International Orthopaedics (SICOT) (2010) 34:155–160
DOI 10.1007/s00264-009-0889-8

REVIEW

Results of high tibial osteotomy: review of the literature

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Received: 19 September 2009 / Accepted: 23 September 2009 / Published online: 17 October 2009

Abstract The aim of this review is to evaluate long-term follow-up and survival analysis studies regarding high tibial osteotomies (HTO) for the treatment of medial knee arthritis. Despite the good number of studies available, comparison and pooling of the results are challenging because of the different evaluation systems and techniques used. However, in general, published studies on HTO report good long-term results with a correct patient selection and a precise surgical technique. Based on our findings, the ideal candidate for an HTO is a young patient (<60 years of age), with isolated medial osteoarthritis, with good range of motion and without ligamentous instability. Furthermore, the literature review shows that the outcomes gradually deteriorate with time. Nevertheless, some issues remain that need resolution; these include the choice between opening or closing wedge tibial osteotomy, the graft selection in opening wedge osteotomies, the type of fixation, the comparison with unicompartmental knee arthroplasty and whether HTO significantly affects a subsequent total joint replacement.

The authors have no grant supports and no conflict of interest to disclose regarding this paper.

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Introduction

High tibial osteotomy (HTO) is a widely performed procedure to treat medial knee arthrosis. Many techniques have been developed (i.e. closing wedge, opening wedge, dome and "en chevron" osteotomies), but opening (medial) and closing (lateral) wedge osteotomies are the most commonly used [5, 8].

The goal of the treatment is to relieve medial compartment knee pain and slow down the arthritic progression. This is achieved by a partial unloading of the medial compartment with a slight overcorrection of the mechanical axis (from 6 to 10° of valgus). Shaw and Moulton [37], in their biomechanical cadaver study, showed that to obtain a complete medial compartment unload the valgus correction should be at least 25°.

Although overall HTO results show the effectiveness of the procedure [6], there are still some debated issues about osteotomies. These include the choice between opening or closing wedge tibial osteotomy, the graft selection in opening wedge osteotomies, the type of fixation, the comparison with unicompartmental knee arthroplasty (UKA) and whether HTO affects a subsequent total joint replacement (TKR) [5].

Indications

Selecting the ideal patient is crucial in achieving good results with HTO for medial knee arthrosis. The review of the literature shows that some conditions are correlated with a poorer prognosis and these include: (1) severe articular destruction (III or more according to the Ahlbäck classification) [1, 22, 26], (2) advanced age [22, 24, 33], (3) patellofemoral arthrosis [35], (4) markedly decreased range

of motion [33], (5) previous arthroscopic débridements [33], (6) joint instability [35] and (7) lateral tibial thrust [33].

Body mass index is a controversial factor; some studies report higher failure rates in lighter patients [3, 33], while some others [18, 32] state the opposite. Given the lower success rates of UKA and TKR in heavier patients, these seem to be more suitable for HTO.

Given these considerations, the ideal candidate for an HTO is a young patient (<60 years of age), with isolated medial osteoarthritis, with good range of motion and without ligamentous instability [5].

Overall results

Survivorship analysis is a good method to understand quality and durability of the results, because inadequate follow-up, loss to follow-up and patients' death are not excluded [5, 36]. Many short- and long-term outcomes and survival analyses have been reported in the literature.

Aglietti et al. [1] performed 139 osteotomies with three different techniques: (1) lateral wedge osteotomy, without internal fixation followed by long leg cast; (2) lateral wedge or "en chevron" osteotomy, fixed with two screws and immobilized with a long leg cast; and (3) closed wedge osteotomy according to Insall et al. [25] without internal fixation and with cylinder cast immobilisation. The outcomes were satisfactory in 87% (from 2 to 5 years of follow-up), in 70% (from 6 to 10 years of follow-up) and in 64% (more then 10 years of follow-up). The authors concluded that the third group of patients had better results and correction, that severe articular destruction had poorer outcomes and that undercorrected knees tended to relapse.

Matthews et al. [32] treated 40 patients with Coventry [16] or Coventry-Bowman [17] techniques followed by cast immobilization. Internal fixation with staples was used in 25 cases and external fixation in three cases. They reported 86% of satisfactorily results at one year from surgery, 64% at three years, 50% at five years and 28% at nine years. They also concluded that obesity, advanced age, overcorrection or undercorrection had the worst outcomes.

Rudan and Simurda [35] treated 79 knees with valgus closing wedge HTO. They evaluated the patients at an average follow-up of 5.8 years and reported 80% of good or excellent results at the last follow up. They noticed that undercorrection and patellofemoral arthrosis were associated with poorer prognosis.

Ivarsson et al. [26] performed 99 lateral closing wedge HTO, fixed with staples and immobilized in a cast. They reported 75% of good and acceptable outcomes at 5.7 years and 60% at 11.9 years. They obtained better results in patients with Ahlbäck grade I or II osteoarthritis and when a slight overcorrection was achieved (from 3° to 7° of valgus).

Naudie et al. [33] performed 94 closing wedge osteotomies and 12 dome osteotomies, fixed with staples and followed by cast immobilization in 75 cases. The Kaplan-Meier analysis showed survivorship of 75% at five years, 51% at ten years, 39% at 15 years and 30% at 20 years. However, in patients younger than 50 years old and with range of motion >120°, the longevity increased to 80% at ten years. They thus underlined the importance of correct patient selection. In their series, earlier failure was associated with age >50 years, previous arthroscopic débridements, lateral tibial thrust, preoperative knee flexion <120°, undercorrection and delayed union.

Sprenger and Doerzbacher [39] treated 76 knees with closing wedge HTO and internal fixation. Survival rates were 65–74% at ten years from surgery. However, ten-year survivorship was 90%, when the femorotibial angle was between 8 and 16° valgus at one year from surgery.

Koshino et al. [30] performed 75 closing wedge HTO, fixed by external fixation, internal fixation or long leg cast. The survivorship reported was 97.3% at seven years, 95.1% at ten years and 86.9% at 15 years from surgery.

Tang and Henderson [43] treated 67 knees with lateral closing HTO, fixed with staples or plate or immobilized in a long leg cast. Survival rates reported were: 89.5% at five years, 74.7% at ten years and 66.9% for 15 and 20 years.

Asik et al. [10] performed 65 open wedge osteotomies fixed with the Puddu plate. They reported significant improvement of pain and knee function at an average follow-up of 34 months.

Chiang et al. [15] used dome-shaped HTO and external fixation to treat 25 knees with medial compartment arthrosis. In their series, the Hospital for Special Surgery (HSS) score was excellent or good in 18 knees at five years and in 13 knees at an average of 15 years.

Papachristou et al. [34] followed up 44 closing wedge HTO, fixed with one or two staples. Survivorship analysis showed a success rate of 80% at ten years, 66% at 15 years and 53% at 17 years from surgery.

Flecher et al. [22] followed up 301 patients treated with closing wedge HTO and internal fixation. Survivorship was 85% at 20 years. They also concluded that the most important risk factors predicting revision (the chosen endpoint) were: age >50 years and preoperative Ahlbäck grade III or more arthrosis.

Gstöttner et al. [24] treated 134 arthritic knees with lateral closing HTO, fixed with staples. The survival rates were 94% at five years, 79.9% at ten years, 65.5% at 15 years and 54.1% at 18 years.

Akizuki et al. [3] followed up 118 closing wedge HTO, fixed with a plate. Survivorship was 97.6% at ten years and 90.4% at 15 years from surgery.

Debated issues

Closing versus opening HTO

Lateral closing wedge HTO has been considered for a long time as the gold standard in treating medial knee osteoarthritis. However, this technique implies: (1) fibular osteotomy or proximal tibiofibular joint disruption, (2) lateral muscle detachment, (3) peroneal nerve dissection, (4) more demanding subsequent total joint replacement and (5) bone stock loss. For all these reasons, the opening wedge HTO gained popularity and became a widely used alternative option. This technique however is not free from drawbacks and these include the necessity of bone graft and possible collapse or loss of correction [4].

Currently, in the literature only one randomized controlled trial has been reported comparing the two techniques [12]. At the one-year follow-up, both groups showed improvement in knee function and pain, without significant differences [12].

However, no conclusion can be drawn on which technique is to be preferred and the choice remains a matter of preference of the surgeon, until further studies become available.

Augmentation in opening wedge HTO

Many methods have been used to fill the osseous gap and these include: bone grafts (autograft or allograft), synthetic bone substitutes (hydroxyapatite, β-tricalcium phosphate, a combination of both, bone cement) with or without platelet-rich plasma (PRP), growth factors and bone marrow stromal cells [5].

Bone graft is generally considered to be the most successful bone filling material because of its osteoconductive, osteoinductive and osteogenic properties [14, 21, 23, 31, 41]. Nevertheless, autograft harvesting involves increased operative time and the donor site morbidity, while allograft has lower osteoinductive properties and carries disease transmission risk. The bone substitutes attempt to reduce these risks, but there are still some concerns about their resistance to compressive loads [9] and biological degradability. The use of bone cement is not recommendable in order to achieve a more biological repair of the osteotomy site [9].

Encouraging results have been reported with the use of PRP, bone marrow stromal cells and growth factors [9, 19, 28], associated both with bone grafting and with bone substitute augmentation. Nevertheless, the use of plasma products still remains experimental and their efficacy compared to autologous iliac crest graft has not been demonstrated yet [9].

Type of fixation

With the diffusion of opening wedge HTO a stable fixation is required and the most commonly used fixation devices include: external fixators (both axial and circular) and plates (conventional, locking, long or short plates, with or without a spacer). A few biomechanical studies comparing the different fixation devices have been published, but the most reliable fixation system is still controversial [4, 5].

Stoffel et al. [40] compared the biomechanical properties of the modified Puddu plate (Arthrex, Naples, FL, USA) and the TomoFix plate (Synthes, Solothurn, Switzerland). The authors concluded that both plates create immediate stability, but with a lateral hinge fracture the TomoFix plate showed enough residual stability, while the Puddu plate required additional lateral fixation.

Agneskirchner et al. [2] compared four different plates: (1) short spacer plate, (2) short spacer plate with multi-directional locking screws, (3) long spacer plate with multi-directional locking screws and (4) long medial tibia plate fixator with locking screws. They stated that a rigid long plate fixator with angle stable locking screws yields the best results.

Zhim et al. [45] compared the biomechanical stability of the Puddu plate (Arthrex, Naples, FL, USA) and the Hoffman II external fixator (Stryker Howmedica, Osteonics, Ruther-

Table 1 Survivorship of HTO in the literature review

Authors	Year	Survivorship
Naudie et al. [33]	1999	75% at 5 years, 51% at 10 years, 39% at 15 years and 30% at 20 years
Sprenger and Doerzbacher [39]	2003	65–74% at 10 years
Koshino et al. [30]	2004	97.3% at 7 years, 95.1% at 10 years and 86.9% at 15 years
Tang and Henderson [43]	2005	89.5% at 5 years, 74.7% at 10 years and 66.9% at 15 and 20 years
Papachristou et al. [34]	2006	80% at 10 years, 66% at 15 years and over 52.8% at 17 years of follow-up
Flecher et al. [22]	2006	85% at 20 years
Gstöttner et al. [24]	2008	94% at 5 years, 79.9% at 10 years, 65.5% at 15 years and 54.1% at 18 years
Akizuki et al. [3]	2008	97.6% at 10 years and 90.4% at 15 years

ford, NJ, USA) and concluded that plate fixation was superior in maintaining correction.

Spahn et al. [38] in their biomechanical investigation on four different fixation devices (conventional plate, angle stable plate with or without spacer), concluded that spacer implants have superior properties and that angle stable plates may prevent fractures of the lateral cortex.

The results are still inconclusive and, even if long locking plates seem to show better biomechanical properties, they are bulky, expensive and hardware removal is required in almost every case [9]. Plates with spacers seem to be more reliable in maintaining the correction.

Comparison between UKA and HTO

Both HTO and UKA are used in the treatment of medial knee arthritis and almost share the same indications. Most comparison studies available in the literature compare UKA versus lateral closing wedge HTO [5, 20].

Broughton et al. [11] retrospectively reviewed at five to ten years follow-up 49 lateral closing wedge HTO and 42 UKA. They reported 76% of good results with UKA and 43% with HTO.

Stukenborg-Colsman et al. [42] prospectively compared the outcome of 32 HTO and 28 UKA, at seven to ten years follow-up and concluded that UKA offers better long-term success and less intraoperative complications.

Dettoni et al. [20] compared 56 consecutive UKA and 54 opening wedge HTO. They found that clinical and radiological midterm results were comparable in the two groups. This is the first study comparing the opening wedge HTO with UKA.

Although these data seem to support the use of UKA rather than HTO, Brouwer et al. [13] in their meta-analysis stated that there is no significant difference in pain, function and gait analysis between HTO and UKA.

Total knee replacement after HTO

All data published fail to demonstrate statistically significant differences between the patients treated with a primary TKR or with a TKR following an HTO [5].

Amendola et al. [7] in their retrospective study compared primary TKR with TKR following HTO. They concluded that previous osteotomy does not affect the outcome of TKR.

Karabatsos et al. [27] in their retrospective cohort study stated that TKR after HTO was technically more challenging than primary TKR and that there were no significant differences between the two groups at the five-year follow-up. Similar results were described by Van Rajii et al. [44] and Kazakos et al. [29].

As mentioned above, there are no studies reporting TKR results after opening wedge HTO. Although no data are available yet, we believe that in this case, joint replacement is easier. In fact, with opening wedge HTO, there is no risk of patella alta, the bone stock is maintained and there is lower risk of impingement between the tibial component stem and the anterior cortex of the tibia [5].

Conclusions

Although a good number of studies are available on HTO outcomes, a close comparison and pooling of the results are a challenge because of the different evaluation systems and techniques used. Furthermore, Brouwer et al. [13] in their systematic review analysis stated that there is "silver" level evidence (www.cochranemsk.org) that valgus HTO improves knee function and reduces pain, but that there is no evidence whether an osteotomy is more effective than conservative treatment and that a conclusion about effectiveness of specific surgical techniques cannot be drawn. Even if there is no scientific evidence, because of the lack of randomized controlled trials, it is common experience that HTO is a reliable procedure for medial arthrosis of the knee with proper patient selection and a precise surgical technique. Nevertheless, it is also evident that the outcomes gradually deteriorate with time (Table 1).

Some conditions are related to poor outcomes and these include: severe articular destruction (III or more according to the Ahlbäck classification) [1, 22, 26], undercorrection [1, 26, 32, 33, 39] or overcorrection [32], advanced age [22, 24, 33], patellofemoral arthrosis [35], noticeably decreased range of motion [33], previous arthroscopic débridements [33], joint instability [36], loss of correction [36] and lateral tibial thrust [33]. On the other hand, a slight valgus correction is associated with better results [26, 33, 36]. Body mass index is a controversial factor.

Good to excellent results have been reported for both opening and closing wedge HTO. In open wedge osteotomy, the most reliable fixation and augmentation techniques are still controversial. Gold standards seem to be locked plates and autologous bone graft.

Although UKA achieves slightly better results compared to HTO, osteotomy is still the treatment of choice for the younger, heavier and more active patient with medial knee arthrosis.

Although a revision of lateral closing HTO to TKR is technically more demanding than a primary implant, there is no difference in the long-term outcomes.

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