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High Tibial Osteotomy for Medial Compartment Osteoarthritis: A Comparison of Clinical and Radiological Results from Closed Wedge and Focal Dome Osteotomies

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This study aimed to evaluate the clinical and radiological results of closed wedge osteotomy (11 knees) and focal dome osteotomy (14 knees) in cases of high tibial osteotomy undertaken for varus knee with medial compartment osteoarthritis. Clinical evaluation was performed using the Knee Society Score and no significant difference was seen between the two groups at final follow-up. Radiological evaluation was made on the basis of the pre- and postoperative mechanical axis, postoperative movement of the tibial axis, loss of correction at final follow-up and patellar height measured using the Insall-Salvati index. Statistically significant differences were seen with focal dome osteotomy compared with closed wedge osteotomy in the Insall-Salvati index at final follow-up, the amount of correction loss and the change in tibial axis location. It is concluded that, in the treatment of medial compartment osteoarthritis by high tibial osteotomy, focal dome osteotomy is more beneficial than closed wedge osteotomy in not creating any additional deformity.

KEY WORDS: Osteoarthritis; Osteotomy; High tibial; Focal dome; Insall-Salvati index; Tibial axis

Introduction

High tibial osteotomy (HTO) is a highly effective procedure in relieving pain, correcting deformity and improving function in cases of medial compartment osteoarthritis (MCOA) of the knee, and can be performed using a variety of techniques that are associated with varying clinical results.[1 – 7] The aim of HTO is to preserve the knee and delay the necessity for total knee arthroplasty (TKA).[8] Although many cases of osteotomy have no need for TKA in the long-term, every case of MCOA is a potential future case for TKA. Therefore HTO should not increase the difficulty of any future procedures that may be undertaken;[8]

primary TKA carried out following HTO has been shown to be more difficult and less successful than where HTO has not been carried out.[9,10] Depending on the osteotomy technique, outcomes such as patella infera, lateral truncation, reduced proximal tibia bone stock, alterations in the joint line and medial displacement of the tibial axis, which can arise for various reasons, play a role in the reduced success of any subsequent TKA.[11]

The most frequently used HTO technique is closed wedge osteotomy, a straightforward and reliable procedure that is performed proximal to the tibial tuberosity, giving correction distal to the apex of the deformity. Paley and Tetsworth,[12] in a detailed analysis of advances in the diagnosis and treatment of lower limb deformities reported that, when osteotomy is performed with the axis of the cylindrical cut centred on the centre of rotation of angulation (CORA), angular correction is achieved without any translation, and this technique was recommended as a new approach for HTO in the treatment of MCOA.[13] This procedure has been named focal dome osteotomy because, when seen from above, it has the shape of a reverse dome distal to the tibial tuberosity, allowing for correction from the centre of the deformity. Studies comparing the functional and radiological outcomes of closed wedge and focal dome osteotomy from a biomechanical point of view are extremely limited.[2,3,5] The present study, therefore, aimed to determine whether there were any differences in the clinical and radiological outcomes between these techniques as a surgical treatment for MCOA.

Patients and methods

PATIENTS AND SURGERY

Between November 1997 and August 2003, patients were evaluated following HTO (closed wedge or focal dome) carried out for varus knee due to MCOA. The surgical indications for HTO were patients who had not responded to conservative treatment, were < 65 years of age with an active lifestyle, had pain in the medial joint line, had lower limb malalignment and MCOA. In patients who underwent closed wedge osteotomy, it was performed proximal to the tibia tuberosity with plate and screws used for fixation. In those who underwent focal dome osteotomy, the size of the tibial plateau was measured on preoperative radiographs and half of this value was accepted as the radius of the circle to be drawn from the centre of the knee joint. The part of the circle passing through the tibia was defined as the osteotomy line. Plate and screws or U-staples were used for fixation of the osteotomy as required. The amount of correction was considered to be sufficient when the mechanical axis was 30 – 40% into the lateral area of the tibial plateau.

After surgery all patients used an adjustable knee splint and were allowed to be mobile on crutches. Partial and then, at approximately 14 weeks, full weight-bearing was permitted according to the results of follow-up radiographs.

As infection prophylaxis, 750 mg cefuroxime sodium was administered intravenously to all patients, the first dose at 2 h prior to surgery and a further three doses at 6, 14 and 22 h postoperatively. Low molecular weight heparin was administered subcutaneously preoperatively and over a 10-day period postoperatively as prophylaxis for thromboembolism.

CLINICAL EVALUATION

Patients were evaluated clinically before and after surgery using the Knee Society Score (KSS) and function score.[14] The preoperative degree of radiological osteoarthritis was assessed according to the Ahlback criteria[15] from orthoradiographs and plain radiographs. The tibial axis and Insall-Salvati index (used to measure the patella height[16]) were measured pre- and postoperatively. The severity of the preoperative deformity and degree of post-operative correction were determined using the mechanical axis, and correction loss was evaluated from postoperative through to final follow-up orthoradiographs.

STATISTICAL ANALYSIS

Values obtained were compared between the closed wedge and focal dome osteotomy groups using paired sample and independent sample *t*-tests. A *P*-value < 0.05 was considered to be statistically significant.

Results

A total of 25 knees of 24 patients were evaluated. Closed wedge osteotomy was performed on 11 (44%) of the knees and focal dome osteotomy on the remaining 14 (56%). Plate and screws were used in all cases following closed wedge osteotomy. Following focal dome osteotomy, plate and screws were used for fixation in two cases and two or three staples were used in the remainder of cases.

Patient characteristics, length of follow-up and the degree of preoperative osteoarthritis for the two groups are given in Table 1, and the clinical and radiological results are given in Table 2.

No statistically significant differences were seen between the postoperative final follow-up results for closed wedge osteotomy and those for focal dome osteotomy in terms of the KSS or function points (Table 2). There was also no statistically significant difference in the amount of correction achieved by the two techniques (Table 2). Statistically significant differences between the two groups were seen, however, in the amount of correction loss at final follow-up and in the postoperative change in the tibial axis, with a significantly smaller correction loss ($P < 0.05$) and tibial axis change ($P < 0.05$) being seen after focal dome osteotomy than after closed wedge osteotomy (Table 2). A typical radiograph of the situation preoperatively compared with after focal dome osteotomy is shown in Fig. 1.

TABLE 1:
Characteristics, length of follow-up and degree of preoperative osteoarthritis in patients undergoing high tibial osteotomy for medial compartment osteoarthritis

	Closed wedge osteotomy	Focal dome osteotomy
Number of patients	10	14
Number of knees	11	14
Gender		
Female	7	13
Male	3	1
Age (years)	52 (30 – 63)	53 (28 – 66)
Follow-up period (months)	52.4 (24 – 84)	35.8 (12 – 60)
Degree of osteoarthritis		
Grade 1	4 (36.4%)	4 (28.5%)
Grade 2	6 (54.5%)	8 (57.1%)
Grade 3	1 (9.1%)	2 (14.3%)

Results are given as the number or the mean (and range) as appropriate.

TABLE 2:
Clinical and radiological results in patients undergoing high tibial osteotomy for medial compartment osteoarthritis

	Closed wedge osteotomy	Focal dome osteotomy	*P*-value
Knee Society Score			
Preoperative	60.9 (55 – 65)	66.8 (55 – 80)	NS
Postoperative	90.9 (85 – 100)	94.4 (85 – 100)	NS
Function score			
Preoperative	62.7 (55 – 70)	70.0 (65 – 80)	NS
Postoperative	90.9 (85 – 100)	89.2 (65 – 100)	NS
Mechanical axis			
Preoperative	9.45 ° varus (8 – 14 ° varus)	10.7 ° varus (6 – 20 ° varus)	NS
Postoperative	2.7 ° valgus (0 – 6 ° valgus)	4.9 ° valgus (2 – 10 ° valgus)	NS
Deformity correction	12.2 ° (8 – 15 °)	14.8 ° (6 – 22 °)	NS
Correction loss immediate postoperative to final follow up	4.4 ° (0 – 12 °)	1.9 ° (0 – 9 °)	< 0.05
Tibial axis change (mm)	4.2 (2 – 6)	0.6 (0 – 2)	< 0.05
Insall-Salvati index			
Preoperative	0.91 (0.8 – 1.05)	0.95 (0.8 – 1.1)	NS
Postoperative	0.78 (0.7 – 1.0)[a]	0.98 (0.8 – 1.1)	< 0.05

Results are given as the mean (and range). NS, not significant ($P > 0.05$).
[a]$P < 0.05$ compared with preoperative value.

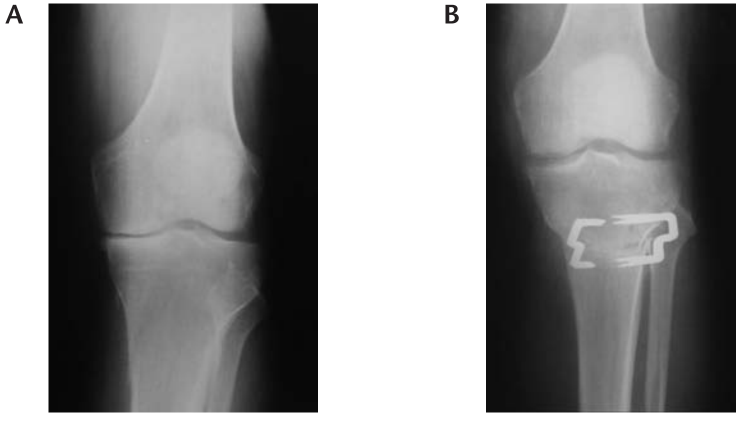

FIGURE 1: Radiographs of the left knee in a 54-year old male with medial compartment osteoarthritis. (A) Preoperative standing anterior–posterior radiographs showing medial joint space narrowing and varus deformity. (B) Standing anterior–posterior radiographs 46 months postoperative to focal dome osteotomy with fixation by three U-staples showing union on the osteotomy line and adequate correction of the varus deformity

There was a statistically significant difference between the pre- and postoperative Insall-Salvati index following closed wedge osteotomy ($P < 0.05$), but not after focal dome osteotomy. The difference in the Insall-Salvati index between the two groups was also statistically significant post-operatively ($P < 0.05$) (Table 2).

With regard to complications, there was one case in each group with delayed union. One patient who underwent closed wedge osteotomy developed a superficial infection and one who underwent focal dome osteotomy had peroneal nerve damage, which recovered spontaneously. Throughout the follow-up period, no patient required TKA.

Discussion

Osteotomies are one of the oldest approaches in orthopaedic surgery for correcting lower limb deformity.[17] The technique most widely used today is HTO, which is performed with the aim of reducing deformity caused by the occurrence of MCOA in the knee, one of the most frequently seen indications for corrective osteotomy.[8]

Following the first report of HTO by Jackson in 1958,[18] there were several studies of osteotomy performed distal to the tibial tuberosity.[19] Over the next 10 years the Coventry approach involving HTO proximal to the tibial tuberosity became much more widely accepted following its publication in 1965.[3,5,8,13] Although the clinical results of this technique were fairly good short-term, they worsened over the longer term; this, together with advances in arthroplasty, gave rise to a greater number of total knee replacements being performed.[20]

The selection of specific treatments for MCOA should take into consideration the patient, the disease and the joint characteristics.[1] HTO applied with the correct technique to a suitable patient is the basis for a successful result. The generally accepted criteria for suitable patients for HTO are men < 60 years of age and premenopausal women, a high level of daily activity or those with occupationally related diseases, non-inflammatory MCOA, and stability of the joint without subluxation ≥ 90° flexion and < 15° flexion deformity.[1] The patients in the present study met these criteria.

Advanced detailed analyses of the definition of lower limb deformities, their diagnosis and treatment have brought new approaches to the fore in corrective surgery. Although it is generally accepted that Coventry osteotomy is inappropriate where there is lateral collateral instability, lateral subluxation, medial plateau depression, flexion < 90° and deformity flexion of > 10°, and lateral compartment osteoarthritis, Paley *et al.*[13] recommended that these should not be taken as absolutes: in the treatment of MCOA there should be an *'à la carte'* approach, with each case being considered according to the state of the deformity.

Many different measurements are used in the analysis of lower limb deformity. Generally, the degree of deformity and the amount of correction following HTO are evaluated according to the anatomical or mechanical axis. In the past, when evaluating lower limb alignment, it was usual to use the anatomical femoral–tibial angle (between the femur and the tibial anatomical axis), whereas today the angle between the femur and the tibial mechanical axis is more often preferred.[13,14] Using measurements of the degree of deformity and the postoperative amount of correction has been shown to give a fairly accurate evaluation of clinical results.[3] The normal position of the tibial mechanical axis would be 0° but, when there is MCOA, there is a shift to a varus position. Although there is no consensus as to how many degrees of correction are necessary in HTO, good clinical results have been obtained with an angle of 2 – 8 ° valgus.[21,22]

A successful osteotomy should not create any other deformity in the bone on which it is performed. In a study of lower limb deformity by Paley and Tetsworth,[12] osteotomy performed from the apex of the deformity (centred on the CORA) only corrected the deformity whereas, when carried out proximal or distal to the CORA, translation developed on the tibia. If there is medial translation and truncation there will be difficulties in any future TKA, as a specially designed component will be necessary and will have to be placed very much to the lateral side.[2]

In Coventry and Maquet osteotomies, the correction is distal to the CORA so, although the lower limb mechanical axis is corrected, there is also a change in the tibial axis. In theory this change is less in a Coventry osteotomy than a Maquet as it is closer to the CORA. However, no change in the tibial axis is expected from a focal dome osteotomy as it is performed centred on the CORA.[8,13]

In a study of HTO by Adili *et al.*,[3] the femoral–tibial angles were 9.4 ° and 7.9 ° after Coventry osteotomy (n = 15) and osteotomy distal to the tibia tuberosity (n = 17), respectively. The mean mechanical axis in the latter group was 32.2 mm medial preoperatively and 4.9 mm lateral postoperatively. The latter group also had significantly better pain and function results. Sen *et al.*[2] compared the results of 26 cases of closed wedge osteotomy (mean follow-up 77 months) with 27 cases of focal dome osteotomy (mean follow-up 72 months): there was a total movement in the mechanical axis of mean 28 mm (from 30 mm medial to 2 mm medial) in the closed wedge osteotomy group and a total movement of mean 44 mm (from 32 mm medial to 12 mm lateral) in the focal dome osteotomy group. The focal dome group also had significantly better postoperative Hospital for Special Surgery Knee Scoring System points. In the present study, the mean postoperative measurements of the mechanical axis were 2.7 ° valgus in the closed wedge osteotomy group and 4.9 ° valgus in the focal dome osteotomy group. Moreover, in contrast to the closed wedge group, the very small alteration achieved in the tibial axis of the focal dome group had a positive effect on the correction of the mechanical axis. This leads us to the opinion that focal dome osteotomy gives a biomechanical advantage by effectively correcting the deformity without creating any new deformity, which will be of benefit if a TKA were to be required in the future.

Although HTO is intended to correct the defective mechanics occurring as a result of MCOA, the degenerative changes in the joint are not solely biomechanical; therefore elimination of the mechanical problem will not necessarily completely halt the progression of osteoarthritis, but there can be a slowing down effect.[23]

When the appropriate angle of correction is achieved with HTO on suitable patients, the need for TKA can be postponed.[24] Studies examining the length of survival of HTO have put it at an average of 6 – 10 years.[4,25] HTO is, therefore, usually used as a holding procedure, with most cases requiring TKA at a later stage.[11] It is, therefore, important to give careful consideration to the potential complications following HTO and especially to the effect they will have on any future arthroplasty.[4] Problems following HTO, such as truncation in the proximal tibia, reduced bone stock, patellofemoral incongruence and difficulties with patella eversion due to patella infera will make subsequent TKA procedures much more difficult, yielding worse results than primary TKA. It might, therefore, be more accurate to compare cases of TKA after HTO with revision rather than primary TKA.[6,9,10]

Depending on the HTO technique, patella infera occurs at a rate of 0 – 80% and creates particular difficulties with patella eversion and exposure of the proximal tibia during TKA.[26] Several measures are used to determine patella height, including the Insall-Salvati, Blackburne-Pell and Caton-Deschamps indices.[16,27,28] In a study by Kaper *et al.*[4] of closed wedge osteotomy on 47 knees, the results from an average of 47 months' follow-up showed a frequent occurrence of post-HTO reduced posterior inclination of the tibia. As the Blackburne-Pell index measures the tibia proximal articular surface, it is not reliable in these cases and it is, therefore, recommended that the Insall-Salvati index be used to evaluate patellar height after HTO.

In a study of HTO cases using the Maquet technique, Noda *et al.*[6] reported a statistically significant reduction in the Insall-Salvati index. In another study evaluating clinical results using the Insall-Salvati index, postoperative patella infera was seen in 12 out of 26 cases of closed wedge osteotomy but in none of the 27 cases of focal dome osteotomy.[5] In the present study, evaluations made using the Insall-Salvati index showed that the change in patella height from preoperative to final follow-up was statistically significant in the closed wedge osteotomy group, but not in the focal dome osteotomy group.

Although the development of patella infera is a well-known problem following HTO, the reasons for its occurrence are not yet fully understood.[4] It has been suggested that it is caused by the development of scar tissue and arthrofibrosis on the patellar tendon as a result of the surgery and immobilization.[26] Stable fixation and early movement of the joint are known to help prevent major changes in patellar tendon length.[26] Kaper *et al.*[4] reported a reduced patellar height of ≥ 10% in eight out of 16 patients (50.0%) with rigid fixation and an early start to movement, and in 17 out of 30 patients (56.7%) with internal fixation and a late start to movement.

Whichever technique is used for HTO, there are several means to achieve stability. The basic aim of any method of fixation is to prevent loss of correction and loss of movement in the joint while the osteotomy heals. The most frequently used method of fixation for HTO is U-staples as they are simple and quick to apply. When closed wedge osteotomies were first performed a single staple was used but nowadays two to three staples are preferred for increased stability. In a cadaver study evaluating fixation methods of primary stability, Flamme *et al.*[29] found that an external fixator and U-staples provided the greatest stability. A circular external fixator is usually preferred in focal dome osteotomies, as used by Sen *et al.*,[2] to achieve a gradual correction, thus helping union, early movement and weight-bearing. However, the use of an external fixator is associated with the disadvantages of increased cost, the necessity of frequent clinical observation, reduced patient comfort, screw site infection, nerve damage and the use of antibiotics. In a study by Adili *et al.*[3] comparing the results of closed wedge osteotomy proximal to the tibial tuberosity without external fixation and osteotomy distal to the tibial tuberosity plus external fixation, the mean length of surgery in the former group was 52 min whereas for the group with external fixation it was 99 min; four of the latter group developed stiffness in the ankle.

To our knowledge there are no published studies of focal dome osteotomy with fixation by U-staples. At the end of the follow-up period in the present study, patients in whom staples had been used showed very minor changes in correction loss from immediately postoperative to final follow-up. The use of U-staples was also simpler and gave fewer complications, therefore a lower cost compared with Ilizarov circular fixation. We believe the insignificant loss of correction was due both to the use of U-staples and to the surgical technique of focal dome osteotomy, which allows freedom of movement to achieve the desired angle of correction.

In conclusion, the results of the present study suggest that, when performing HTO for MCOA, preference should be given to the surgical procedure of focal dome osteotomy with two or three U-staples for fixation; this technique produces no additional deformity in the proximal tibia and protects the bone stock whilst achieving an adequate angle of correction with no change in the patella height.

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Conflicts of interest

No conflicts of interest were declared in relation to this article.

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