteotomy with hemocallotaxis has become popular. (Turi 1987)

Clinical results can be affected by the elapsed time since the osteotomy, patient age, the degree of preoperative varus deformity, preoperative flexion arch, relative body weight, the degree of destructive changes of the medial compartment, previous medial menisectomy, the correction of axial alignment, preoperative loss of knee extension and presence of a lateral tibial thrust.

High tibial osteotomy is a well-established procedure for treatment of the varus osteoarthritic knee. (Coventry 1993) High tibial osteotomy produces satisfactory clinical results in the short term, but this result deteriorates with time. Many patients who undergo high tibial osteotomy require total knee replacement. (Insall 1984)

Certain technical problems must be considered in performing total knee replacement after high tibial osteotomy.

Scarring between the osteotomy site and the surrounding soft tissue are often seen after high tibial osteotomy and patella infera is not uncommon after osteotomy. During subsequent conversion to total knee replacement after osteotomy, the soft tissue scarring makes the subperiosteal exposure of the proximal tibia more difficult. The shortening of the patellar ligament makes the eversion of the patella difficult, with the additional risk of avulsing of the tibial tubercle. (Windsor 1988) During the exposure, the quadriceps turndown and tibial tubercle osteotomy may be required.

It could be difficult to obtain the accurate correction at operation and to maintain the appropriate correction after osteotomy. Undercorrection or overcorrection, contribute to technical difficulty of obtaining optimal soft tissue balancing during total knee replacement after high tibial osteotomy.

Valgus tibial osteotomy inevitably produces some transposition of the tibial condyle with respect to its bony axis. (Nakamura 2001) The greater the angle of correction obtained the greater the transposition. The greater the distance between the center of the deformity and the center of the correction, the greater the transposition. The transposition of the tibial condyle leads to difficulty in obtaining appropriate alignment and in optimal positioning of the tibial component during the subsequent total knee replacement. (Windsor 1988)

The high tibial osteotomy can cause the change of the tibial slope angle. The tibial slope angle regularly decreases after closing wedge and dome osteotomy and increases after opening wedge osteotomy. The decrease of the tibial slope angle requires considerable resection from the posterior aspect of the tibial plateau during the total knee replacement, which can lead to a decrease in trabecular bone strength. Extended posterior tibial resection may weaken the distal insertion of the posterior cruciate ligament at posterior cruciate retaining total knee replacement.

These disadvantages are associated with all typed of high tibial osteotomy.

Considerable lateral overhang of the lateral tibial plateau can develop, especially after closing wedge osteotomy, which can cause impingement of the peg of the tibial component on the lateral part of the tibial cortex during the subsequent total knee replacement. The tibial component can be medialized or downsized because of abutment of the peg against the truncated lateral tibial metaphysis.

Especially after closing wedge osteotomy, reduced amount of bone stock on the lateral side can be present. Because of the lateral bone loss, only minimal lateral tibial

bone can be resected during the subsequent total knee replacement and the requirement of bone grafting on the lateral side of the tibia is not uncommon. To restore the preosteotomy lateral joint line position, the use of a relatively thicker tibial component is necessary. (Windsor 1988)

Materials and methods

We have prepared two studies separable from each other, in the one we compared the transposition of the tibial condyle and the shortening of the patellar ligament following the combined and the closing wedge osteotomy. Papp³. The other study analyzed the clinical effects of combined osteotomy, and its radiological effects taking into consideration aspects differing from those of the first study. Papp^{1,2}. Although the two studies were executed parallelly the analysis on the clinical and radiological effects of the combined osteotomy were closed earlier than the comparative radiological analysis of the combined and closing-wedge osteotomy. Due to the above the presentation of the material and the method was carried out partially parallelly and partially separately.

From 1 January 1993 to 31 December 2000 150 consecutive high tibial osteotomies were performed. One hundred and three (92 patients) were combined (group A) and 47 (41 patients) were closing wedge (group B) osteotomies. In group-A, 16 knees (14 patients) failed to turn up at the final follow-up and 7 knees (5 patients) died during the follow-up interval. All 23 knees (19 patients) were excluded from the study. The remaining 80 knees (73 patients; 43 men and 30 women) had a mean age of 50.7 years (24-69) at the time of osteotomy. The mean follow-up was 66.15 months (25-108). Reasons for varus gonarthrosis were idiopathic (78 knees; 71 patients) and post-traumatic (2 knees; 2 patients). In group-B, six knees (five patients) failed to turn up at the final follow-up. All six knees (five patients) were excluded from the study. The remaining 41 knees (36 patients; 21 men and 15 women) had a mean age of 51.2 years (38-68) at the time of osteotomy. The mean follow-up was 66.6 months (25-108). Reasons for varus gonarthrosis were idiopathic in all cases. In group-A, all 80 knees (73 patients) and in group-B, all 41 knees (36 patients) were assessed radiologically before surgery, in the 10th postoperative week, in the 12th postoperative month and at the time of the final follow-up. In group A all 80 knees (73 patients) were assessed radiologically in the postoperative 54,15 (13-96) month too.

Indication of the osteotomies

In both groups, arthroscopies were performed if the conservative therapy was unsuccessful for 3 months, if:

- the pain was restricted for the medial knee compartment;
- the range of movement was 120° or more;
- narrowing of the medial joint space did not exceed 50% on the standing anteroposterior radiograph;
- varus deformity located to the tibia.

If during arthroscopy we saw grade I or II chondromalacia, according to Outerbridge (1961), in the medial compartment, with intact cartilage in the lateral compartment, high tibial osteotomy was performed immediately after arthroscopy. In younger patients (less than 50 years), osteotomy was performed even in grade III chondromalacia. Chondromalacia patellae grade 1 or II in any localization 1, 2, 3, 4 according to Ficat (1979) was not considered a contraindication. At combined osteotomy, the center of the

correction is the center of the tibial condyle, while at closing wedge osteotomy it is the medial cortex and so, with combined osteotomy, twice the correction can be achieved than with traditional closing wedge osteotomy.

There is a pronounced difference between the indications of the closing wedge and combined osteotomy depending on the amount of the planned correction. If the desired correction was less than 10° , we chose closing wedge osteotomy and if it was more than 10° , our choice was combined osteotomy. If the desired correction was 10° patients were randomized either to a combined or to closing wedge osteotomy.

Contraindication

- loss of extension, more than 5° ;
- medial instability more than ++;
- rheumatoid arthritis;
- poor general conditions;
- generalized osteoarthritis according to standing radiograph.

Radiographic planning and evaluation

Preoperatively, in the 10th postoperative week, in the 12th postoperative month and at the time of the final follow-up, anteroposterior (the patella was facing forward), standing weight-bearing anteroposterior, lateral and axial view radiographs were made in both groups.

The preoperative radiographic assessment of varus deformity (measurement of the femorotibial angle according to Bauer 1969) was performed on a standing weight-bearing anteroposterior radiograph. The femorotibial angle equals the sum of the femoral condyle-femoral shaft angle (the lateral angle between the anatomic axis of the femur and the tangent to the subchondral plate of the femoral condyles) and the femoral condyle-tibial plateau angle (the lateral angle between the tangent to the subchondral plate of the femoral condyles and the tangent to the subchondral plate of the tibia) and the tibial plateau-tibial shaft angle (the lateral angle between the tangent to the subchondral plate of the tibia and the anatomic axis of the tibia).

In cases of the abnormal slackness of lateral ligaments, we measured the femorotibial angle (as Dugdale 1992 recommended) on a supine non weightbearing radiograph. We considered the femorotibial angle of 175° as a normal value.

We planned the femorotibial angle of $171-169^\circ$ ($4-6^\circ$ of valgus position). The first line was drawn parallel to the subchondral plate of the tibia, 2 cm distally to it in both groups. This line represented the upper osteotomy. In group-A. the first line was dissected. From this point, the second line was drawn at the desired angle in the lateral direction. This second line represented the lower osteotomy. In group-B the second line was drawn at the planned angle from the point where the first line intersected the medial cortex of the tibial head. This second line represented the lower osteotomy.

The amount of the lateral tibial bone loss was determined by measuring the distance between the tangent to the lateral subchondral tibial plate and the top of the fibular head on a preoperative standing weight-bearing radiograph too.

The amount of the transposition of the tibial condyle with respect to its bony axis was calculated according to the method of Yoshida (1987) [The axis of the tibia and its

perpendicular line through the edge of the lateral tibial plateau (point B) was drawn. The intersection of the perpendicular line with the medial tibial cortex is point-A, while the intersection of the axis of the tibia with its perpendicular line is point-C. [The ratio of the lateral portion (the distance from B to C) to the total width (the distance from A to B) is used as the tibial condylar offset.] The tibial condylar offset was measured on a preoperative standing weight-bearing radiograph too.

Preoperatively, the length of the patellar tendon was determined according to the method of Insall-Salvati (1971) on lateral radiographs with the knee flexed 30-60°. A true lateral radiograph was obtained by superimposing one femoral condyle over the other.

We measured the tibial slope angle according to the method of Bonnin (1990) on a lateral radiograph too (the angle between the tangent to the medial tibial plateau and the perpendicular line of the axis of the tibia).

On the 10th postoperative week, the healing of the osteotomy was checked and the femorotibial angle, the distance between the tangent to the lateral subchondral tibial plate and the top of the fibular head and the tibial condylar offset were examined on standing weight-bearing radiographs.

On the 12th postoperative month and at the time of the final follow-up the femorotibial angle, the distance between the tangent to the lateral subchondral tibial plate and the top of the fibular head and the tibial condylar offset were examined again.

On the 10th postoperative week, on the 12th postoperative month and at the time of the final follow-up, the Insall-Salvati ratio and the tibial slope angle were calculated on lateral radiographs again.

The radiological data of the femorotibial angle, the distance between the tangent to the lateral subchondral tibial plate and the top of the fibular head, Insall-Salvati ratio and tibial slope angle were collected, and at the time, at the final follow-up, were compiled prospectively. The data of the tibial condylar offset were recorded and compiled retrospectively.

Statistical analysis was performed using the Student's t-test, the sign test and the Spearman rank order correlation test. P-values below 0.05 were considered significant.

In group A narrowing of the medial joint space was graded according to Coventry's (1993) method: I. joint space narrowing < 50%, II. joint space narrowing > 50%, III. joint space obliteration.

In the 6th postoperative week osteotomy healing was checked and the femorotibial angle was examined.

In group A the Insall-Salvati ratio was calculated, and the femorotibial angle was examined in the postoperative 54,15 (13-96) month too.

Operative technique

The closing wedge osteotomy was performed according to the method of Coventry (1965), but the fibular osteotomy was done at the border of the middle and the distal third of the fibula. The tibial osteotomy was secured by staple.

The combined osteotomy was performed according to a method developed by Papp^{1,2} with an aiming device invented by them.

The patient is supine. Regional anesthesia is used, and the limb is exsanguinated using a pneumatic tourniquet. Prior to tibial osteotomy, a fibular osteotomy was done at the border of the middle and distal third of the fibula through a vertical incision. The proximal tibial osteotomy was performed parallel to the tibial plateau, 2 cm distally to the joint line, through a curved transverse incision. The distal osteotomy was performed

with the help of the aiming device. The result of performing the distal osteotomy was a half bone wedge that was based laterally. This half bone wedge was removed. The distal part of the tibia was placed into the valgus position, so the lateral part of the osteotomy closes and the medial part of the osteotomy opens. The half bone wedge was placed into the gap opened medially. The osteotomy was secured by two staples.

Postoperative care

The postoperative care was similar in both groups. On the first postoperative day, the patients started passive exercises with a continuous passive motion device and active exercises as well. Partial weight-bearing was permitted in the 6th postoperative week and fullweight-bearing in the 10th week.

The clinical assessment of the combined osteotomy

In group A 80 knees (73 patients) were assessed clinically preoperatively and in the postoperative 54,15 (13-96) month.

Clinical assessment was made according to the Lysholm and Gillquist score system of 100 points. Results > 85 points are considered excellent, 70-85 points are good, and < 70 points are poor.

Primary hypothesis and statistical analysis

Many risk factors were analyzed, including: age, preoperative varus deformity, preoperative knee flexion, relative body weight, advanced chondromalacia (grade III) in the medial compartment, previous partial medial menisectomy, undercorrection and overcorrection.

Postoperative femorotibial angle > 171° (on the standing weight-bearing anteroposterior radiograph at 10th postoperative) was considered undercorrection and femorotibial angle < 169° was considered overcorrection.

A relative body weight was calculated using the following equations: Height of the patient in cm – 100 = normal (ideal) body weight in kp. (N). Relative body weight = [(body weight of the patient in kp. – N) / N] x 100. The high relative body weight (> 1,25 ideal body weight) was considered overweight.

We hypothesised that age, preoperative varus deformity, preoperative knee flexion would not influence the clinical result. However we hypothesised that being overweight, having advanced chondromalacia (grade III) in the medial compartment, previous partial medial menisectomy and insufficient correction of the femorotibial angle (undercorrection and overcorrection) would be associated with poor clinical outcome.

The paired t test was used to analyze parametric data. F-test was used to analyze ratio variances. P<0,05 were considered significant.

Results

In group-A, of the 80 osteotomies, 78 healed by the 10th week, 1 healed by the 18th week. There was a nonunion in one case due to collapsing of the half bone wedge placed medially. This nonunion was refreshed and a wedge of bone of appropriate size

obtained from the iliac crest, was inserted into the gap medially. The osteotomy was fixed by L-shaped plate. On the 12th week after revision the osteotomy was healed.

In group-B all osteotomies healed by the 10th week.

The peroneal nerve palsy and anterior compartment syndrome were not noted in our study. Intraarticular fracture, intraarticular position of staples and deep infection were not observed.

In group-A, four deep vein thromboses were detected as general complication. In group-B, one deep vein thromboses was noted. In group-A, the revision rate was 1.25% and in group-B, it was 0%.

The angular correction was more in group-A (11.835°) than in group-B (9.465°). The loss of the correction was significant between the 10th postoperative week and the 12th postoperative month in both groups ($P < 0.001$). The loss of the correction was significant between the 12th postoperative month and the time of the final follow-up in both groups ($P < 0.001$).

In group A, the Insall-Salvati ratio remained unchanged in 65% (52/80) of knees and patella infera (an Insall-Salvati ratio of less than 0.8) was noted in two cases.

In group-B, patella infera was detected in two cases.

The tibial slope angle decreased significantly in both groups during the first 10 weeks and between the 10th postoperative week and the 12th postoperative month ($P < 0.001$). In group-A, the tibial slope angle decreased significantly between the 12th postoperative month and the time of the final follow-up ($P < 0.001$). In group-B, the decrease of the tibial slope angle was not significant between the 12th postoperative month and the time of the final follow-up ($P = 0.248$).

The tibial condylar offset increased significantly in both groups during the first 10 weeks ($P < 0.001$). The tibial condylar offset decreased significantly in both groups between the 10th postoperative week and the 12th postoperative month ($P < 0.001$). In group-A the tibial condylar offset decreased significantly between the 12th postoperative month and the time of the final follow-up ($P < 0.001$). In group-B, the decrease of the tibial condylar offset was not significant between the 12th postoperative month and the time of the final follow-up ($P = 0.479$).

The distance between the tangent to the lateral subchondral tibial plate and the top of the fibular head decreased significantly in both groups during the first 10 weeks, between the 10th postoperative week and the 12th postoperative month and between the 12th postoperative month and the time of the final follow-up ($P < 0.001$).

In group-A, there was correlation between the change of the tibial condylar offset and the angle of correction during the first 10 weeks ($r = -0.828$), between the 10th postoperative week and the 12th postoperative month ($r = -0.343$) and between the 12th postoperative month and the time of the final followup ($r = -0.701$).

In group-B, there was correlation between the change of the tibial condylar offset and the angle of correction during the first 10 weeks ($r = -0.645$) and between the 12th postoperative month and the time of the final follow-up ($r = -0.406$). There was no correlation between the change of the tibial condylar offset and the angle of correction between the 10th postoperative week and the 12th postoperative month ($r = -0.006$).

During the first 10 weeks, there was a correlation between the change of the distance between the tangent to the lateral subchondral tibial plateau and the top of the fibular head and the angle of the correction (in group A- $r = 0.307$, in group B- $r = 0.849$) and there was no correlation between the change of the distance between the tangent to the lateral subchondral tibial plateau and the top of the fibular head and the angle of the correction between the 10th postoperative week and the 12th postoperative month (in group A- $r = 0.084$, in group B- $r = -0.165$) and between the 12th

postoperative month and the time of the final follow-up (in group *A* - $r = -0.060$, in group *B* - $r = 0.163$).

Clinical and radiological results after combined osteotomy

The mean preoperative Lysholm and Gilquist score was $65,375 \pm 4,382$ (range: 56-76) and it was $83,625 \pm 9,689$ (range: 64-98) at final follow-up. This change was statistically significant. ($P < 0,001$, $F = 4,889$)

The result was excellent in 35 (44%) good in 36 (45%) and poor in 9 (11%) knees.

The mean preoperative femorotibial angle was $181,75 \pm 3,037$ (range: 179-192). The mean postoperative femorotibial angle (on the standing weight-bearing anteroposterior radiograph at 10 weeks postoperative) was $169,925 \pm 1,111$ (range: 168-173). This change was statistically significant. ($P < 0,001$, $F = 7,473$)

Of the 80 knees, 67 was corrected to between the desired 171° and 169° of femorotibial angle (on the standing weight-bearing anteroposterior radiograph at 10 weeks postoperative). 8 were corrected to $> 171^\circ$ of the femorotibial angle (undercorrected knees) and 5 were corrected to $< 169^\circ$ of femorotibial angle (overcorrected knees).

Between the 10th postoperative week and 12th postoperative month, a loss of correction was detected in every case (on the standing weight-bearing anteroposterior radiograph). The loss of correction was 1° in 68 cases, 2° in 10 cases, and 3° in 2 cases. Between the 12th month and final follow-up, additional loss of correction was noted only in cases of gradual progression of the arthrosis of the medial compartment. However the recurrence of varus deformity was not noted, and the valgus alignment did not increase in any case.

The Insall-Salvati ratio remained unchanged in 65% ($n = 52$) of the knees after combined osteotomy. The Insall-Salvati ratio decreased in 35% ($n = 28$) of the knees, but patella infera (with ratio $< 0,8$) was detected only in 2 cases.

The knee flexion changed from $128,31 \pm 3,176$ (range: 120-135) to $127,37 \pm 3,233$ (range: 120-135). This change was not statistically significant. ($p = 0,966$, $F = 1,035$)

Patient age did not influence clinical outcome (estimated value: $r = -0.11$).

Preoperative alignment did not affect the clinical results (estimated value: $R = -0.06$)

Preoperative knee flexion did not influence the clinical outcome (estimated value: $r = -0.02$). Overcorrection (femorotibial angle $< 169^\circ$) did not affect the clinical results (estimated value: $r = -0.09$)

Being overweight, having chondromalacia grade III in the medial compartment, previous partial medial meniscectomy, and undercorrection (femorotibial angle $> 171^\circ$) correlated with poor clinical outcome. (estimated values: $r = -0.56$, $r = -0.65$, $r = -0.57$, $r = -0.24$ respectively)

Discussion

The goal of the high tibial osteotomy is to correct the femorotibial angle and to redistribute the tibial plateau forces. There is some disagreement concerning the correct postoperative alignment of the knee, but most authors recommend an overcorrection of 2-10°. (Coventry 1993)

In majority of cases the loss of the osseous correction can be detected after high tibial osteotomy. The loss of the osseous correction can start shortly after the high tibial osteotomy indicating an insufficient osteotomy fixation. After bone healing, the progression of the

gonarthrosis and the inadequate compensation of the adduction moment forces can lead to the loss of the osseous correction. (Prodromos 1985)

The overcorrection can protect the recurrence of the varus deformity and the progression of the arthritic process of the knee. The correction of the varus deformity reduces the adduction moment forces. Rigid fixation may decrease the incidence of the loss of the osseous correction. Maintaining the medial cortex is decisive for primary stability of the osteotomy. If the medial cortex is cut another medial implant is necessary to ensure sufficient primary stability.

Considerable overcorrection can start arthritic process in the lateral compartment and can also be undesirable cosmetically. The extreme overcorrection overloads the lateral compartment, which leads to the increase of the valgus deformity. (Hernigou 1987)

If the considerable lateral ligamentous laxity is present, the component of the varus alignment due to abnormallateral joint opening should be subtracted to avoid the extreme overcorrection. On a supine non weight-bearing radiograph, the effects of lateral ligamentous laxity are not apparent; therefore, in cases of the abnormal slackness of lateral ligaments we measured the preoperative femorotibial angle (as Dugdale 1992 and Ogata 1991 recommended) on supine non weight-bearing radiographs.

On the ground of these considerations we aimed to correct between 171° and 169° of femorotibial angle ($4-6^{\circ}$ of overcorrection).

In groups A and B, the recurrence of varus deformity was not noted because:

- in majority of cases we performed high tibial osteotomies in early stages of the gonarthrosis;
- the combined osteotomy secured by two staples and the closing wedge osteotomy secured by maintained medial tibial cortex and lateral staple with average overcorrection of 5° (in both groups) warrant enough stability to avoid the varus recurrence.

In groups A and B, the valgus alignment did not increase in any case because in cases of abnormal slackness of lateral ligaments we measured the preoperative femorotibial angle on supine anteroposterior radiographs.

In groups A and B, malalignment at the time of the final follow-up was not noted, which can compromise the likelihood of successful conversion to the subsequent total knee replacement.

The distance between the tibial tubercle and the joint line is decreased due to closing wedge osteotomy, creating redundancy in the patellar tendon. Scarring in this region may cause the patellar tendon to attach at the site of the osteotomy. The patellar tendon is shortened and it contracts. New bone formation during healing of the osteotomy also may cause contracture of the patellar tendon.

Scuderi (1989) reported considerable shortening of the patellar tendon and high incidence of patella infera after closing wedge osteotomy. Their patients were treated with postoperative immobilization.

Using early mobilization and rigid internal fixation, the incidence of the shortening of the patellar tendon and the incidence of patella infera can be decreased.

Our patients started passive exercises with a continuous passive motion device and active exercises on the first postoperative day in both groups. We did not apply any cast.

The combined osteotomy prevented the shortening of the patellar tendon (measured by Insall-Salvati ratio) in 65% (52/80) of the cases because: In contrast with the closing wedge osteotomy after combined osteotomy there is not metaphyseal bone loss in the central part of the tibial head, so the distance between the tibial tubercle and the joint line does not change (no redundancy of the patellar tendon). In contrast with the closing wedge osteotomy, at combined osteotomy, the distal osteotomy can always be performed proximally to the tibial tubercle (less new bone formation).

Using the early mobilization, the closing wedge osteotomy prevented the developing of the patella infera in majority of cases (39/41) too.

The tibial slope angle did change mainly during the first year in both groups, it did not change considerably after the first year, either in group-A or in group-B.

Nakamura (2001) and Cullu (2005) reported considerable decreasing of the tibial slope angle after dome osteotomy. We compared the data from this study with Nakamura's and Cullu's results and stated that after dome osteotomy the tibial slope angle decreased more than after combined osteotomy.

The high tibial osteotomy inevitably produces some transposition of the tibial condyle with respect to its bony axis.(Nakamura 2001) The transposition of the tibial condyle leads to difficulty in obtaining of appropriate alignment and in optimal positioning of the tibial component during total knee replacement after osteotomy.

For measuring this transposition, we calculated the tibial condylar offset according to the method of Yoshida. (1987)

There was correlation between the change of the tibial condylar offset and the angle of the correction in both groups. The tibial condylar offset changed mainly during the first 10 weeks in both groups.

After combined osteotomy, the transposition of the tibial condyle was less than after closing wedge osteotomy although the average angle of correction was more after combined osteotomy (11.835°) than after closing wedge osteotomy (9.465°). Yoshida (1987) reported that after dome osteotomy, the tibial condylar offset increases more than after closing wedge osteotomy.

The greater the distance, between the center of the deformity and the center of the correction, the greater the transposition of the tibial condyle.

The tibial condylar offset changes less after combined osteotomy than after closing wedge osteotomy because at combined osteotomy, the center of the correction is the center of the tibial condyle, while at closing wedge osteotomy, it is the medial cortex of the tibial condyle.

Theoretically (we have not performed total knee replacement after combined osteotomy), the combined osteotomy causes less difficulty in optimal positioning of the tibial component during the subsequent total knee replacement than the closing wedge osteotomy.

To assess the amount of the lateral tibial bone loss after osteotomies, we measured the change in the distance between the tangent to the lateral tibial subchondral plate and the top of the fibular head.

There was correlation between the amount of the lateral tibial bone loss and the angle of the correction in both groups. This distance decreased mainly in the first 10 weeks in both groups. The distance decreased more after closing wedge osteotomy than after combined osteotomy, because for performing the same correction at combined osteotomy, a bone wedge must be removed, which is half the size of the removed wedge at closing wedge osteotomy. After combined osteotomy the decrease in the distance between the tangent to the lateral tibial plate and the top of the fibular head was less than after closing wedge osteotomy although the average angle of correction was more after combined osteotomy (11.835°) than after closing wedge osteotomy (9.465°).

Theoretically (we have not performed total knee replacement after combined osteotomy), the combined osteotomy makes the lateral bone resection and the restoring of the preosteotomy position of the lateral joint line less difficult than closing wedge osteotomy during the subsequent total knee replacement.

Disadvantages of the combined osteotomy

- There was significant loss of the osseous correction after combined osteotomy during

the first year (although there was no varus recurrence).

- In contrast to hemicallotasis at combined osteotomy, there is no possibility to modify the angular correction after operation during the bonehealing period.
- In contrast to the focal dome osteotomy (Paley 1994), there was transposition of the tibial condyle after combined osteotomy.
- In contrast to the dome and opening wedge osteotomy (including hemicallotasis), there was lateral tibial bone loss after combined osteotomy.

Advantages of the combined osteotomy

- Similar to the dome osteotomy and in contrast to the closing wedge osteotomy and opening wedge osteotomy considerable correction can be achieved with combined osteotomy.
- There was no shortening of the patellar tendon in 65% (52/80) of cases after combined osteotomy.
- The decrease of the tibial slope angle is less after combined osteotomy [according to the literature (Nakamura 2001, Cullu 2005)] than after dome osteotomy.
- The transposition of the tibial condyle is less after combined osteotomy than after closing wedge osteotomy, although the average angle of correction was more after combined osteotomy (11.835°) than after closing wedge osteotomy (9.465°) and (according to the literature Yoshida 1987) after dome osteotomy.
- The lateral tibial bone loss is less after combined osteotomy than after closing wedge osteotomy although the average angle of correction was more after combined osteotomy (11.835°) than after closing wedge osteotomy (9.465°).

We found along with others (Insall 1984, Coventry 1993) that patient age, preoperative alignment, and preoperative knee flexion did not affect clinical outcome.

We found that a high relative body weight was associated with poor clinical results. Our results agree with those of Coventry (1993). This finding is in contrast with opinion of Naudie (1999).

The clinical outcome of our study was better in early (grade I-II) rather than late (grade III) stages of chondromalacia of the medial compartment. Our results agree with those of Coventry (1982) and Yasuda (1992).

Naudie (1999) did not find a significant association between previous partial or total medial meniscectomy and failure rates of high tibial osteotomy. In our study the previous partial medial meniscectomy was associated with poor clinical results. Our results agree with those of Noyes (2000).

Overcorrection protects from the recurrence of varus deformity in most cases, but considerable overcorrection can start the arthritic process in the lateral compartment and also can be undesirable cosmetically. Therefore, the goal of correction was between 171° and 169° of femorotibial angle. In our study undercorrection was associated with a poor result but overcorrection (femorotibial angle $< 169^{\circ}$) did not influence the clinical outcome.

Statistical analysis confirmed that patient age, preoperative varus deformity, preoperative knee flexion, and overcorrection (femorotibial angle $< 169^{\circ}$) did not influence clinical results.

Based on the statistical analysis, being overweight, chondromalacia grade III in the medial compartment, previous partial medial meniscectomy, and undercorrection (femorotibial angle $> 171^{\circ}$) were identified as considerable risk factors.

In the absence of these considerable risk factors, results were excellent or good in

every case.

Analysis of risk factors suggests that careful patient selection (preoperative reduction of body weight, meniscus refixation instead of meniscectomy) and sufficient correction of the femorotibial angle can improve clinical results.

Finally, we can state that in groups A and B, malalignment at the time of the final follow-up was not noted, which can compromise the likelihood of successful conversion to the subsequent total knee replacement.

The combined osteotomy does not lead to considerable transposition of the tibial condyle and to considerable lateral tibial bone loss; therefore, theoretically, the combined osteotomy does not impair the subsequent total knee replacement.

Summary

High tibial osteotomy changes the patella and tibial condyle position, which makes the subsequent total knee replacement technically demanding. Our aim was to develop an osteotomy, which does not considerably change the position of the tibial condyle and the position of the patella.

From 1 January 1993 to 31 December 2000, combined osteotomy [After the first osteotomy made 2 cm distally to the joint line, a bone wedge is removed based laterally. Its tip ends at the center of the proximal osteotomy (half bone wedge). The distal part of the tibia is placed into the valgus position and the half bone wedge is placed into the gap opened medially] was performed on 103 knees and closing wedge osteotomy was performed on 47 consecutive knees. Eighty combined (group A) and 41 closing wedge (group B) osteotomy were studied. All knees were assessed radiologically before surgery, in the 10th postoperative week, in the 12th postoperative month and at the time of the final follow-up (in group A-66.15 months, in group B-66.61 months). We examined the change of the femorotibial angle, of the patellar height according to the method of Insall and Salvati, of the tibial slope angle according to the method of Bonnin, of the tibial condylar offset according to the method of Yoshida and of the distance between the lateral tibial plateau and the top of the fibular head. The clinical assessment was made according to the Lysholm and Gillquist score system of 100 points. Mean follow up was 54,15 months.

In group A and B, the recurrence of the varus deformity was not noted and valgus alignment did not increase in any case. In group A, the Insall-Salvati ratio remained unchanged in 65% of knees. The tibial slope angle decreased in both groups. There was correlation between the change of the tibial condylar offset and the angle of the correction in both groups. There was correlation between the change of the distance between the lateral tibial plateau and the top of the fibular head, and the angle of the correction in both groups. After combined osteotomy, the transposition of the tibial condyle and the decrease of the distance between the lateral tibial plateau and the top of the fibular head was less than after closing wedge osteotomy, although the average angle of correction

was more after combined osteotomy (11.835°), than after closing wedge osteotomy (9.465°). In group A the clinical result was excellent in 44%, good in 45%, and poor in 11% of the knees.

Theoretically, the lack of the recurrence of the varus deformity, the increase of the valgus alignment and (in majority of cases) the shortening of the patellar tendon do not compromise the likelihood of successful conversion to the subsequent total knee replacement, either after combined or after closing wedge osteotomy. The combined osteotomy does not lead to considerable transposition of the tibial condyle and to considerable lateral tibial bone loss; therefore, theoretically, the combined osteotomy does not impair the subsequent total knee replacement.

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High tibial osteotomy, femorotibial angle, Insall-Salvati ratio, tibial condylar offset, lateral tibial metaphyseal bone loss, tibial slope angle, Lyshol-Gillquist score.

