International Orthopaedics (2023) 47:963–971
https://doi.org/10.1007/s00264-022-05544-5

ORIGINAL PAPER

Is combined robotically assisted unicompartmental knee arthroplasty and anterior cruciate ligament reconstruction a good solution for the young arthritic knee?

Constant Foissey[1] · Cécile Batailler[1] · Jobe Shatrov[2] · Elvire Servien[1,3] · Sébastien Lustig[1,4]

Received: 28 July 2022 / Accepted: 4 August 2022 / Published online: 13 August 2022

Abstract

Purpose Anterior cruciate ligament (ACL) deficiency can be a consequence or a cause of femoro-tibial osteoarthritis (OA). Several studies have published satisfactory outcomes of unicompartimental knee arthroplasty (UKA) and combined ACL reconstruction despite its absence classically being considered a contraindication. A major challenge in the ACL deficient knee is obtaining appropriate gap balancing and limb axis. Robotically assisted UKA allows for precise control of these factors; however, it's utilisation as a tool with combined ACL reconstruction and UKA has not been described. The purpose of this study was to evaluate the clinical and radiological outcomes of robotically assisted UKA with combined ACL reconstruction.

Methods This was a retrospective single-centre study of ten patients operated by a single surgeon from 2016 to 2020. All surgery was performed using a cemented fixed bearing UKA prosthesis (Journey uni, Smith and Nephew®) (8 medial, 2 lateral) inserted with the assistance of an image-free robotic-assisted system (BlueBelt, Navio, Smith and Nephew®). All ACL reconstructions were performed using hamstring autograft. Clinical assessment included International Knee Score (IKS) score, Tegner score and patient satisfaction. Radiological assessment was performed to assess radiolucent lines, progression of OA in the other compartments, Hip-Knee-Ankle angle and Posterior Tibial Slope.

Results There were eight females (80%), mean age was 57 ± 7 [48–70], mean BMI was 26 ± 3 [22–31]. The mean follow-up was 45 months ± 13 months [24–66]. Mean post-operative IKS knee and function score were respectively 96 ± 4.5 [88–100] and 93 ± 8.2 [74–100], mean Tegner score was 4.5 ± 1.4 [3–6]. Nine patients (90%) returned to sport; one patient (10%) was dissatisfied because of residual pain preventing a return to a desired level of sport. 100% of the radiological objectives were achieved. No radiolucent lines were seen at the last follow-up. There were two re-operations (20%) for stiffness requiring arthroscopic arthrolysis at two and three months respectively following surgery, with full recovery of the flexion at the last follow-up in both cases. No other complications were observed.

Conclusion Robotic UKA associated with ACL reconstruction provides satisfactory early patient outcomes and accurate implant positioning. The first results in terms of return to sports were promising.

Keywords Unicompartmental knee arthroplasty · Unicompartmental knee replacement · Anterior cruciate ligament reconstruction · Robotic-assisted procedure · Accuracy · Failure · Loosening

Level of evidence: retrospective, consecutive case series; Level IV

✉ Constant Foissey
constant.foissey@chu-lyon.fr

1 Orthopaedics Surgery and Sports Medicine Department, FIFA Medical Center of Excellence, Croix-Rousse Hospital, Lyon University Hospital, 103 Grande rue de la Croix-Rousse, 69004 Lyon, France

2 Sydney Orthopaedic Research Institute (SORI), St. Leonards, Sydney, Australia

3 LIBM – EA 7424, Interuniversity Laboratory of Biology of Mobility, Claude Bernard Lyon 1 University, Lyon, France

4 Univ Lyon, Claude Bernard Lyon 1 University, IFSTTAR, LBMC UMR_T9406, F69622 Lyon, France

Introduction

The three biomechanical consequences of anterior cruciate ligament (ACL) deficiency are increased anterior translation of the tibia [1], loss of the synchronization between the lateral femoral condyle and tibial plateau (pivot shift) [2], and the medialisation of the centre of rotation due to an internal rotation of the tibia [3]. The natural history of ACL deficiency can lead to femoro-tibial osteoarthritis (OA) due the biomechanical changes, cartilage and meniscal injuries caused by the initial injury or through repetitive episodes of instability. Conversely, tibio-femoral OA can also lead to ACL deficiency [4], typically progressing anterior to posterior in the medial compartment and destroying the ACL and damaging the lateral compartment [5].

The classic surgical options for OA secondary to ACL deficiency are either a high tibial osteotomy (HTO) combined with ACL reconstruction in early to moderate stages [6, 7] or a TKA in advanced stages. However, patients are often young, physically active and TKA may limit activity. Furthermore, it carries a high risk of revision within five years (5% under 55 years old [8]). Isolated UKA on the other hand for ACL deficient monocompartmental knee OA has been shown to have an intolerable rate of 21% failure at two years [9], with majority of failures occurring due to early tibial loosening [10].

Several studies have challenged the classic indication of not performing UKA in ACL deficient knees, published encouraging results with survival rates over 90% at 5 years follow-up [11–13]. Despite these good results, the Oxford team in their series of 52 patients at five years reported a 10% rate radiolucencies, one conversion to TKA and one PE dislocation [13] reflecting the challenging nature of this surgery. Combined surgery is technically difficult as adjustment of the posterior tibial slope (PTS), hip-knee-ankle (HKA) angle, height of the polyethylene (PE) and finally the tension of the ACL reconstruction influence gap balancing in both flexion and extension. Robotic assistance system allows for precise control of the aforementioned difficulties [14]; however, results when used for this specific indication to the best of our knowledge have not been published.

The purpose of this study was to evaluate the early clinical and radiological outcomes of combined single-stage robotic-assisted UKA and ACL reconstruction in patients with an ACL deficiency and concomitant symptomatic medial or lateral compartment knee OA.

Methods

Consecutive patients from a single-centre undergoing robotic-assisted UKA with combined ACL reconstruction between October 2016 and April 2020 were included and retrospectively reviewed. Inclusion criteria was isolated medial or lateral femorotibial OA with post-traumatic ACL deficiency confirmed on MRI imaging, a reducible deformity and BMI < 35. Exclusion criteria were a lower limb coronal plane deformity greater than 10° of varus or 15° of valgus associated procedure (osteotomy, controlateral UKA, patellofemoral arthroplasty) and a fixed anterior subluxation of the tibia (Fig. 1). ACL degenerative deficiency secondary to OA was considered as a contraindication to surgery as in that situation degenerative changes are, most of the time, present in the lateral compartment [5]. In that situation, a TKA was then performed. All cases were performed by the same surgeon who performs more than 50 UKA per annum.

Assessed data

Pre-operatively, all patients completed an IKS score (functional and knee scores). Radiographic examination was performed before surgery, at two months, then once a year post-operatively (weight bearing antero-posterior and lateral knee radiographs, patellar axial view and full-length standing radiographs). A pre-operative MRI was

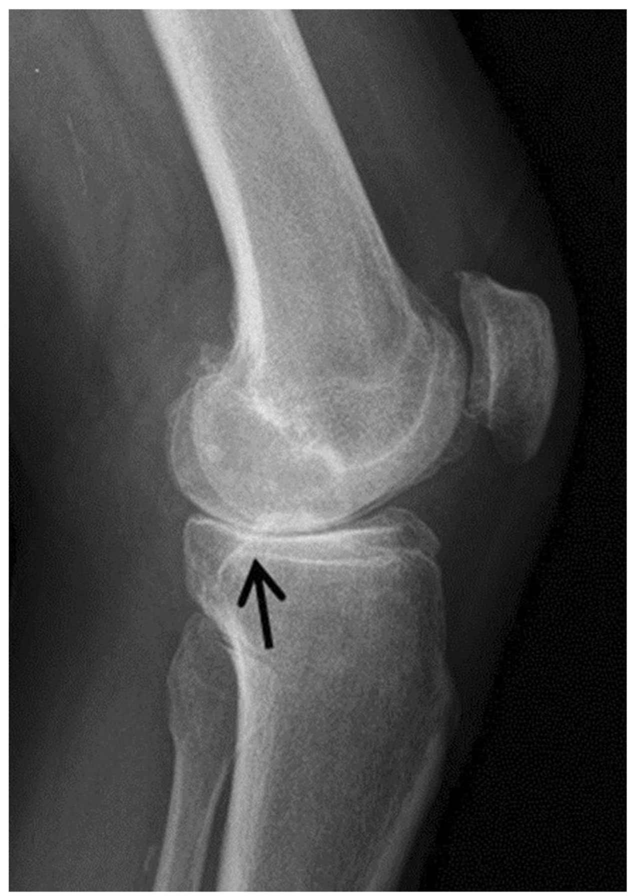

Fig. 1 Patient with a medical history of ACL rupture with a fixed anterior subluxation of the tibia that contra-indicate the surgery

routinely performed to assess the integrity of the ACL as well as cartilage wear of the two other compartments. Radiological evaluation was assessed by an independent orthopaedic surgeon and included the HKA angle and the PTS. The PTS was measured as the angle between the articular surface of the tibia and the posterior cortex of the tibia [15]. All measurements were performed with the software Centricity Universal Viewer Zero Footprint (version 6.0 SP7.0.2—GE Healthcare, Barrington, USA). Outlier rates were determined for mechanical axis alignment (HKA objective: 178° ± 2° for varus deformation, 182° ± 2° for valgus deformation), and PTS (5° ± 3°) [14, 16]. Radioluciencies were assessed and classified as physiological or pathological (progressive, poorly defined, > 2 mm thick, no matching radiodense line). Radiolucencies beside the vertical wall of the femur were not assessed, as this is not a site where the component is fixed and few cement is placed [17]. Clinical results were assessed post-operatively, at the last follow-up, by Tegner level activity scale [18], IKS score (divided into functional and knee scores) [19], forgotten joint score (FJS) [20] and by a satisfaction score (divided into very satisfied, satisfied, disappointed). Complications, all re-operations and revision were recorded.

Surgical techniques

The implant used was a cemented, cutting type unicompartmental prosthesis with a metal back fixed-bearing tibial component (Journey Uni, Smith and Nephew®). Surgery was performed in the supine position with a tourniquet. A standard skin incision for a mid-vastus approach was performed and the gracilis and semitendinosis tendons were harvested and prepared to form a four-strand graft with the pedicle left attached to the tibia. Next, arthroscopy was performed to assess all three compartments to confirm suitability for the UKA. The notch was cleared and the femoral and tibial tunnel prepared using an outside-in drilling technique. A standard femoral tunnel was created for all cases; however, for medial UKA the tibial tunnel was placed slightly more laterally than usual in order to avoid impingement of the graft on the prosthetic tibial plateau. Planning of bone cuts, implant positioning and balancing were performed using the Blue-Belt Navio robotic surgical system (Smith and Nephew®) according to a previously described technique by Lustig et al. [21]. With the trial components in place, the ACL graft was pulled into the tunnels and checked for impingement. Next, the graft was fixed into the tibial tunnel with a screw, then final implant was cemented and finally graft fixation on the femoral side performed with a screw (Fig. 2). A significant advantage of robotic assistance is the control of the HKA angle to avoid any over-correction (Fig. 3a), control of the tibial slope (Fig. 3b) (to avoid excess strain on the ACL graft) and to control the graft tension whilst targeting gap balancing with fine adjustments with thickness of the PE (Fig. 4).

Statistics

All statistical analysis was performed using XLstat (version 2015.1, Addinsoft, Paris, France). Descriptive data analyses such as means, standard deviations and ranges were performed. Comparisons were made using independent *t* tests for normally distributed variables and the Mann–Whitney *U* test for none normally distributed variables. Categorical variables were summarized by their percentages. Significance was set at alpha = 0.05; *P* values < 0.05 were considered statistically significant.

Fig. 2 Pre-operative and 2 years follow-up X-Rays of a robotic medial UKA (Journey Uni, Smith and Nephew®) with ACL reconstruction in a patient who underwent 3 Lemaire interventions

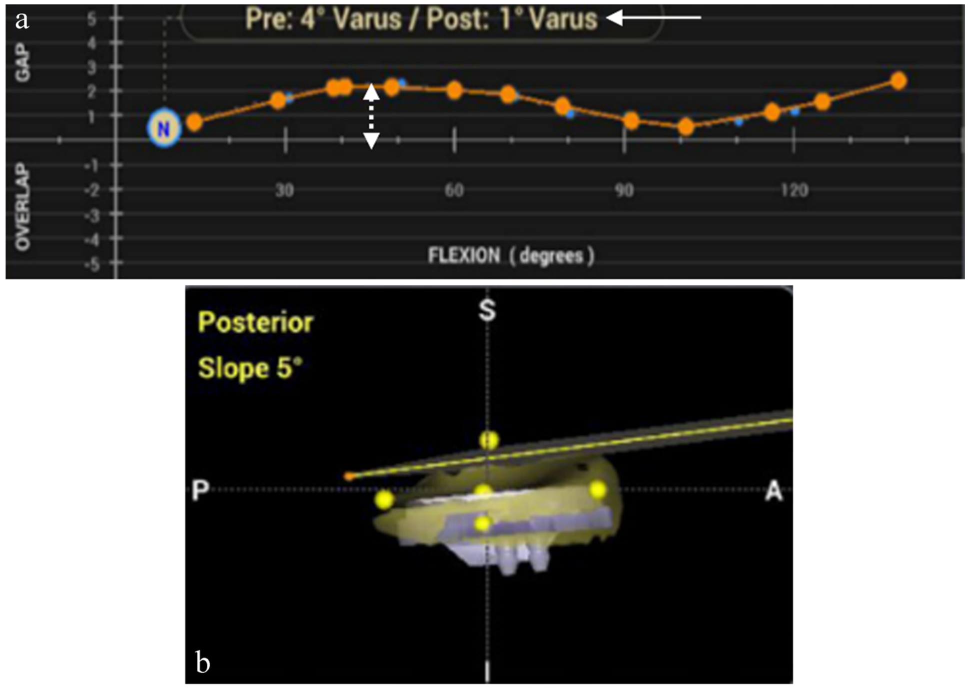

Fig. 3 Contribution of Navio® during the planning. (**a**) Planning of residual HKA angle ← and gap balancing ↕, (**b**) Planning of PTS

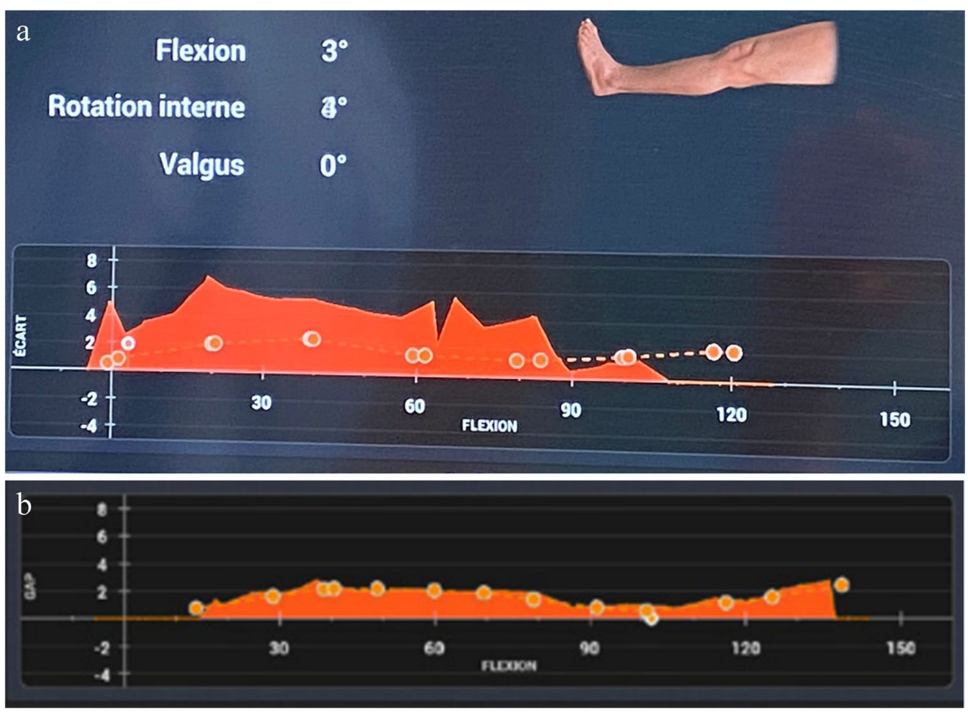

Fig. 4 Contribution of Navio® during the testing with trials. The dotted line represents the planning, the continued area represents the actual testing: (**a**) Without tightening the ACL gaps are too loose between 0° and 90° of flexion, (**b**) Perfect testing corresponding to the planning

Results

Two lateral UKA and eight medial UKA were performed. Patient demographic details are described in Table 1. Mean follow-up was 45 ± 13 months [24–66], no patients were lost to follow-up.

Clinical results

IKS knee and function scores were significantly improved following surgery (Table 2). The mean post-operative Tegner score was 4.5 ± 1.4 [3–6]. Nine patients (90%) returned to the desired level of sport. Five patients (50%) were able to ski and four (40%) to practice running again.

Table 1 Demographic data

Preoperative data	Population (n = 10)
Age (years)	57.3 ± 7 [47–69]
BMI (kg/M^2)	26.3 ± 2.7 [22–30]
Gender	8 F (80%), 2 M (20%)
Side	4 L (40%), 6 R (60%)
Compartment	2 external, 8 internal
Stage OA (Ahlback)	3 ± 1 [2–4]
Medical history:	
- External meniscectomy	2 (20%)
- Internal meniscectomy	4 (40%)
- ACL reconstruction	2 (20%)

F, female; *M*, male; *L*, left; *R*, right; *OA*, osteoarthritis

No anteroposterior instability was observed. Only one person (10%) was disappointed by the surgery due to a limitation of sport, with no pain in daily life.

Complications

Two (20%) arthrolysis under arthroscopy for stiffness were required at two and three months after surgery. PTS correction was acceptable in both cases(4° and 5°), ROM improved to 120° and 130° and both patients were very satisfied with the end-result of the surgery.

No complication due to the robotic-assisted surgery occurred: Specifically, no pin site related problems or conversion no mechanical technique were required. The mean operative time was 128 min. ± 21 [96–150].

Radiological results (Table 2)

No patients demonstrated progress radiolucency's or OA in the contralateral compartment at the last follow-up. There were no outliers concerning the radiological accuracy (Fig. 5).

Discussion

The most important finding of this study was that satisfactory patient reported outcomes and a high level (90%) of return to sport in a young and active population (mean Tegner = 4.5) was achieved following robotically assisted UKA with combined ACL reconstruction. Radiographic results demonstrated a high level of accuracy using this imageless robotic platform, with the alignment objectives being achieved in 100% of cases.

UKA combined with ACL reconstruction is a technically more demanding procedure; however, the utilisation of robotic-assistance for this indication has not been described. Whilst early evidence suggests robotically assisted UKA may have superior survival outcomes compared to mechanical UKA [22], the outcomes of combined ACL reconstruction with UKA are limited to surgery performed with manual instrumentation. A systematic study by Volpin et al. in 2019 [11] reported pooled data from eight studies with 186 patients that underwent combined mechanical UKA and ACL reconstruction at a mean follow-up of 37.6 months. The global clinical results were very satisfying. Complications are summarized in Table 3. The most frequent complication was PE dislocation (n = 3, 1.6%) in two series using a mobile bearing [13, 23]. Achieving balancing may reduce the incidence of liner dislocation [24], and robotically assisted surgery aids this goal by providing anticipated gaps with implant panning.

Table 2 Comparison of pre- and post-operative clinical and radiographic data

	Pre-operative (n = 10)	Post-operative (n = 10)	*P*-value
Clinical:			
- IKS score—Function	61.3 ± 7.4 [48–75]	93.1 ± 8.2 [74–100]	< 0.0001
- IKS score—Knee	58.1 ± 6.2 [49–68]	95.8 ± 4.5 [88–100]	< 0.0001
- Tegner	2.6 ± 1.2 [1–3]	4.8 ± 1.4 [3–6]	< 0.0001
- Flexion (°)	131.5 ± 7.1 [120–140]	127 ± 4.8 [120–130]	0.19
- Satisfaction		1 D (13%), 1 S (10%), 8 VS (80%)	
- FJS		86.7 ± 20.1 [46–100]	
Radiographic:			
- HKA (°):			
Internal UKA	175.1 ± 4.8 [169–180]	178.6 ± 1.1 [177–180]	0.04
External UKA	184.5 ± 0.5 [184–185]	181.5 ± 0.5 [181–182]	0.33
- Correction HKA (°)		4 ± 2 [1–8]	
- PTS (°)	9 ± 2.6 [4–12]	4.5 ± 1.3 [3–6]	< 0.0001
- Correction PTS (°)		3.6 ± 2.6 [0–7]	

D, disappointed; *S*, satisfied; *TS*, very satisfied; *HKA*, Hip-Knee-Ankle angle; *UKA*, unicompartmental arthroplasty; *PTS*, posterior tibial slope

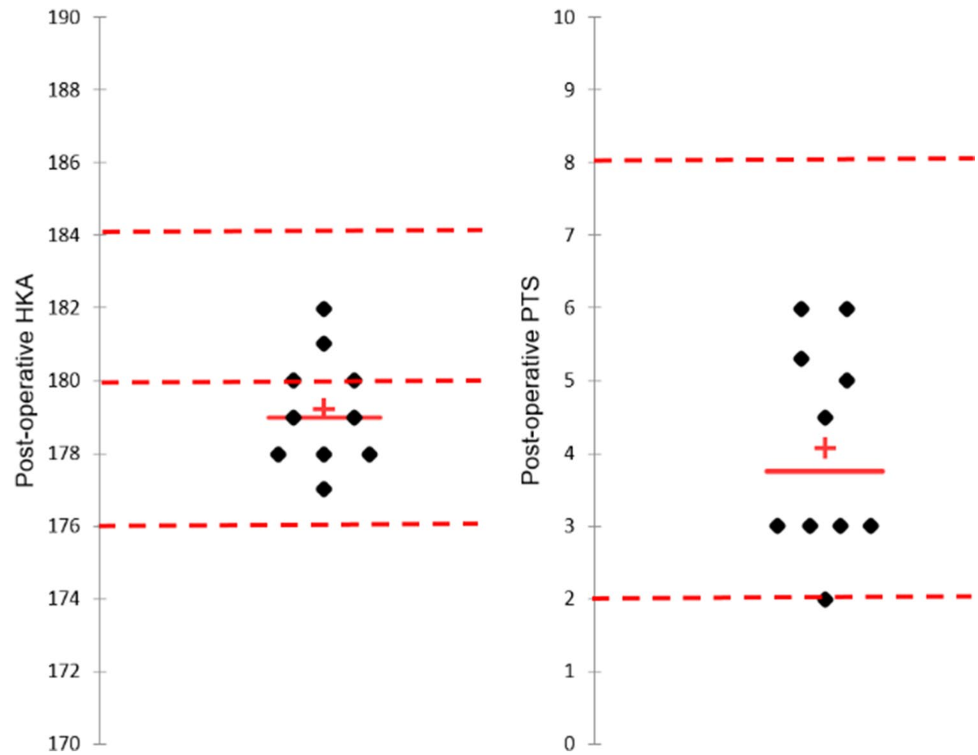

Fig. 5 Repartition of the post-operative radiographic results ---- objectives + mean —— median

Additionally in this study, one (0.5%) patient had contralateral OA and 37 (20%) were observed to have radiolucency's. Stephanie et al. [25] reported that these complications could be decreased by avoiding over or under correction, which is also aided by the assistance of the robotic system. In the current study, neither of these complications were observed.

None of those studies reported the radiological results in term of global accuracy. This criteria was yet studied by Batailler et al. [31] when performing standard UKA and found a significant difference between the mechanical and the robotic (16% of outliers versus 32% for medial UKA) with a lower rate of revision in the robotic group (5% versus 9%, NS).

The rate of arthrolysis under arthroscopy was high (n = 2, 20%), without any subsequent consequences and good recovery of flexion at the last follow-up. Arthroscopic arthrolysis for stiffness with UKA is not widely described in the literature, Fournier et al. [32] in a series of 22 arthrolysis and found that robotic-assistance was a protective factor against requiring surgery for stiffness. Derreveaux et al. [33] found that combined procedures with UKA (HTO, ACL, bicompartmental arthroplasty) had a high risk of stiffness (22% of arthrolysis). In the current study, stiffnesses was not correlated with excessive correction of the PTS (PTS = 6° each, correction = 4° and 5°). Several studies agreed to say that a greater PTS

Table 3 Comparison of our series to the literature

	Year	No of patients	Mean follow-up (months	Complications
Pandit [26]	2006	15	34	1 (7%) infection
Tinius [27]	2007	32	31	0
Dervin [28]	2007	10	20	1 (10%) arthrolysis
Krishnan [29]	2009	9	24	0
Weston-Simons[13]	2012	51	60	1 (2%) conversion to TKA due to contralateral OA 1 (2%) tibial onlay dislocation 1 (2%) infection
Tinius [30]	2012	27	53	
Tian[23]	2016	28	52	2 (7%) tibial onlay dislocation
Ventura[12]	2017	14	27	1 (7%) controlteral OA
Current study	2022	10	45	2 (20%) arthrolysis

in TKA is correlated to a better flexion [34, 35]. However, those results cannot be extrapolated to UKA [36, 37]. The less a prosthesis is constraint the more antero-posterior stability depends on ligaments and a lower PTS [38]. Thus, Hernigou and Deschamps recommended a PTS between 3° and 7° with a significant increased risk of anterior tibial translation and no gain on the flexion beyond [36].

The average age of patients in this study was 57 years. An important objective of the intervention in this patient population is to facilitate ongoing participation in sporting activities. In the current study, one patient was disappointed and whilst not experiencing pain, was not able to return to any sport. Literature suggests that TKA is a less satisfying option for patients, wishing to return to sport. Witjes et al. in a literature review found a return to sport between 36 and 89% for the TKA versus 75 to 100% for UKA [39]. The contribution of robot-assistance for a retrun to sport was previously reported by Canetti et al. who found a faster return to sport in favour of the robotic group after a lateral UKA [40].

Monocompartmental arthritis may be treated with either UKA or HTO. A previous study in 2016 by Mancuso et al. comparing either HTO or UKA with ACL reconstruction found a higher complication rate with HTO (21%) than UKA (2.8%) and a comparable rate of revision (2.6% vs 2.8%) [41]. However this comparison may not be valid as HTO is often utilised in younger patients with moderate stage of OA [42]. Furthermore, HTO has been shown in some studies to allow a faster return to sport [43] and with less risks of conversion to TKA [44].

Most of the limitations mentioned by Figueroa et al. [45] in their state of the art concerning new technologies were not observed here: there were no pin-site related problems, the Navio® system does not need any pre-operative CT and the duration of the intervention (mean = 128 min) seems reasonable given the complex nature of the intervention. Previous studies have not reported their operating time.

The limits of this study are that it is retrospective in nature with a low number of patients and relatively short-term follow-up. However, to the best of our knowledge this is the first study of its kind reporting outcomes of robotically assisted UKA and combined ACL reconstruction. Besides, among the eight studies of the literature review of Volpin et al. [11], only four had more than 15 patients and only two had a mean follow-up greater than three years.

Conclusion

Imageless robotically assisted surgery is a precise and accurate tool to assist with the challenges faced when performing UKA with combined ACL reconstruction. This is the first series reporting its results for this specific indication and demonstrates excellent accuracy, good clinical results and an excellent rate of return to sport. Longer term follow-up and a larger comparative series are required to further understand the benefits gained from its use.

Author contribution Constant Foissey: study design, data collection, statistical analysis, literature review and manuscript writing.

Cécile Batailler: study design, manuscript editing

Jobe Shatrov: literature review, manuscript editing

Elvire Servien: study design, manuscript editing

Sébastien Lustig: study design, supervision, literature review and manuscript editing

All authors read and approved the final manuscript.

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The Advisory Committee on Research Information Processing in the Field of Health (CCTIRS) approved this study on June 4, 2015 under number 15–430. For this type of study, formal consent is not required.

Conflict of interest No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article. CF, CB and JS declare that they have no conflict of interest. ES: Consultant for Corin. SL: Consultant for Stryker, Smith Nephew, Heraeus, Depuy Synthes; Institutional research support from Groupe Lepine, Amplitude; Editorial Board for Journal of Bone and Joint Surgery (Am)

References

1. Neyret P, Ait Si Selmi T, Gluchurk Pires L (1999) Conférence d'enseignement. Arthrose et laxité. In: Sauramps medical (ed) Annales d'arthroscopie. Paris, pp 25–46
2. Logan M, Dunstan E, Robinson J et al (2004) Tibiofemoral kinematics of the anterior cruciate ligament (ACL)-deficient weightbearing, living knee employing vertical access open "interventional" multiple resonance imaging. Am J Sports Med 32:720–726. https://doi.org/10.1177/0095399703258771
3. Amis AA, Bull AMJ, Lie DTT (2005) Biomechanics of rotational instability and anatomic anterior cruciate ligament reconstruction. Oper Tech Orthop 15:29–35. https://doi.org/10.1053/j.oto.2004.10.009
4. White SH, Ludkowski PF, Goodfellow JW (1991) Anteromedial osteoarthritis of the knee. J Bone Joint Surg Br 73:582–586. https://doi.org/10.1302/0301-620X.73B4.2071640
5. Bellemans J, Vandenneucker H, Vanlauwe J, Victor J (2010) The influence of coronal plane deformity on mediolateral ligament status: an observational study in varus knees. Knee Surg

Sports Traumatol Arthrosc 18:152–156. https://doi.org/10.1007/s00167-009-0903-0
6. Bonin N, Ait Si Selmi T, Donell ST et al (2004) Anterior cruciate reconstruction combined with valgus upper tibial osteotomy: 12 years follow-up. Knee 11:431–437. https://doi.org/10.1016/j.knee.2004.02.001
7. Schneider A, Lustig S, Neyret P, Servien E (2017) Retour au sport après reconstruction combinée du ligament croisé antérieur et ostéotomie tibiale de valgisation par addition interne: résultats à 10 ans de recul moyen d'une série consécutive de 36 cas. Rev Chir Orthop Reparatrice Appar Mot 103:S276–S277. https://doi.org/10.1016/j.rcot.2017.09.380
8. Ben-Shlomo Y, Blom A, Boulton C, et al (2019) The National Joint Registry 16th Annual Report 2019. National Joint Registry, London
9. Goodfellow J, O'Connor J (1992) The anterior cruciate ligament in knee arthroplasty. A risk-factor with unconstrained meniscal prostheses. Clin Orthop Relat Res 276:245–252
10. Adravanti P, Budhiparama NC, Berend KR, Thienpont E (2017) ACL-deficient knee and unicompartmental OA: state of the art. J ISAKOS 2:161–170. https://doi.org/10.1136/jisakos-2016-000066
11. Volpin A, Kini SG, Meuffels DE (2018) Satisfactory outcomes following combined unicompartmental knee replacement and anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 26:2594–2601. https://doi.org/10.1007/s00167-017-4536-4
12. Ventura A, Legnani C, Terzaghi C et al (2017) Medial unicondylar knee arthroplasty combined to anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 25:675–680. https://doi.org/10.1007/s00167-015-3808-0
13. Weston-Simons JS, Pandit H, Jenkins C et al (2012) Outcome of combined unicompartmental knee replacement and combined or sequential anterior cruciate ligament reconstruction: a study of 52 cases with mean follow-up of five years. J Bone Joint Surg Br 94:1216–1220. https://doi.org/10.1302/0301-620X.94B9.28881
14. Batailler C, White N, Ranaldi FM et al (2019) Improved implant position and lower revision rate with robotic-assisted unicompartmental knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 27:1232–1240. https://doi.org/10.1007/s00167-018-5081-5
15. Brazier J, Migaud H, Gougeon F et al (1996) Evaluation of methods for radiographic measurement of the tibial slope. A study of 83 healthy knees. Rev Chir Orthop Reparatrice Appar Mot 82:195–200
16. Kleeblad LJ, van der List JP, Pearle AD et al (2018) Predicting the feasibility of correcting mechanical axis in large varus deformities with unicompartmental knee arthroplasty. J Arthroplasty 33:372–378. https://doi.org/10.1016/j.arth.2017.09.052
17. Gulati A, Chau R, Pandit HG et al (2009) The incidence of physiological radiolucency following Oxford unicompartmental knee replacement and its relationship to outcome. J Bone Joint Surg Br 91-B:896–902. https://doi.org/10.1302/0301-620X.91B7.21914
18. Klasan A, Putnis SE, Grasso S et al (2021) Tegner level is predictive for successful return to sport 2 years after anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 29:3010–3016. https://doi.org/10.1007/s00167-020-06335-4
19. Insall JN, Dorr LD, Scott RD, Scott WN (1989) Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 248:13–14
20. Klouche S, Giesinger JM, Sariali E-H (2018) Translation, cross-cultural adaption and validation of the French version of the Forgotten Joint Score in total hip arthroplasty. Orthop Traumatol Surg Res 104:657–661. https://doi.org/10.1016/j.otsr.2018.04.010
21. Lustig S, Neyret P (2014) Navio PFS. Instrumentation robotisée sans imagerie préopératoire pour la mise en place des prothèses unicompartimentales. Maitrise Orthopédique 237:2–6
22. St Mart J-P, de Steiger RN, Cuthbert A, Donnelly W (2020) The three-year survivorship of robotically assisted versus non-robotically assisted unicompartmental knee arthroplasty. Bone Joint J 102-B:319–328. https://doi.org/10.1302/0301-620X.102B3.BJJ-2019-0713.R1
23. Tian S, Wang B, Wang Y et al (2016) Combined unicompartmental knee arthroplasty and anterior cruciate ligament reconstruction in knees with osteoarthritis and deficient anterior cruciate ligament. BMC Musculoskelet Disord 17:327. https://doi.org/10.1186/s12891-016-1186-5
24. Gleeson RE, Evans R, Ackroyd CE et al (2004) Fixed or mobile bearing unicompartmental knee replacement? A comparative cohort study. Knee 11:379–384. https://doi.org/10.1016/j.knee.2004.06.006
25. Petterson SC, Blood TD, Plancher KD (2020) Role of alignment in successful clinical outcomes following medial unicompartmental knee arthroplasty: current concepts. J ISAKOS. https://doi.org/10.1136/jisakos-2019-000401
26. Pandit H, Beard DJ, Jenkins C et al (2006) Combined anterior cruciate reconstruction and Oxford unicompartmental knee arthroplasty. J Bone Joint Surg Br 88:887–892. https://doi.org/10.1302/0301-620X.88B7.17847
27. Tinius M, Ecker TM, Klima S et al (2007) Minimally invasive unicondylar knee arthroplasty with simultaneous ACL reconstruction : treatment of medial compartment osteoarthritis and cruciate ligament defect. Unfallchirurg 110:1030–1038. https://doi.org/10.1007/s00113-007-1356-x
28. Dervin GF, Conway AF, Thurston P (2007) Combined anterior cruciate ligament reconstruction and unicompartmental knee arthroplasty: surgical technique. Orthopedics 30:39–41
29. Krishnan SR, Randle R (2009) ACL reconstruction with unicondylar replacement in knee with functional instability and osteoarthritis. J Orthop Surg Res 4:43. https://doi.org/10.1186/1749-799X-4-43
30. Tinius M, Hepp P, Becker R (2012) Combined unicompartmental knee arthroplasty and anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 20:81–87. https://doi.org/10.1007/s00167-011-1528-7
31. Batailler C, White N, Ranaldi FM et al (2018) Improved implant position and lower revision rate with robotic-assisted unicompartmental knee arthroplasty. Knee Surg Sports Traumatol Arthrosc. https://doi.org/10.1007/s00167-018-5081-5
32. Fournier G, Gaillard R, Swan J et al (2021) Stiffness after unicompartmental knee arthroplasty: risk factors and arthroscopic treatment. SICOT J 7:35. https://doi.org/10.1051/sicotj/2021034
33. Derreveaux V, Schmidt A, Shatrov J et al (2022) Combined procedures with unicompartmental knee arthroplasty: high risk of stiffness but promising concept in selected indications. SICOT-J 8:4. https://doi.org/10.1051/sicotj/2022002
34. Kang K-T, Koh Y-G, Son J et al (2018) Influence of increased posterior tibial slope in total knee arthroplasty on knee joint biomechanics: a computational simulation study. J Arthroplasty 33:572–579. https://doi.org/10.1016/j.arth.2017.09.025
35. Fujimoto E, Sasashige Y, Masuda Y et al (2013) Significant effect of the posterior tibial slope and medial/lateral ligament balance on knee flexion in total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 21:2704–2712. https://doi.org/10.1007/s00167-012-2059-6
36. Hernigou P, Deschamps G (2004) Posterior slope of the tibial implant and the outcome of unicompartmental knee arthroplasty. J Bone Joint Surg Am 86:506–511
37. Suzuki T, Ryu K, Kojima K et al (2019) The effect of posterior tibial slope on joint gap and range of knee motion in mobile-bearing unicompartmental knee arthroplasty. J Arthroplasty 34:2909–2913. https://doi.org/10.1016/j.arth.2019.07.010

38. Warren PJ, Olanlokun TK, Cobb AG et al (1994) Laxity and function in knee replacements. A comparative study of three prosthetic designs. Clin Orthop Relat Res 200–208
39. Witjes S, Gouttebarge V, Kuijer PPFM et al (2016) Return to sports and physical activity after total and unicondylar knee arthroplasty: a systematic review and meta-analysis. Sports Med 46:269–292. https://doi.org/10.1007/s40279-015-0421-9
40. Canetti R, Batailler C, Bankhead C et al (2018) Faster return to sport after robotic-assisted lateral unicompartmental knee arthroplasty: a comparative study. Arch Orthop Trauma Surg 138:1765–1771. https://doi.org/10.1007/s00402-018-3042-6
41. Mancuso F, Hamilton TW, Kumar V et al (2016) Clinical outcome after UKA and HTO in ACL deficiency: a systematic review. Knee Surg Sports Traumatol Arthrosc 24:112–122. https://doi.org/10.1007/s00167-014-3346-1
42. Dettoni F, Bonasia DE, Castoldi F et al (2010) High tibial osteotomy versus unicompartmental knee arthroplasty for medial compartment arthrosis of the knee: a review of the literature. Iowa Orthop J 30:131–140
43. Jacquet C, Gulagaci F, Schmidt A et al (2020) Opening wedge high tibial osteotomy allows better outcomes than unicompartmental knee arthroplasty in patients expecting to return to impact sports. Knee Surg Sports Traumatol Arthrosc. https://doi.org/10.1007/s00167-020-05857-1
44. El-Galaly A, Nielsen PT, Kappel A, Jensen SL (2020) Reduced survival of total knee arthroplasty after previous unicompartmental knee arthroplasty compared with previous high tibial osteotomy: a propensity-score weighted mid-term cohort study based on 2,133 observations from the Danish Knee Arthroplasty Registry. Acta Orthop 91:177–183. https://doi.org/10.1080/17453674.2019.1709711
45. Figueroa F, Parker D, Fritsch B, Oussedik S (2018) New and evolving technologies for knee arthroplasty—computer navigation and robotics: state of the art. J ISAKOS 3:46–54. https://doi.org/10.1136/jisakos-2017-000146