Changes in osseous correction after proximal tibial osteotomy

Radiostereometry of closed- and open-wedge osteotomy in 33 patients

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33 patients (22 men), median age 54 (40–68) years, with medial gonarthrosis grades 1–3, were treated by closed-wedge osteotomy (high tibial osteotomy = HTO, n 16) or open-wedge osteotomy by hemicallotasis (hemicallotasis osteotomy = HCO, n 19).

2 patients were operated on bilaterally. The patients were studied by RSA (radiostereometric analysis) for measuring 3-D changes in the correction achieved. In the HTO group the RSA measurements were obtained at the time of plaster removal, 1 month later and 1 year after surgery. In the HCO group, the RSA measurements were performed at the time of removal of the external fixator, 1 month later and 1 year after surgery.

After removal of the fixation, HTO was associated with increased medial/lateral and distal translation of the proximal segment, compared to HCO. In addition, the tibial plateau rotated more around the longitudinal axis of the tibia after HTO.

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Medial gonarthrosis of the knee joint is associated with varus deformity in most cases. The closed-wedge osteotomy is a treatment recommended for the younger and active patient (Coventry and Bowman 1982, Hernigou et al. 1987, Koshino et al. 1989, Coventry et al. 1993). Earlier studies have shown that the long-term result depends on the degree of correction achieved after bone healing. A slight over-correction gives the best short- and long-term results (Kettelkamp et al. 1976, Valenti et al. 1990, Odenbring et al. 1991, Coventry et al. 1993). Various techniques for fixation of the osteotomy had been described, including plaster fixation, orthoses, combinations of staples, plates and external fixation (Ivarsson and Larsson 1989, Koshino et al. 1989, Miniaci et al. 1989, Yasuda et al. 1992, Zuegel et al. 1996).

In many cases, loss of the osseous correction implies a poorer clinical result (Hernigou et al. 1987, Odenbring et al. 1991, Coventry et al. 1993). In some, this process starts shortly after the operation, indicating an insufficient osteotomy fixation. In others this process starts after clinical bone healing and might depend on progression of the gonarthrosis or an inadequate compensation of the adduction moment forces acting on the knee (Prodromos et al. 1985, Wang et al. 1990).

During the few last years, angular correction by hemicallotasis has gained interest as a valid alternative (Fowler et al. 1991, Elting and Hubbell 1993, Magyar et al. 1998). Clinically, it is difficult to decide when the bone has healed sufficiently for removal of the external fixator, without any risk of a substantial loss of correction.

We determined the 3-dimensional changes in the osseous correction achieved during the first year after tibial osteotomy with the closed-wedge and the progressive opening-wedge techniques.

Patients and methods

33 patients (22 men), median age 54 (40–68) years, with medial gonarthrosis grades 1–3 (Ahlbäck 1968), were studied with RSA (radiostereometric analysis). The patients were randomized to closed wedge tibial osteotomy (high tibial osteotomy, HTO, n 16) or progressive opening wedge osteotomy by callus distraction (hemicallotasis osteotomy, HCO, n 19) in a prospective and con-

secutive study on osteotomy techniques. 2 patients were operated on bilaterally and were randomized to HTO on one side and HCO on the other. The operations were performed in two seances of 2 and 6 months, respectively, between the procedures. The randomization was made before the study started and the results were put in closed and numbered envelopes. An envelope was opened, in numerical turn, just before the operation, and the operative technique stated in the envelope was used. The Ethics Committee of Lund University approved the study, and the patients consented to participate.

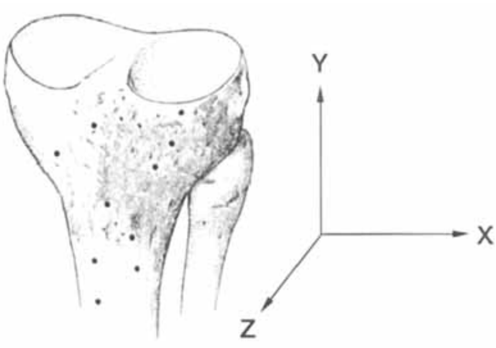
The indication for operation was medial gonarthrosis grades 1–3 (Ahlbäck 1968), and the aim of the study was to evaluate the clinical and radiographic results.

In the HTO group, there were 12 men and 3 women having a median age of 53 (40–68) years, a height of 177 (162–192) cm and a weight of 92 (62–108) kg. In the HCO group, there were 10 men and 8 women having a median age of 55 (40–64) years, a height of 175 (156–194) cm and a weight of 89 (60–113) kg. There were no differences between the groups concerning gender, age, height, weight or grade of gonarthrosis.

The preoperative median HKA angles were 170 (164–176)° in the HTO group and 172 (168–179)° in the HCO group ($p = 0.07$), varus defined as $< 180°$. The osseous correction in the HTO group was measured as the difference between the preoperative and postoperative tibial plateau angle (PT angle = angle between the tibial condyles and the tibial anatomical axis in the frontal plane). Radiographs for postoperative PT angles were obtained the day after surgery. In the HCO group, the HKA angle at the time of the completed correction was compared to the preoperative HKA angle for evaluation of the angular change obtained.

Surgery

HTO. A cylindrical bone resection was made in the collum fibulae. The tibial osteotomy was done 2–2.5 cm below the knee joint with a reciprocal saw, using the Tjörnstrand guide instrument (Odenbring et al. 1989), aiming at a correction of 4° valgus. After removing the bone wedge, the gap was closed and stabilized with a long-stepped bone staple (Howmedica) (Odenbring 1991). The wound was closed and a plaster cast applied. The patient was allowed weight bearing immediately. The cast was kept on for median 44 (36–94) days.



Tantalum markers (•) in proximal tibia and 3-D coordinate system.

HCO. The Orthofix OF-Garche (Orthofix Srl, Bussolengo, Italy) fixator was used. The fixator was attached to the tibia by four threaded cortical pins. The osteotomy was performed, slightly obliquely at the level of the distal third of the tibial tuberosity. A reciprocal saw was used and the osteotomy extended to about the medial 3/4 of the tibial circumference. This left intact the lateral cortex, which acted as a hinge during the distraction phase. No fibular osteotomy was performed. The patient was allowed immediate weight bearing and the median fixation time was 90 (61–146) days.

RSA. During operation, preparation for RSA was done in both groups by inserting tantalum markers proximal and distal to the osteotomy site. The tantalum markers represent distinct points for radiographic studies (Figure). The radiographic examination was performed with the knee in a calibration cage, marked with tantalum balls for defining a 3-dimensional coordinate system. Radiographs in different planes make it possible to stereometrically determine the tantalum markers in the extremity in relation to the coordinate system of the cage, thus permitting detection of 3-dimensional movements, translations and rotations, between two different investigations (Selvik 1989). The motion of the proximal segment of tantalum markers was measured in relation to the distal segment.

The Maximal Total Point Movement (MTPM) represents the 3-dimensional vector for the tantalum marker that moved most in any direction during the entire series.

The accuracy of RSA was evaluated by double measurements in 15 patients randomly selected from the two groups. After the initial investigation, patients were allowed to move around for 30 minutes before a second investigation. Patient-specific differences between the two RSA measurements were used to assess its accuracy, here presented using measurement error limits, which include at least 95% of the measurement errors.

In the HTO group, the RSA investigations were obtained at the time of plaster removal, 1 month later and 1 year after surgery. In the HCO group, the RSA investigations were performed at the time of removal of the external fixator, 1 month later and 1 year after surgery. The results 1 month after completion of fixation and after 1 year were used for comparisons between the groups.

Statistics

Age, weight, height and HKA angles are presented as median (range). RSA data are presented as mean (95% confidence limits of the means). The Wilcoxon signed rank test was used for analyses within groups. The Mann-Whitney test and the (M)ANOVA test was used for comparing the groups. Fisher's exact test was used to compare the proportions of postoperative corrections between the groups.

Table 1. HKA angles in the HTO and the HCO groups. Median (range)

	HTO	HCO	P-value
Preoperative	170 (164–176)°	172 (168–179)°	0.07
Postoperative	182 (178–187)°	183 (182–187)° [a]	0.7
1 year	182 (175–193)°	184 (180–190)°	0.4

[a] The HKA angle was calculated from the peroperative change in the PT angle

Table 2. RSA in both groups. Mean mm (translations, MTPM), mean° (rotations), (95 % confidence limits of means)

	HTO	HCO	P-value
1 month			
X-translation	1.3 (-0.2–2.7)	0.0 (-0.2–0.3)	0.004
Y-translation	-1.9 (-3.2– -0.5)	0.1 (-0.4–0.5)	< 0.001
Z-translation	0.2 (-0.9–1.2)	-0.2 (-0.7–0.2)	0.9
X-rotation	1.1 (-0.6–2.7)	-0.8 (-1.9–0.2)	0.07
Y-rotation	1.1 (-0.2–2.4)	0.1 (-0.2–0.3)	0.02
Z-rotation	2.8 (1.1–4.5)	-0.2 (-0.8–0.4)	0.09
MTPM	4.1 (2.7–5.4)	0.7 (0.1–1.3)	< 0.001
1 year			
X-translation	1.3 (-0.2–2.7)	0.0 (-0.2–0.3)	0.006
Y-translation	-1.9 (-3.3– -0.6)	0.1 (-0.4–0.5)	< 0.001
Z-translation	0.3 (-0.7–1.3)	-0.2 (-0.6–0.1)	0.9
X-rotation	1.6 (-0.1–3.2)	-0.7 (-1.8–0.3)	0.20
Y-rotation	1.5 (0.4–2.6)	0.0 (–0.1–0.1)	0.02
Z-rotation	3.0 (1.4–4.6)	0.0 (-0.6–0.6)	0.2
MTPM	4.1 (2.6–5.5)	1.0 (0.4–1.6)	< 0.001

Results

The postoperative median alignment in the HTO group was 182 (178–187)°. In the HCO group, the postoperative median alignment was 183 (182–187)° (Table 1). 11/16 in the HTO group and 18/19 in the HCO group were corrected to an interval of 182–186° ($p = 0.07$). The median HKA angles at the 1 year follow up were 182 (175–193)° in the HTO group and 184 (180–190)° in the HCO group (Table 1). At the 1-year evaluation, 7/16 in the HTO group and 16/19 in the HCO group were within the interval of 182–186° ($p = 0.02$).

The RSA variables are presented in Table 2. In the HTO group the proximal fragment was displaced –1.9 (–3.2 to –0.5) mm after 1 month and –1.9 (–3.3 to –0.6) mm after 1 year. The corresponding values in the HCO group were close to 0. Displacement in the horizontal plane was also larger in the HTO group, 1.3 (–0.2 to 2.7) mm after 1 month and 1.3 (–0.2 to 2.7) mm after a year but close to 0 in the HCO group. The rotations of the tibial plateau around the longitudinal axis were 1.1 (–0.2 to 2.4)° and 1.5 (0.4 –2.6)°, respectively, in the HTO group but close to 0° in the HCO group. There was also a tendency for a difference in the rotation around the sagittal axis at the 1-month follow-up with a change of 2.8 (1.1–4.5)° in the HTO group and –0.2 (–0.8 to 0.4)° in the HCO group. The corresponding results after 1 year were 3.0 (1.4–4.6)° and 0.0 (–0.6 to 0.6)°.

MTPM in the HTO group was 4.1 (2.7–5.4) mm at the 1-month follow-up compared to 0.7 (0.1–1.3) mm in the HCO group. At the 1-year follow-up the corresponding MTPM-values were 4.1

(2.6–5.5) mm and 1.0 (0.4–1.6) mm. The accuracy of the RSA investigation, assessed by comparing the outcomes of consecutive double measurements in 15 randomly chosen subjects, was for translation and rotation 0.2 mm and 0.3°, respectively.

Discussion

The patients in this study were part of a randomized, prospective and consecutive study on different osteotomy techniques. The patients included in the RSA study were not selected for participation. Nevertheless, there was a tendency towards a difference in preoperative HKA angles (Table 1). The power of this tendency was low (0.48) and interpreted as a random variation. Our study focused mainly on micromotions between the segments studied after osteotomy and there was no significant difference between the groups concerning HKA angles postoperatively.

The purpose of the tibial osteotomy, regardless of the technique used, was to unload the arthrotic compartment by an osseous angular deviation in the frontal plane (Coventry 1984, Maquet 1985). In terms of RSA, this is mainly a change in the rotation around the sagittal axis (z-rotation), and postoperative changes around this axis indicate the rotation stability in the frontal plane. There was a tendency towards a difference between the two groups at the 1-month follow-up, indicating a more stable situation in the HCO group.

We also found differences of displacement in the horizontal and vertical planes (the x- and y-translations), indicating a less stable situation in the HTO group, with a movement in the plane of the osteotomy and shortening of the tibia. In the HCO group, these displacements were negligible.

In case of later arthroplasty, a rotation of the tibial plateau around the vertical axis (y-rotation) can make the operation technically more demanding (Katz et al. 1987, Windsor et al. 1988). This rotation was significantly smaller in the HCO group, after both 1 month and 1 year, as also was the MTPM.

Technically, it can be difficult to obtain the appropriate correction at operation and various authors have reported a widely varying precision with the HTO (Vainionpää et al. 1981, Hernigou et al. 1987, Matthews et al. 1988, Koshino et al. 1989). The HCO technique has the advantage of permitting a continuous radiographic evaluation and thus giving an opportunity for better precision (Fowler et al. 1991, Elting and Hubbell 1993, Magyar et al. 1998).

Another problem is to maintain the correction achieved during the bone-healing period, and several techniques using different fixations have been described (Ivarsson and Larsson 1989, Koshino et al. 1989, Miniaci et al. 1989, Yasuda et al. 1992, Zuegel et al. 1996). In some cases, a gradual loss of correction occurs during the first few years, and could be explained by several factors, i.e., a progression of the gonarthrosis, insufficient bone healing, unbalanced moment forces acting on the knee (Prodromos et al. 1985, Wang et al. 1990).

The proportion of patients with an HKA angle of 182–186° did not differ after correction, but was significantly smaller in the HTO group after one year.

There is a methodological problem in comparing the two techniques, because the fixation time differs and the time-points for comparison between the groups are not obvious. The two groups were compared at the time of completion of external fixation or plaster fixation, which was when the osteotomy generally was considered clinically stable, without need for further external support. The results of the HTO group are interpreted as effects of insufficient fixation, stability and/or fixation time. On the other hand, it could also mean that the external fixation time in the HCO group was too long.

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