SYSTEMATIC REVIEW

The clinical Outcome of One-stage High Tibial Osteotomy and Anterior Cruciate Ligament Reconstruction. A Current Concept Systematic and Comprehensive Review

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Abstract

Background: Patients with an anterior cruciate ligament-deficient varus-angulated knee may need not only an isolated high tibial osteotomy (HTO), but also an additional anterior cruciate ligament reconstruction (ACLR). A number of prospective clinical trials have been published considering the combination of HTO and ACL reconstruction. Our aim was to investigate whether one-stage combined HTO and ACL reconstruction is an effective, well-established technique with long-term results in the treatment of varus-angulated knees with ACL deficiency.

Methods: A systematic review was conducted by two independent reviewers by searching the MEDLINE/PubMed and the Cochrane Database of Systematic Reviews. These databases were queried with the term 'combined high tibial osteotomy anterior cruciate ligament reconstruction' and 'simultaneous high tibial osteotomy anterior cruciate ligament reconstruction'.

Results: From the initial 41 studies we finally chose and assessed 6 studies were eligible according to our inclusion-exclusion criteria. The vast majority of the patients were treated with hamstrings autograft (85.6% of the patients), whereas a small minority had a patellar Bone-to-Bone autograft (12.8% of the patients) and 3 patients received a patellar allograft. High tibial open wedge osteotomy was performed in 116 patients (57.4%) and closed wedge in 86 patients (42.6%). The mean pre-operative angle of the patients included in our review was 6.6º varus, while the mean final post-operative angle was found to be 1.3º valgus. All 6 studies illustrated improved post-operative IKDC with the use of one-stage HTO and ACLR, whereas the reoperation rate was very low.

Conclusion: Despite the lack of high quality studies, it seems that one-stage HTO and ACLR is a safe and effective procedure for treatment of patients suffering from symptomatic varus osteoarthritis in combination with anterior knee instability.

Level of evidence: II

Keywords: Combined HTO ACL reconstruction, One-stage high tibial osteotomy and anterior cruciate ligament reconstruction, Simultaneous HTO ACL reconstruction, Systematic review

Introduction

High tibial osteotomy (HTO) for the correction of varus malalignment in the lower extremity was introduced by Coventery in 1965 (1). Different types of osteotomy (closing wedge, opening wedge, dome, chevron) have been described, whose main purpose is limb axis correction and unloading of the

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overloaded compartment in order to delay the arthritic progression (2-4).

Nowadays, HTO remains a popular operation, mostly performed in young patients suffering from an osseous tibial varus deformity combined with a symptomatic medial knee compartment (5, 6). Other therapeutic options like unicompartmental knee arthroplasty (UKA) or total knee arthroplasty (TKA) do not salvage the joint, while they have the disadvantage of sacrificing part of the (or the entire) knee joint (7). After all, it seems that these less bone-preserving strategies have different indications than the HTO, specifically requiring a higher degree of OA, older age and lower activity level (8-10).

Recently, the efficacy of HTO has been extended in the treatment of anterior cruciate ligament (ACL) deficient varus knees (11, 12). ACL deficiency alters knee kinematics and progression of arthritic changes in the medial side of the knee joint (13-15).

According to the literature, patients with an ACL-deficient varus-angulated knee may need not only an isolated HTO, but also an additional ACL reconstruction (as a simultaneous or staged procedure) (16, 17). ACL insufficiency was considered in the past as contraindication for performing HTO (18). Nowadays, the combination of a painful varus osteoarthritis (OA) with ACL instability is often treated by a simultaneous HTO and ACL reconstruction (ACLR).

The results concerning isolated HTO are inferior in comparison with the combined HTO-ACLR procedure, possibly due to the reciprocal relation between the alignment and stability (19-21). Despite that, some authors suggest that a single HTO without any ACL reconstruction could be the appropriate treatment (22). After all, the one-stage HTO and ACLR is a technically demanding procedure which needs an experienced surgeon (23). Apart from the combined-expected clinical outcome, someone might assume that the simultaneous HTO-ACLR could theoretically also combine the possible complications of the two different surgical techniques included (HTO and ACL reconstruction).

In a systematic analysis comparing HTO and unicompartmental knee arthroplasty (UKA), Mancuso et al. reported that combined HTO and ACL reconstruction had the lowest revision rate but the highest rate of complications (24). In another systematic review, Li et al. concluded that simultaneous HTO and ACL reconstruction is a salvage procedure for physically active young patients because it provides satisfactory restoration of anterior stability, alleviation of medial compartment OA, improvement of subjective evaluations, and a predictable return to recreational sports (25). That systematic review included, among others, biomechanical analysis and clinical results from relatively old studies with great heterogeneity.

More recently, a number of prospective clinical trials have been published considering the combined HTO and ACL reconstruction (20, 26-28). The goal of this review was to answer the question: is one-stage combined HTO and ACL reconstruction an effective, well-established technique with long-term results in the treatment of varus-angulated knees with ACL deficiency? Also, we planned to explore the safety, side effects, and complications of this mode of treatment.

Materials and Methods

A systematic review was conducted by two independent reviewers (MM and OS) who searched the MEDLINE/PubMed database and the Cochrane Database of Systematic Reviews. These databases were queried with the term 'combined high tibial osteotomy anterior cruciate ligament reconstruction' and 'simultaneous high tibial osteotomy anterior cruciate ligament reconstruction'. To maximize the search, backward chaining of reference lists from retrieved papers was also undertaken.

The inclusion criteria were clinical studies about patients with ACL-insufficiency in a varus-angulated knee, treated with one-stage combined high tibial osteotomy and ACL reconstruction. These trials should contain a clinical follow-up evaluation (with tests and/or scores) and they must have been written in English. Furthermore, they should have been published during the last 15 years (from February 2003 till January, 2018, which was the end of our search).

We excluded all irrelevant studies (12), those published more than 15 years ago (7) or newer studies including clinical results from patients operated before 1995 (due to major advances in the ACL reconstruction technique) (2), case reports (2), biomechanical studies (1), reviews (4), studies without any clinical outcome (2), studies not written in English (3 articles in German), gait analysis studies (1) and editorial comments (1) [Figure1].

A summary flowchart of our literature search can be found in Figure 1. The quality of the evidence was

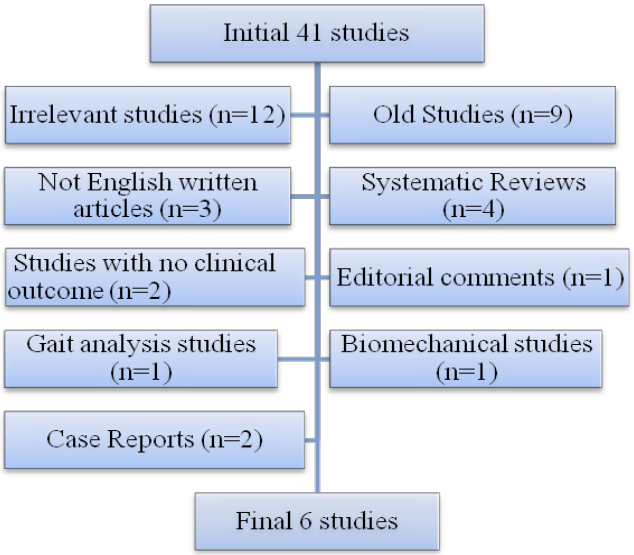

Figure 1. Study selection.

classified using the US Preventive Services Task Force system for ranking the level of evidence.

The conflicts between the two reviewers were discussed until agreement was achieved. If no agreement could be reached, it was planned that the senior author (MK) would decide. The two reviewers (MM, OS) independently extracted the data from each study and assessed the variable reporting of outcome data. The methodological quality of each study was included and the detected biases were assessed independently by each reviewer. The primary outcome measure was the postoperative statistically significant improvement of the clinical scores used in comparison with the preoperative scores per study. The secondary outcome was reoperations' rate per study.

Results

From the initial 41 studies we finally chose and assessed 6 studies which were eligible according to our inclusion-exclusion criteria. This review dealt with 1 prospective controlled study level II, 3 prospective cohort studies level III, 1 retrospective comparative study level III, and 1 retrospective case series level IV [Table 1] (22, 24-28). The aforementioned studies included 202 patients in total. The mean age of the patients included in this review was 46.6 years old, while more than three quarters of them were males (155 males and 47 females). The mean follow-up was 6.3 years post-operatively [Table 1].

The vast majority (85.6%) of the patients were treated with hamstrings autograft, whereas a small minority (12.8%) had a patellar bone-to-bone autograft and 3 patients received a patellar allograft [Table 2]. High tibial open wedge osteotomy was performed in 116 patients (57.4%) and closed wedge in 86 patients (42.6%) [Table 2].

The mean pre-operative angle of the patients included in our review was 6.6° varus, while the mean final post-operative angle was found to be 1.3° valgus [Table 2]. All 6 studies reported improved post-operative IKDC with the use of one-stage HTO and ACLR [Table 3], whereas the reoperation rate was very low [Table 4]. Two studies used bone substitute to fill the gap of the HTO [Table 5] (28, 29).

Arun et al published a retrospective case series of 30 patients undergoing simultaneous ACL reconstruction and medial open wedge HTO with a minimum 2-year follow-up (26). According to the authors, increasing the slope causes an anterior shift in tibial resting position that is accentuated under axial loads. This suggests that decreasing the tibial slope may be protective in an ACL deficient knee. The pre- and post-operative posterior tibial slopes were measured. Functional outcome was analyzed using clinico-radiological criteria, IKDC scoring and Lysholm score. The authors reported improvement in both IKDC and Lysholm scores in all patients but better results in those with >5° decrease in posterior slop.

Table 1. Type of study, level of evidence, number of patients initially enrolled and finally evaluated

Study	Year	Study level	Patients enrolled	Patients evaluated
Mehl et al (22)	2016	Prospective Controlled II	27 (1Revision to TKA)	26
			26	26
Vaishya et al (26)	2016	Prospective non controlled III	46 (6 lost follow up)	40
Arun et al (25)	2015	Retrospective IV	30 (2revision and 2 lost follow up)	26
Schuster et al (24)	2015	Prospective non controlled III	23	23 (22 in full examination)
Trojani et al (27)	2014	Retrospective Comparative III	34	29
Zaffagnini et al (28)	2013	Prospective non controlled III	32	32

Table 2. Mean age, sex and follow-up per study

Study	Males : Females	Mean Age (years)	Mean Follow-up (years)
Mehl et al (22)	17 : 9	40.5 (SD: 6.4)	4 (SD: 2.1)
	19 : 7	35.4 (SD: 7.2)	7.7 (SD: 3.8)
Vaishya et al (26)	27 : 13	37.3 (30-55)	1.3 (0.9-1.4)
Arun et al (25)	25 : 1	36.30 (23 -45)	6.23 (2 -13)
Schuster et al (24)	19 : 4	47 (+/-5.8)	6 (5.2-7.5)
Trojani et al (27)	20 : 9	43 (25-56)	6 (2-12)
Zaffagnini et al (28)	28 : 4	40.1 (27-54)	6.5 (4-10)

Table 3. Type of surgery, graft type for the ACL reconstruction and type of osteotomy performed

Study	Type of surgery	Graft type	Osteotomy type
Mehl et al	Group1:HTO	14 Patellar BtB autografts 3 Patellar BtB allografts 9 Hamstrings autografts	25 Closed Wedge 28 Open Wedge
	Group2:HTO+ACLR	Hamstrings autograft	
Vaishya et al	HTO+ACLR	Hamstrings autograft	Open Wedge
Arun et al	HTO+ACLR	Hamstrings autograft	Open Wedge
Schuster et al	HTO+ACLR+CR	12 Patellar BtB autografts 17 Hamstrings autografts	Open Wedge
Trojani et al	Group 1: HTO (12 patients) Group 2: HTO+ACLR (14 patients)	Hamstrings autograft (with extra-articular augmentation)	Closed Wedge
Zaffagnini et al	HTO+ACLR	Hamstrings autograft	Closed Wedge

Table 4. Pre-operative and post-operative alignment and osteoarthritis grading

Study	Alignment		OA grading	
	Pre-op	Post-op	Pre-op	Post-op
Mehl et al	Group 1: 6º varus (SD: 3.1º)	0.4º valgus (SD: 3.3º)	2.7(SD: 0.62) Kellgren-Lawrence	3.09(SD: 0.42)
	Group 2: 5.1º varus (SD: 2.2º)	2.1º valgus (SD: 2.1º)	1.9(SD: 0.38) Kellgren-Lawrence	2.51(SD: 0.59)
Vaishya et al	10.5º varus	0.5º valgus	N/A	33(82.5%) grade2 7(17.5%) grade3 Kellgren-Lawrence
Arun et al	N/A	N/A	N/A	N/A
Schuster et al	8.5º varus (+/-2.4º)	2.0º valgus (+/-2.3º)	N/A	N/A
Trojani et al	5º varus	2.5º valgus (5º varus - 11º valgus)	4 B (IKDC) 19 C 6 D	7 B 14 C 8 D
Zaffagnini et al	6.2º varus	0.4º varus	1 B (IKDC) 13 C 18 D	12 A 17 B 1 C 2 D

In a prospective clinical study, Mehl et al compared 26 patients who underwent HTO alone (group 1) with 26 patients who underwent single-stage HTO and ACLR (group 2) because of varus OA and ACL deficiency (22). The mean follow-up was 5.8 years post-operatively. Eighty-one percent of all patients reported an improvement of pain and 79% an improvement of instability without significant group difference. Significant worse results were observed in group 1 for the Lysholm score and the IKDC score. No group difference was found for the KT-2000 examination. The rate of post-operative complications was low with 4%, and no significant group differences were found. The authors concluded that HTO alone can improve pain and even subjective knee stability in the vast majority of the patients (22).

Schuster et al prospectively surveyed 23 knees who were submitted to combined HTO, ACLR, and chondral

Table 5. Clinical outcome scores per study

Study	Scores	Pre-operative IKDC	Post-operative IKDC
Mehl et al	KT 2000, IKDC, Lysholm	N/A	Group 1: 64.8(SD 13.0) Group 2: 74.0(SD 15.6)
Vaishya et al	IKDC, KOOS	N/A	87.5 (60-100)
Arun et al	IKDC, Lysholm	54.41 (when decrease<5º in posterior slop) 54.14 (when decrease>5º in posterior slop)	65.25 (when decrease<5º in posterior slop) 74 (when decrease>5º in posterior slop)
Schuster et al	KT 1000 , IKDC	47.7 (+/-11)	73.1 (+/-16)
Trojani et al	IKDC, VAS	N/A	77 (34-97)
Zaffagnini et al	KT 1000, IKDC, Tegner, EQ-5D, VAS	58	72

resurfacing (CR) procedures (26). These knees had symptomatic medial OA, ACL insufficiency, varus malalignment and full-thickness large-area cartilage defects. The rate of follow-up was 100% at 6 years, with no arthroplasty until then. The mean subjective IKDC score improved from 47.7 to 72.8 at 1 year, 70.9 at 3 years, and 73.1 at 5 years. Four ACL grafts were insufficient, and 2 grafts were stable but showed signs of degeneration. Good cartilage regeneration was seen in most cases, but no correlation with subjective IKDC score was apparent. Finally, the effect of the CR, as well as the reason for the considerable rate of graft insufficiency, remains unclear.

In 2016 Vaishya et al included in their study 40 patients suffering by chronic ACL insufficiency with associated varus malalignment due to knee OA (28). Simultaneous ACLR along with medial opening wedge osteotomy was done. The patients were assessed with IKDC and KOOS scores and any change in anterior tibial translation was also checked. The combined procedure showed a mean varus angle correction of 9°. There was a significant improvement in knee scores after the surgery, whereas no intra-operative complication and slippage of the synthetic graft were noted in any case. According to the authors, this treatment option reliably corrects varus deformity and obviates the use of any hardware.

Zaffagnini et al investigated the medium-term clinical and radiographic outcomes of 32 patients who underwent single-bundle over-the-top ACL surgery combined with HTO for varus-related early medial OA and ACL deficiency knee (30). All scores significantly improved from pre-operative status to final follow-up. OA progression was recorded only on the medial compartment, with severe medial OA in 22 % of the patients. No patients underwent osteotomy revision, ACL revision, unicompartmental knee arthroplasty (UKA), or total knee arthroplasty (TKA).

Finally, Trojani et al. reported a series of 29 patients operated on by ACL reconstruction combined with valgus HTO for chronic anterior knee instability associated with medial tibiofemoral OA (29). Bone-patellar tendon-bone transplant was used in 12 patients and hamstring tendon transplant in 17 as ACL autografts. an asymmetric wedge plate was used for medial opening wedge HTO. At a mean 6-year follow-up, 23 patients had resumed sports activities with 45% in competitive sports; 28 were free of instability; and 21 free of pain. The mean subjective IKDC score was 77 and 70% of the patients had A or B global objective IKDC scores. The mean knee axis was in 2.5° valgus.

Discussion

Any combination of conditions increasing medial joint forces is associated with factors leading to more rapid degeneration of the medial compartment (31, 32). Varus alignment causes a static adduction force to the knee, which results in an increased loading of the medial compartment and tensioning of the lateral structures as well as elevated tension of the ACL (23). Varus thrust of the knee is a dynamic increase of an often preexisting varus angle and it is suspected to be a major reason for failure of ACL reconstructions (33).

Concomitant HTO and ACL reconstruction is a combined surgical procedure intended to improve kinematics and kinetics in the unstable ACL-deficient knee with varus malalignment and medial compartment knee OA (20). Kean et al. showed that improving the lower limb alignment and knee stability significantly alters the coronal and sagittal moments about the knee during walking (34). Controversy still exists regarding the subjective and objective evaluations and the prevalence of complications.

The last few years a number of clinical trials were conducted in relation to the clinical outcome of one-stage HTO and ACL reconstruction for patients suffering from symptomatic varus OA in combination with anterior knee instability (22, 26-30). So, a current evaluation of the literature is needed to elucidate the necessity of this procedure.

In contrast to an older review by Li et al., we used different inclusion-exclusion criteria, while our methodology was not only systematic but also narrative,

comprehensive and critical (25). Our systematic review investigated comprehensively and balanced the more recent published data regarding the above-mentioned topic. As a result, we included only studies, which were published during the last 15 years and, also, contained clinical information about patients operated -at least- after 1995.

The study of Arun et al. measured the functional outcome in relation to posterior tibial slop (27). A larger sample size and meta-analysis are required to validate that study, while the authors admitted that MRI could be a better tool to calculate the posterior tibial slope. Mehl et al. collected prospectively the mid- to long-term clinical and radiological results in patients with symptomatic varus OA and ACL deficiency (22). A weak point of this study was the heterogeneity of the group. The patients had been treated according to recommendations of current studies at the time of operation which led to a selection bias and therefore, to a decrease of statistical significance regarding the group comparison. Further limitations are the lack of pre-operative values of the clinical scores (Lysholm and IKDC) and of pre-operative values of the KT-2000 measurement.

The long minimum follow-up period (5 years) of the patients included in the prospective study of Schuster et al. was an advantage (26). According to the authors, patients included in that study elected not to undergo TKA and were referred for joint preservation, which represents a selection bias. The absence of a control group without a cartilage-addressing procedure makes it impossible to evaluate the effect of the CR. As for Vaishya et al., the cohort of their patients was not large, while a second look arthroscopy which would have ideally allowed to re-assess the previous cartilage changes, was not performed (28). This study had also a 2-year follow-up, which is considered to be rather small for this type of surgery.

In addition, the study of Zaffagnini et al. was characterized by patients' heterogeneity, which made it difficult to generalize and standardize its findings (30). The relatively small number of patients included did not allow statistical analysis between small subgroups, while the mid-term follow-up might be too short to evaluate the outcome of a salvage procedure such as the combined ACL reconstruction and closing-wedge osteotomy. Finally, since there was no control group of patients treated in another way, the authors only managed to compare their results to the available literature. Last but not least, the limitations of the study by Trojani et al. lie in its retrospective design, without any control group (29). The series was, however, homogeneous in terms of surgical technique, managed in a single center and continuous without any loss to follow-up.

In summary, all 6 studies demonstrated satisfactory clinical results with the use of combined HTO and ACLR in patients suffering from symptomatic varus OA in combination with anterior knee instability. The patients have considerable benefit if both the procedures are carried out simultaneously, because with only one hospital stay and one rehabilitation for two procedures, they can quickly return to recreational and professional life (27).

Notwithstanding, limited conclusions can be made about the optimum treatment of the aforementioned category of patients due to the complete lack of high-quality trials. Well-designed randomized controlled clinical studies (level I) with larger number of patients are needed to establish the superiority of the simultaneous HTO and ACLR over: a) the staged procedure; b) the primary TKA; c) the combined unicompartmental knee arthroplasty (UKA) and HTO; d) the HTO alone; and e) the UKA alone.

Combined one-stage HTO and ACLR is a safe and effective procedure for the treatment of patients suffering from symptomatic varus OA in combination with anterior knee instability. The presence of an experienced, well-trained physician is considered to be mandatory in order to perform this relatively demanding operation and avoid intra-operative complications, like the wrong position of the ACL tibial tunnel in connection with the tibial osteotomy.

All other authors declare they have no conflict of interest.

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References

1. Coventry MB. Osteotomy of the upper portion of the tibia for degenerative arthritis of the knee. A preliminary report. J Bone Surg Am. 1965; 47(1):984-90.

2. Amendola A, Bonasia DE. Results of HTO in medial OA of the knee. In: Amendola A, Bellemans J, Bonnin M, MacDonald S, Menetrey J, editors. Paris: Springer; 2012.
3. Insall JN, Joseph DM, Msika C. High tibial osteotomy for varusgonarthrosis. A long-term follow-up study. J Bone Joint Surg Am. 1984; 66(7):1040-8.
4. Amendola A, Bonasia DE. Results of high tibial osteotomy: review of the literature. Int Orthop. 2010; 34(2):155-60.
5. Akizuki S, Shibakawa A, Takizawa T, Yamazaki I, Horiuchi H. The long-term outcome of high tibial osteotomy: a ten- to 20-year follow-up. J Bone Joint Surg Br. 2008; 90(5):592-6.
6. Sprenger TR, Doerzbacher JF. Tibial osteotomy for the treatment of varus gonarthrosis: survival and failure analysis to twenty-two years. J Bone Joint Surg Am. 2003; 85-A(3):469-74.
7. Griffin T, Rowden N, Morgan D, Atkinson R, Woodruff P, Maddern G. Unicompartmental knee arthroplasty for the treatment of unicompartmental OA: a systematic study. ANZ J Surg. 2007; 77(4):214-21.
8. Sisto DJ, Blazina ME, Heskiaoff D, Hirsh LC. Unicompartment arthroplasty for osteoarthrosis of the knee. Clin Orthop Relat Res. 1993; 286(1):149-53.
9. Santoso MB, Wu L. Unicompartmental knee arthroplasty, is it superior to high tibial osteotomy in treating unicompartmental osteoarthritis? A meta-analysis and systemic review. J Orthop Surg Res. 2017; 12(1):50.
10. Pfitzner T, Perka C, von Roth P. unicompartmental vs. total knee arthroplasty for medial osteoarthritis. Z Orthop Unfall. 2017; 155(5):527-33.
11. O'Neill DF, James SL. Valgus osteotomy with anterior cruciate ligament laxity. Clin Orthop Relat Res. 1992; 278(1):153-9.
12. Stein BE, Williams RJ 3rd, Wickiewicz TL. Arthritis and osteotomies in anterior cruciate ligament reconstruction. Orthop Clin North Am. 2003; 34(1):169-81.
13. Lewek M, Rudolph K, Axe M, Snyder-Mackler L. The effect of insufficient quadriceps strength on gait after anterior cruciate ligament reconstruction. Clin Biomech (Bristol, Avon). 2002; 17(1):56-63.
14. Webster KE, Feller JA, Wittwer JE. Longitudinal changes in knee joint biomechanics during level walking following anterior cruciate ligament reconstruction surgery. Gait Posture. 2012; 36(2):167-71.
15. Kessler MA, Behrend H, Henz S, Stutz G, Rukavina A, Kuster MS. Function, osteoarthritis and activity after ACL-rupture: 11 years follow-up results of conservative versus reconstructive treatment. Knee Surg Sport Traumatol Arthrosc. 2008; 16(5):442-8.
16. McNamara I, Birmingham TB, Fowler PJ, Giffin JR. High tibial osteotomy: evolution of research and clinical applications--a Canadian experience. Knee Surg Sport Traumatol Arthrosc. 2013; 21(1):23-31.
17. Giffin JR, Shannon FJ. The role of the high tibial osteotomy in the unstable knee. Sport Med Arthrosc Rev. 2007; 15(1):23-31.
18. Rudan JF, Simurda MA. High tibial osteotomy. A prospective clinical and roentgenographic review. Clin Orthop Relat Res. 1990; 255(1):251-6.
19. Dejour H, Neyret P, Boileau P, Donell ST. Anterior cruciate reconstruction combined with valgus tibial osteotomy. Clin Orthop Relat Res. 1994; 299(1):220-8.
20. Marriott K, Birmingham TB, Kean CO, Hui C, Jenkyn TR, Giffin JR. Five-year changes in gait biomechanics after concomitant high tibial osteotomy and ACL reconstruction in patients with medial knee osteoarthritis. Am J Sport Med. 2015; 43(9):2277-85.
21. Bonin N, Ait Si Selmi T, Donell ST, Dejour H, Neyret P. Anterior cruciate reconstruction combined with valgus upper tibial osteotomy: 12 years follow-up. Knee. 2004; 11(6):431-7.
22. Mehl J, Paul J, Feucht MJ, Bode G, Imhoff AB, Südkamp NP, et al. ACL deficiency and varus osteoarthritis: high tibial osteotomy alone or combined with ACL reconstruction? Arch Orthop Trauma Surg. 2017; 137(2):233-40.
23. Herman BV, Giffin JR. High tibial osteotomy in the ACL-deficient knee with medial compartment osteoarthritis. J Orthop Traumatol. 2016; 17(3):277-85.
24. Mancuso F, Hamilton TW, Kumar V, Murray DW, Pandit H. Clinical outcome after UKA and HTO in ACL deficiency: a systematic review. Knee Surg Sports Traumatol Arthrosc. 2016; 24(1):112-22.
25. Li Y, Zhang H, Zhang J, Li X, Song G, Feng H. Clinical outcome of simultaneous high tibial osteotomy and anterior cruciate ligament reconstruction for medial compartment osteoarthritis in young patients with anterior cruciate ligament-deficient knees: a systematic review. Arthroscopy. 2015; 31(3):507-19.
26. Schuster P, Schulz M, Richter J. Combined biplanar high tibial osteotomy, anterior cruciate ligament reconstruction, and abrasion/microfracture in severe medial osteoarthritis of unstable varus knees. Arthroscopy. 2016; 32(2):283-92.
27. Arun GR, Kumaraswamy V, Rajan D, Vinodh K, Singh AK, Kumar P, et al. Long-term follow up of single-stage anterior cruciate ligament reconstruction and high tibial osteotomy and its relation with posterior tibial slope. Arch Orthop Trauma Surg. 2016; 136(4):505-11.
28. Vaishya R, Vijay V, Jha GK, Agarwal AK. Prospective study of the anterior cruciate ligament reconstruction associated with high tibial opening wedge osteotomy in knee arthritis associated with instability. J Clin Orthop Trauma. 2016; 7(4):265-71.
29. Trojani C, Elhor H, Carles M, Boileau P. Anterior cruciate ligament reconstruction combined with valgus high tibial osteotomy allows return to sports. Orthop Traumatol Surg Res. 2014; 100(2):209-12.
30. Zaffagnini S, Bonanzinga T, Grassi A, Marcheggiani Muccioli GM, Musiani C, Raggi F, et al. Combined ACL reconstruction and closing-wedge HTO for varus angulated ACL-deficient knees. Knee Surg Sports Traumatol Arthrosc. 2013; 21(4):934-41.
31. Noyes FR, Schipplein OD, Andriacchi TP, Saddemi SR, Weise M. The anterior cruciate ligament-deficient

knee with varus alignment. An analysis of gait adaptations and dynamic joint loadings. Am J Sport Med. 1992; 20(6):707-16.
32. Shahpari O, FallahKezabi M, Kalati HH, Bagheri F, Ebrahimzadeh MH. Clinical outcome of anatomical transportal arthroscop-ic anterior cruciate ligament reconstruction with hamstring tendon autograft. Arch Bone Jt Surg. 2018; 6(2):130-9.
33. van de Pol GJ, Arnold MP, Verdonschot N, van Kampen A. Varus alignment leads to increased forces in the anterior cruciate ligament. Am J Sport Med. 2009; 37(3):481-7.
34. Kean CO, Birmingham TB, Garland JS, Jenkyn TR, Ivanova TD, Jones IC, et al. Moments and muscle activity after high tibial osteotomy and anterior cruciate ligament reconstruction. Med Sci Sports Exerc. 2009; 41(3):612-9.