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Satisfactory long-term outcomes for combined Anterior Cruciate Ligament reconstruction and lateral closing wedge High Tibial Osteotomy

Piero Agostinone, Gian Andrea Lucidi, Giacomo Dal Fabbro, Stefano Di Paolo, Anna Pagano, Marianna Viotto, Maria Pia Neri, Alberto Grassi, Stefano Zaffagnini

Purpose: A combined anterior cruciate ligament (ACL) reconstruction and high tibial osteotomy (HTO) is considered a valuable treatment in young patients affected by symptomatic medial osteoarthritis and ACL deficiency. However, only a few studies investigated the outcomes of this procedure, especially in the long term. Therefore, the aim of this study is to report clinical and radiographic outcomes of ACL reconstruction and lateral closing wedge HTO at a mean of 14 years of follow-up.

Methods: Patients were prospectively evaluated pre-operatively, after 6.5±2.7 years and 14.3±2.2 years. Patient-reported outcome measures (PROMs) were collected, knee laxity was assessed through KT-1000 arthrometer, and limb alignment and knee osteoarthritis were evaluated on long-cassette radiographs. Survivorship of the surgical procedure was calculated through the Kaplan-Meier method.

Results: 32 patients were initially enrolled and completed the mid-term evaluation (6.5±2.7 years), and 23 patients (72%) were available for the final evaluation at 14.3±2.2 years after surgery. Statistically significant improvement was found for all the clinical scores (VAS, WOMAC, Tegner, Subjective IKDC, Objective IKDC) between the pre-operative status and the mid-term follow-up ($p < .001$). VAS, subjective IKDC and objective IKDC showed no statistically significant differences ($p > .05$) between the mid-term and the final follow-up; a significant decrease of WOMAC ($p < .05$) and Tegner ($p < .001$) was found from mid-term to final follow-up. Significant

progression of osteoarthritis was found for all the knee compartments. The survivorship was 95.7% at 5 years, 82.6% at 10 years, and 72.8% at 15 years.

Conclusions: Combined ACL reconstruction and lateral closing wedge HTO showed satisfactory clinical outcomes and survivorship at a mean of 14 years follow-up.

Level of evidence: IV

Keywords: ACL, lateral closing wedge HTO, genu varum, survivorship

Introduction

The combination of anterior cruciate ligament (ACL) reconstruction (ACLR) and high tibial osteotomy (HTO) is considered a valuable procedure in the case of ACL deficiency and medial osteoarthritis (OA) in genu varum [2, 4, 6, 13, 15, 21, 24, 26]. Orthopedic surgeons sometimes do not take into account this kind of treatment because more technically demanding and with a supposed higher rate of complications than an isolated procedure [13, 15]. However, the combination of ACLR and HTO guarantees some advantages, such as the reduction of forces on reconstructed ACL, which is useful, especially in the case of ACL revision [23]. Moreover, the isolated ACL reconstruction addresses only knee laxity, and it is not able to reduce OA progression and symptoms [8]. Thus, ACLR plus HTO is widely accepted as a savage procedure in active or highly demanding patients [15, 26]. Several studies described different techniques for combined ACLR and HTO. They reported good clinical results and low failure rate at short and mid-term follow-up, but there is a lack of information about the outcomes in the long term. Furthermore, most of the researchers investigated medial opening wedge HTO, and only a few investigated lateral closing wedge HTO [4, 13, 15, 24, 26].

The aim of the present study was to report the clinical and radiographic outcomes of combined ACLR and lateral closing wedge HTO in the long term. The hypothesis was that combined ACLR and HTO

has a low failure rate, and good clinical outcomes in the long term, in order to delay the recourse to arthroplasty in young and active patients with symptomatic medial OA.

Methods

Ethics

The study was approved by the Institutional Review Board of Istituto Ortopedico Rizzoli. All the patients signed the informed consent.

Cohort selection and data collection

This study represented the long-term evaluation of an original cohort of patients prospectively recruited between 2002 and 2007, who underwent a combined procedure of ACLR or revision with hamstrings plus lateral closing wedge HTO. The surgical indication was unstable and painful varus knee with hip-knee-ankle (HKA) angle > 5° or > 3° in the presence of previous medial meniscectomy.

Exclusion criteria for the study were: age > 60 years, posterior cruciate ligament lesion, medial collateral ligament grade III lesion, inflammatory synovitis, grade D OA according to IKDC radiographic score, and ACL revision with allograft. Patients were clinically and radiologically evaluated pre-operatively, at mid-term, and at long-term follow-up. Data regarding the pre-operative and mid-term evaluations were available in a previously published study [26].

Every patient completed a self-administrated questionnaire including the visual analogue scale (VAS) for pain, the Western Ontario and McMaster Universities Arthritis Index (WOMAC), the International Knee Documentation Committee (IKDC), the Tegner Activity Scale; moreover, the Lysholm Knee Scoring Scale (Lysholm) and the Knee Injury and Osteoarthritis Outcome Score (KOOS) were collected at final follow-up. A knee physical examination was

conducted according to the objective IKDC score and knee laxity was assessed with KT-1000 arthrometer, performed by the same surgeon (P.A).

The radiological evaluation was performed by two different surgeons separately (P.A. and G.D.F.) and, in case of disagreements, a senior author (S.Z.) helped to assess OA progression and limb alignment. For this purpose, long cassette (Figure 1) and lateral knee radiographs were collected.

OA was evaluated according to the IKDC radiographic score [11]. Alignment angles measured on the long cassette radiographs were the hip-knee-ankle angle (HKA), the medial proximal tibial angle (MPTA), and the distal lateral femoral angle (DLFA), while the posterior tibial slope (PTS) was assessed on the lateral radiographs. Moreover, the tibial plateau percentage (TP%) was calculated on the long cassette radiographs [9, 26]. Complications and subsequent surgeries during the follow-up period were also recorded. Patients that underwent revision surgeries (ACLR or HTO or both), arthroplasty implants, or who showed an anterior side-to-side knee laxity > 5 mm measured with KT-1000 were considered failures [10]. Patients who underwent arthroplasty or revision surgery were excluded from the clinical examination and self-administrated questionnaire; moreover the first were also excluded from the radiological evaluation and were considered grade D in IKDC radiographic score.

Surgical procedure

Pre-operative HTO planning was performed on full-length standing radiographs; a line is drawn from the center of the femoral head to a point located at the junction of the medial two-thirds and the lateral one-third of the tibial plateau, a second line is drawn from the center of the ankle joint to the previous point. The angle formed by the intersection of the two lines determines the degree of correction required. The lateral closing wedge HTO was performed under an intraoperative image intensifier. The disruption of the proximal tibiofibular joint was avoided to prevent proximal migration and laxity

in the posterolateral structures. An osteotomy of the fibula was performed at the fibular neck, with bone removal to allow for compression of the osteotomy site. Internal fixation was accomplished with a Krakcow staple [17].

The ACLR or revision was performed with the "Over the top plus lateral plasty" technique described by Marcacci and Zaffagnini [16]. Hamstrings were harvested preserving the tibial insertion. Then a tibial tunnel was drilled to the postero-medial footprint of the ligament. Finally, the graft was passed through the tibial tunnel and fixed at the Over-the-top site on the lateral femoral condyle with two metal staples. Then, the distal portion of the graft was passed below the iliotibial band and fixed on Gerdy's tubercle with a metal staple (Figure 2).

Rehabilitative protocol

The patients were instructed to wear a knee extension brace for the initial four weeks. From the first post-operative days, quadriceps muscle isometric exercises and electric muscle stimulation were allowed. After two weeks the patients began passive knee mobilization (0°- 90°) with motorized hardware; a complete range of motion was achieved in the sixth week. No weight bearing was allowed in the first four weeks, then progressive weight bearing was allowed. Exercises in the pool and cyclette started from the fifth week, running was allowed after four months and the return to sport after eight months.

Statistical Analysis

The statistical analysis was performed using MedCalc (MedCalc Software bv, Ostend, Belgium). Continuous variables were presented as a mean and standard deviation; the Tegner score was presented as median and interquartile range; categorical variables were presented as numbers and percentages. The Two-Way ANOVA for repeated measures test was performed to assess the between-group differences of continuous variables. The Chi-square test was performed to assess the

differences in categorical variables. Differences between the groups were considered statistically significant if $p<0.05$. For the multiple comparisons, p-values were adjusted using the Bonferroni post-hoc correction. Survival analysis was performed via the Kaplan-Meier method. The intraclass correlation coefficient (ICC) was calculated for the radiographic measurements, and they showed excellent agreements (ICC HKA 0.93; ICC MPTA 0.97; ICC LDFA 0.85; ICC PTS 0.86; ICC TP% 0.83). Considering a sample power of 0.8 and an effect size of 0.6 (medium effect) as resulting from previous literature on similar rationale and outcome, the minimum sample size required was 28 patients.

Results

Thirty-two patients met the inclusion and exclusion criteria and were enrolled in the study. All of them were available for the mid-term evaluation at 6.5±2.7 years (range 4-10) of follow-up. Of the initial cohort, 23 patients (72%) were available for the final evaluation at 14.3±2.2 years (range 10-19) of follow-up. Out of the 23 patients, 10 patients had undergone previous ACL reconstruction with patellar tendon. Both primary ACL reconstruction and revision were performed in chronic settings. Detailed demographical and surgical data of the patients at the final follow-up were presented in Table 1.

Statistically significant improvement was found for all the scores (VAS, WOMAC, Tegner, Subjective IKDC, Objective IKDC) between the pre-operative status and the mid-term follow-up ($p< .001$). Only VAS registered a significant difference between preoperative status and final follow-up ($p< .0001$). A significant decrease of WOMAC ($p< .05$) and Tegner ($p< .001$) was found between the mid-term and the final follow-up (Table 2 and 3); however, 5 patients (29%) showed a Tegner activity scale higher or equal to 5 at the long term evaluation.

142 The Lysholm score at the final follow-up was 77.4±14.7; regarding the subscales of the KOOS score
143 at the final follow-up: KOOS symptoms was 76.7±18.0, KOOS Pain was 82.8±14.1, KOOS ADL
144 was 89.9±13.3, KOOS QoL was 63.9±25.0, and KOOS sport was 60.6±28.9.

145 The knee laxity measured with the KT-1000 arthrometer revealed no statistically significant
146 differences in side-to-side anterior tibial displacement between the mid-term follow-up and the final
147 follow-up (2.2±1.0 mm vs 1.9±2.1 mm; p> .05). Only one patient reported a side to side difference >
148 5 mm.

149 Considering the patients' satisfaction, 17 patients (74%) reported being satisfied with the
150 intervention.

151

152 *Radiographical data*

153 The evaluation of the OA progression according to radiographic IKDC showed statistically
154 significant differences in degenerative changes of the medial compartment between the pre-operative
155 evaluation and the mid-term follow-up (p< .05). Moreover, a significant progression of OA was found
156 for the lateral (p< .05) and the patellofemoral (p< .0001) compartments between the mid-term follow
157 up and the final follow up (Table 3).

158 The radiographic measurement revealed a statistically significant correction of the HKA (p<.05),
159 MPTA (p< .001), and PTS (p< .05) angles between the pre-operative status and the final follow-up.
160 The TP% showed a statistically significant lateral shift (p< .0001) of the mechanical axis from the
161 preoperative status and the mid-term evaluation that was maintained at the final follow-up (Table 4).

162

163 *Survival analysis*

A total of 6 Failures (26.1%) were registered at the final follow-up: 1 unicompartmental knee prosthesis, 4 total knee prosthesis, and 1 ACL failure (KT1000 side to side > 5 mm). Analyzing the Kaplan-Meier curve, the survivorship was 95.7% at 5 years, 82.6% at 10 years, and 72.8% at 15 years (Figure 3).

Discussion

The main finding of the present study was that ACL reconstruction combined with lateral closing wedge HTO represents a valuable option in young and active patients affected by ACL injury and medial OA in genu varum, with satisfactory clinical outcomes and good survivorship at long-term follow-up.

The combination of these two procedures is a controversial topic, the HTO is widely accepted for young patients with symptomatic medial OA [15, 22, 24, 26]; however, its association with ACL reconstruction is debated in the case of concurrent chronic ACL deficiency [15]. Noyes et al [21] suggested performing a combined procedure in patients that desire to resume athletics, and isolated HTO in those who simply expect pain relief, agreeing to reduce their sport activity.

Many techniques have been described [2, 4, 15, 24, 26], most of the studies available are case series at a short- to mid-term follow-up, and the main HTO performed was a medial opening wedge HTO [15], which is believed to cause an increase of the posterior tibial slope [1, 20] potentially increasing the load on the reconstructed ACL [3].

Schneider et al [24] recently published a case series in which 36 knees that underwent ACLR plus medial opening wedge HTO were evaluated at a mean of 9.8 years of follow-up. Clinical scores reported by the authors showed good outcomes, the mean subjective IKDC was 71.8 and the mean Lysholm was 82.1. A higher mean subjective IKDC was reported in another study by Bonin et al [4], with a mean value of 78.5 at a mean of 12 years of follow-up, but in line with the results by Schneider

et al. Our results showed lower scores, with a mean subjective IKDC of 65.2 and a mean Lysholm of 77.4; however, the patients included in the present study had a minimum follow-up of 10 years, which was substantially higher.

OA progression over time was expected, especially for the medial compartment [4, 15, 24]; interestingly, the medial compartment degeneration seemed to occur in the early years. On the other hand, a progressive increase of OA grade for the lateral and the patellofemoral compartment was registered between the mid-term follow-up and the final evaluation. These results were in line with the study by Schneider et al [24], who reported a significant OA progression for all the compartments at ten years. The lateral compartment degeneration could be related to the overcorrection of the mechanical axis, also of a few degrees, as theorized by Amis in a previous biomechanical study

[1]. Regarding the patellofemoral joint, the HTO seems to influence the patellar height and the patellar tilt [1, 12]. This evidence could potentially explain the progression of patellofemoral OA.

But the main concerns of performing combined ACLR and HTO are represented by the supposed higher risk of complications and negative influence on return to sport [15, 19, 24]. Older studies [6, 24] considered unrealistic a return to high-level activities. However, the improvement in surgical techniques and rehabilitation protocols suggested good outcomes in this regard, even in the long term [4, 24]. Our results confirmed this evidence; at the mid-term follow-up 62% of patients were graded as Tegner 5 or higher [26], the percentage dropped to 29% at the final follow-up, but it should be considered excellent data since it was registered at minimum 10 years from surgery.

Li et al [15] reported 24% of surgical complications after combined ACLR and HTO, the main was stiffness, as also indicated in our research. However, in a recent systematic review, Miltenberg et al [18] found a postoperative complication rate range between 0% and 27% for isolated HTO; thus the combined procedure should not be avoided based on a supposed higher risk of complications.

Most of the studies on ACLR and HTO focused their attention on the OA progression and the return to sport [4, 13, 15, 24, 26], a factor that would deserve more attention is the survivorship of the procedure, especially in terms of conversion to knee arthroplasty. The recourse to unicompartmental knee arthroplasty (UKA) or HTO in the case of medial OA is a debated topic [25]. The UKA seemed to provide better pain relief and survivorship similar to HTO but also seemed to cause a reduced range of motion [14, 15, 25], and some authors advocated the UKA should be reserved for an older population with reduced physical activity [25]. Moreover, the survivorship of total knee arthroplasty after HTO was reported to be superior to the same procedure when performed as a revision of UKA [7, 14]. Our study found survivorships of 82.6% and 72.8% at ten and fifteen years of follow-up for the combined procedure; the results were in line with the ones reported in the recent review by Ollivier et al [22] for isolated lateral closing wedge HTO, which registered a survival rate range between 70% and 97.6% at 10 years. Thus, the osteotomy could be considered a procedure useful to delay arthroplasty in young patients, at least for ten years, and the combination with ACLR represents a reasonable solution in the case of chronic ACL deficiency for more active patients.

Limitations

The present study had several limitations, the major one was represented by the small sample size, which did not allow for identifying risk factors of surgical failure; however, similar studies with shorter follow up usually evaluated a small cohort of patients. The lack of a control group of isolated HTO is another limit, but the studies available with a control group had only a few years of follow-up, not allowing a proper evaluation of the survivorship and clinical outcomes in the long term. The high drop-out rate as we had 9 patients lost at follow-up out of 32 of the initial cohort, but the long time elapsed between the first and the last assessments has to be considered. Finally, the heterogeneity of the study population, in terms of OA, first ACLR or revision ACLR, and meniscal status, makes it difficult to generalize our results, but it is a common limitation of analogous studies [15, 24].

Conclusion

Combined ACL reconstruction and lateral closing wedge HTO showed satisfactory clinical outcomes and survival rate at a mean of 14 years of follow-up, even though these parameters deteriorated compared with the mid-term evaluation.

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FIGURES LEGEND

Fig. 1. Long cassette radiograph of lower limbs. A: pre-operative; B: mid-term follow-up (5 years); C: final follow-up (13 years). HKA and its values are reported.

Fig. 2. Surgical technique of combined lateral closing wedge high tibial osteotomy and anterior cruciate ligament reconstruction.

Fig. 3. Kaplan-Meier curve describing the survivorship of the combined procedure of ACL reconstruction and HTO.

LIST OF ABBREVIATIONS:

ACL: Anterior Cruciate Ligament; ACLR: Anterior Cruciate Ligament Reconstruction; HTO: High Tibial Osteotomy; OA: Osteoarthritis; PROMs: Patient- Reported Outcome Measures; VAS: Visual Analogue Scale; WOMAC: Western Ontario and McMaster Universities Arthritis Index; IKDC: International Knee Documentation Committee; KOOS : Knee Injury and Osteoarthritis Outcome Score; HKA: Hip-Knee-Ankle Angle; DLFA: Distal Lateral Femoral Anlge; PTS: Posterior Tibial Slope; TP%: Tibial Plateau Percentage; UKA: Unicompartimental Knee Arthroplasty

MPTA: Medial Proximal Tibial Angle