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Age over 50 years is not a contraindication for anterior cruciate ligament reconstruction

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Abstract

Purpose To report clinical and functional results of ACL reconstruction in patients over 50 years old and investigate the influence of surgery on osteoarthritis progression in this cohort of patients.

Methods A systematic review was performed on PubMed, Scopus, Google scholar, Cochrane library and EMBASE, using a strategy search design to collect clinical studies reporting outcomes of ACL reconstruction in patients aged 50 years or older. The primary outcome measure was clinical and functional results, including failure rate defined as reoperation for revision ACL surgery or conversion to total knee arthroplasty; secondary outcomes included radiological findings, expressed according to the validated grading score.

Results A total of 16 studies were found suitable and included. Overall, 470 arthroscopic ACL reconstructions were performed in 468 patients (278 males, 190 females), with a mean age of 53.6 years (50–75 years). The total failure rate, described as reoperation for revision ACL surgery was 2.7% (10 knees), ranging from 0 to 14.3% in the selected studies. All papers reviewed showed a statistically significant improvement of clinical and functional scores at final follow-up, comparable to younger control group, when reported. Post-operative objective stability testing with KT-1000 arthrometer device or equivalent was performed in seven studies, with a mean side-to-side difference of 2.2 mm (0.2–2.7 mm). Radiographic signs of progression of osteoarthritis were reported in six studies, where severe signs of degeneration (grade 3 or 4 according Kellgren–Lawrence or Ahlbäck classification) shifted from 4 out of 216 knees (1.9%) before surgery to 28 out of 187 knees (15%) following ACL reconstruction, after a mean period of follow-up ranging from 32 to 64 months.

Conclusion ACL reconstruction in patients older than 50 years is a safe procedure with good results that are comparable to those of younger patients previously reported. Age itself is not a contraindication to ACL surgery because physiological age, clinical symptoms and functional requests are more important than chronological age in decision process. Since cohort size in the present study is not large enough, and taking into account the high occurrence of concomitant meniscal and chondral lesions, more high-quality studies are necessary to draw definitive conclusions about development of osteoarthritis of the knee after ACL surgery in these patients.

Level of evidence IV.

Keywords Anterior cruciate ligament reconstruction · Aging athletes · Older patients · Outcomes · Osteoarthritis

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Introduction

The management of anterior cruciate ligament (ACL) deficiency in older patients remains a matter of debate among clinicians [10]. In the past a non-operative management has been advocated with satisfactory outcomes [42], but recent studies seem to demonstrate that conservative treatment is related to increased risks of residual instability and associated meniscal and chondral injuries [23, 25, 43, 49], forcing patients to a significant modification of sport and recreational activities [11]. Recent data predict that middle-aged individuals will double in the year 2050 [21], and physical activity level in this population seems to be increasing to face up the challenging worldwide lifestyle of this century; for these reasons, nowadays ''the older patients" refuse the limitations of a restricted return to activity related to the non-operative treatment, preferring a surgical ACL reconstruction despite the risk of surgical complications [46]. Therefore, the age limitation and management of ACL-deficient knees in these patients have come into question, as indications for surgery are more frequently being considered in this age group [10, 46]. Several articles have recently focused on ACL reconstruction in patients aged 50 years or older, and this growing body of evidence has broadly changed the approach of the surgeons toward the management of the ACL-deficient knees in this population.

On the other hand, clinicians are worried about risk of higher rate of complication and progression of chondral degeneration with surgical approach [13, 19, 46, 55], and consequent poorer results. Moreover, the bone quality and healing response in the elderly population, with related effects on graft incorporation and healing potential represent another area of concern [5, 20].

A lack of clinical evidence supporting a decision-making process in this population exists, justifying the uncertainty and controversy associated with ACL reconstruction in older patients.

With the aim to combine results of surgical management of ACL injury in patients older than 50 years, we conducted a systematic review from available published literature with the aim to answer to the following questions: (1) are clinical and instrumental results of ACL reconstruction in this population satisfactory? (2) Does ACL reconstruction affect osteoarthritis progression in this cohort of patients?

Materials and methods

Search strategy and eligibility criteria

A systematic review was performed according the guidelines of Preferred Reporting Items for Systematic reviews and Meta Analyses (PRISMA) [40], using a strategy search design to collect clinical studies reporting outcomes of ACL reconstruction in patients aged 50 years or older. The primary outcome measure was clinical and functional results; secondary outcomes included radiological findings, expressed according to the validated grading score. Inclusion criteria adopted in our systematic review protocol were: (1) single- or double-arm studies, whether with a prospective or retrospective design; (2) studies of patients who underwent arthroscopic ACL reconstruction; (3) minimum patients' age of 50 years; (4) report of outcome measurements in the studies in terms of failure rates, clinical and functional scores, and instrumental measurements, (5) average follow-up of at least 12 months. No language or data restriction was adopted in our search strategy.

A systematic search was conducted by two independent reviewers on PubMed, Scopus, Google scholar, Cochrane library and EMBASE, for studies available till July 2018. The medical keywords used for initial screening were "anterior cruciate ligament reconstruction" OR "ACL reconstruction" AND "50" OR "50" OR "aged" OR "aging" OR "older patient".

Institutional board review and funding source

An institutional review board was not obtained because all data were extracted from previously published studies. No external funding was received for the initiation or completion of this study.

Studies selection and data extraction

From an initial search comprising 1952 abstracts, a total of 183 full-text articles were identified after elimination of duplicate results and screening abstract for relevance. In addition, the research was extended to the reference list of all relevant articles, including other 65 virtually suitable papers. At this point, all studies not meeting aforementioned inclusion criteria were excluded, such as case reports [38, 54], expert opinion and review articles [10], ex vivo or animal analyses, studies not involving only patients older than 50 years or studies with a mean follow-up lesser than 12 months; the selection process is resumed in Fig. 1.

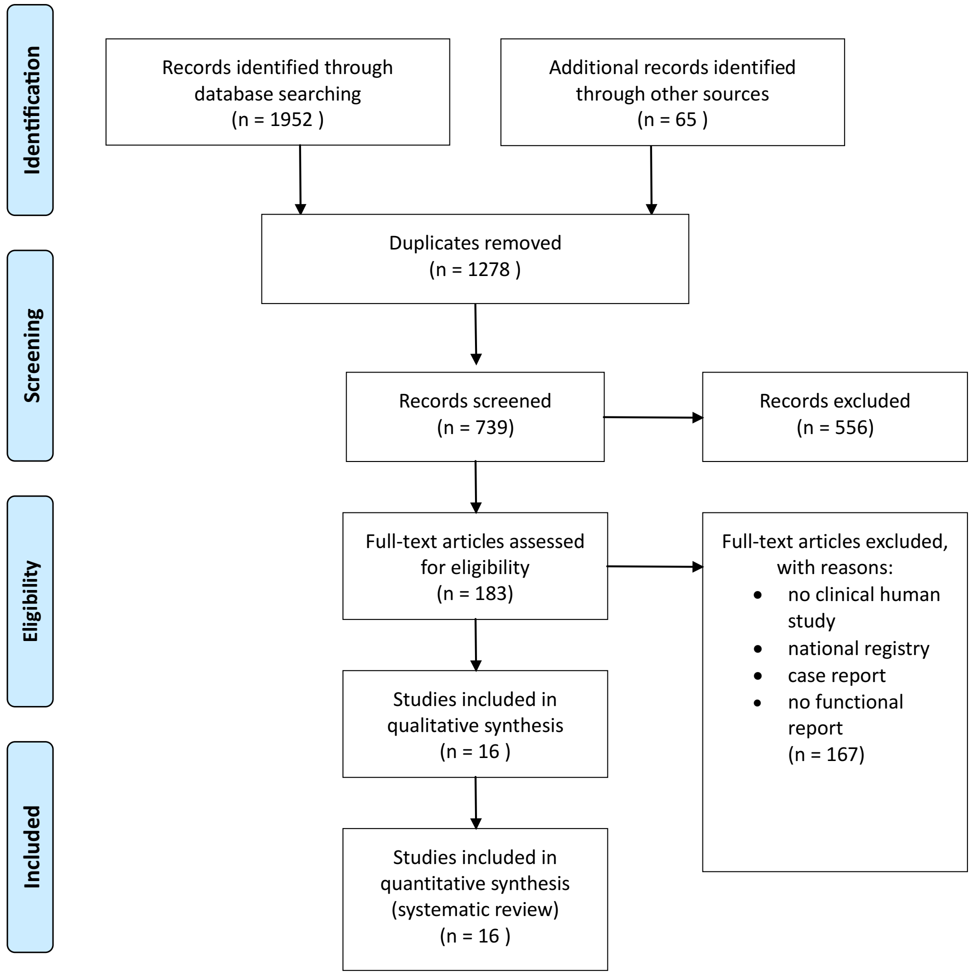

Fig. 1 The QUOROM flow diagram, describing the number of studies identified, included and excluded with relative reasons

A total of 16 studies [4, 6–8, 12, 17, 22, 27, 31, 44, 48, 50, 52, 53, 56, 57] were found suitable, and were included in the present systematic review.

One of the authors extracted data from each study, providing details on the number of patients with relative demographic data, duration of follow-up, time from injury to surgery and surgical technique with related graft choice (Table 1). If available, associated lesions (ligament, meniscal, and chondral lesions) were extracted, giving particular care to concomitant chondral lesions, that were graded from 0 to IV, according the International Cartilage Repair Society (ICRS) classification [9] or the Outerbridge classification [45] (Table 2).

Outcome assessment

The clinical outcomes and functional measurements in the reviewed studies were extracted and reported as a mean (Table 3), according the International Knee Documentation Committee (IKDC) score [3], the Lysholm and Gillquist score [33] and the Cincinnati knee score [41]; all these three scales evaluate clinical outcomes based on symptomatic as well as functional variables, with a score ranging from 0 to 100, with 0 representing the worst result and 100 representing optimal outcome with few symptoms or disability. Patients' activity level was evaluated thanks to the Tegner activity score [36], a rating scale that aims to provide a standardized method of grading work and sporting activities; a minimum score of 0 represents disability because of knee problems, whereas a maximum score of 10 corresponds to participation in national and international elite competitive sports.

In addition to clinical outcome scores, we detected also other parameters providing objective information about knee stability (Table 3); these included post-operative manual maximum side-to-side differences on arthrometry and clinical Lachman and pivot-shift testing. For stability testing, if performed, the KT-1000 arthrometer device (MEDmetric Corp, San Diego, California) or equivalent was used, with a manual maximum side-to-side difference < 3 mm accepted as normal [18]. The Lachman test was evaluated as negative for grade 0 and grade + 1 (slightly increased laxity with a firm end point), or positive if a grade 2 + (increased translation with a delayed end point), or a grade 3 + (translation

Table 1 Studies included with level of evidence, demographic details of patients, surgical variables, time to surgery and mean follow-up

References	Level of evidence	Study design	Journal	Number of knees	Patient sex		Mean age (years)	Graft	Technique	Time to surgery (months)	Follow-up (months)
					Male	Female					
Arbuthnot et al. [4]	4	Retrospective case series	Knee Surg Sports Traumatol Arthrosc, 2010	14	7	7	60 (55–75)	9 BPTB autograft, 5 HS autograft	Single bundle transtibial single bundle anteromedial	N.A	114 (2–240)
Baker Jr et al. [6]	4	Retrospective case series	Orthop J Sports Med, 2014	13	4	9	63.5 (60–73)	4 BPTB autograft, 6 HS autograft, 3 allograft	Single bundle transtibial single bundle anteromedial	5.8 (0.3–21.9)	115.7 (53–193)
Bali et al. [7]	4	Retrospective case series	Indian J Orthop, 2015	55	45	10	53.8 (50–66)	22 BPTB autograft, 33 HS autograft	Single bundle	N.A	46.2 (24–72)
Blyth et al. [8]	4	Prospective case series	Knee Surg Sports Traumatol Arthrosc, 2003	31	15	15	54.5 (50–66)	10 BPTB autograft, 21 HS autograft	Single bundle	88 (2–396)	46 (24–95)
Cinque et al. [12]	3	Retrospective cohort study	Orthop J Sports Med, 2017	33	14	19	57.7	15 BPTB allograft 18 BPTB allograft	Single bundle anteromedial	N.A	37 (24–68)
Dahm et al. [17]	4	Retrospective case series	J Bone Jt Surg Br, 2008	35	14	20	57 (50–66)	12 BPTB autograft, 23 BPTB allograft	Single bundle	24 (1–156)	72 (25–173)
Figueroa et al. [22]	4	Prospective case series	Knee, 2014	50	33	17	52.12 (50–64)	45 HS autograft, 5 allograft	Single bundle transtibial	2 (1–3)	53.2 (36–68)
Iorio et al. [27]	2	Prospective cohort study	Int Orthop, 2018	36	28	8	54 (50–62)	36 HS autograft	Single bundle	N.A	64 (60–72)
Kinugasa et al. [31]	3	Retrospective cohort study	Arthroscopy, 2011	11	5	6	58.5 (50–71)	11 HS autograft	Double bundle	27.4 (1–158)	15.5 (12–20)
Osti et al. [44]	3	Retrospective case–control study	Knee Surg Sports Traumatol Arthrosc, 2011	20	12	8	56 (50–62)	N.A	Single bundle	2.5 (2.4–3.2)	32 (24–49)
Stein et al. [48]	4	Retrospective case series	Orthopedics, 2006	19	10	9	54 (50–64)	N.A	Single bundle	N.A	24 (9–48)
Struewer et al. [50]	4	Retrospective cohort study	Int Orthop, 2013	41	23	18	33.9 (45–64)	19 BPTB autograft, 22 HS autograft	Single bundle transtibial single bundle anteromedial	N.A	32 (28–36)
Toanen et al. [52]	4	Retrospective case series	Am J Sports Med, 2017	12	7	5	61 ± 1.4	12 HS autograft	Single bundle	11.5 (6–18)	49.6 ± 24
Trojani et al. [53]	4	Retrospective case series	Orthop Traumatol Surg Res, 2009	18	6	12	57 (51–66)	18 HS autograft	Single bundle anteromedial	11 (3–72)	30 (12–59)

Table 1 (continued)

References	Level of evidence	Study design	Journal	Number of knees	Patient sex		Mean age (years)	Graft	Technique	Time to surgery (months)	Follow-up (months)
					Male	Female					
Ventura et al. [56]	4	Retrospective case series	Arthroscopy, 2012	50	39	11	54.4 (50–65)	50 HS autograft	Single bundle double bundle	32.6 (3–125)	41 (24–84)
Wolfson et al. [57]	4	Retrospective case series	Bull Hosp Jt Dis, 2013	32	16	16	58.4 (51–65)	4 BPTB autograft, 2 HS autograft, 26 allograft	Single bundle transtibial	N.A	60 (26–108)

All data are reported as mean ± standard deviation (min–max)

BPTB bone–patellar tendon–bone, *HS* hamstring, *N.A* not available

with no end point) was reported. Likewise, the pivot-shift test was considered negative if graded 0 (with no shift) or evaluated positive if rated as grade I (gliding), grade II (clunk) and grade III (gross rotary laxity).

Lastly, radiographic findings were extracted and detailed in Table 3, if reported according validated classification systems for osteoarthritis assessment [1, 29].

Assessment of methodological quality

Two independent reviewers evaluated each study grading the level of evidence based on a previously published classification [37]. In addition, two reviewers independently assessed the reporting and methodologic quality of each study, using a modified Coleman Methodology Score (CMS) [15], as proposed by Brown [10], to focus on specific items on ACL surgery, such as validated functional scores, manual test laxity and instrumental measurements.

Any unresolved disagreements between reviewers were resolved by consultation with a third investigator.

Results

The strategy search, after the exclusion process detailed above (Fig. 1), generated a systematic review of 16 studies [4, 6–8, 12, 17, 22, 27, 31, 44, 48, 50, 52, 53, 56, 57], including 1 prospective cohort study [27], 3 retrospective cohort studies [12, 31, 44], 1 prospective case series [8] and 11 retrospective case series [4, 6, 7, 17, 22, 48, 50, 52, 53, 56, 57]. All articles were written in English language and published between 2003 and 2018.

Synthesis of data

Overall, 470 arthroscopic ACL reconstruction were performed in 468 patients (278 males, 190 females), with a mean age of 53.6 years (50–75 years). The mean follow-up was 50.4 months (2–240 months). A satisfying homogeneity was found in the surgical techniques described, since an anatomic single bundle technique was reported in all paper except in two [31, 56], where a double bundle technique was described. Graft choice included a bone-patellar tendon-bone (BPTB) autograft in 95 knees (22%), hamstring tendon autograft in 261 knees (60.6%) and allograft (patellar tendon allograft in 65 patients, Achilles tendon allograft in 1 patient, tibialis posterior in 1 patient and unspecified type of allograft in 8 patients) in 75 knees (17.4%). On contrary, the mean time from injury to surgery differs significantly in the papers selected, ranging from 2.5 to 88 months.

Associated lesions were found in all but 2 articles [27, 50] (Table 2), especially 197 concomitant meniscal lesions (41.9%), requiring partial meniscectomy in 87.8% cases,

Table 2 Concomitant injury, with related additional surgery, and cartilage status

References	Additional injury	Ligamentous surgery	Meniscal surgery	Cartilage injury	Cartilage lesion classification	Cartilage surgery
Arbuthnot et al. [4]	11 knees (78.5%)	1 PLC reconstruction	10 meniscectomy 1 meniscal repair	8 knees (57.1%)	5 grade[a] II 3 grade IV	5 chondroplasty 3 microfracture
Baker Jr et al. [6]	N.A	1 MCL repair	12 meniscectomy	N.A	N.A	4 chondroplasty
Bali et al. [7]	26 knees (47.3%)	N.A	26 meniscectomy	N.A	N.A	N.A
Blyth et al. [8]	N.A	2 extra articular augmentation	9 meniscectomy 3 meniscal repair	25 knees (75.8%)	8 grade[a] I, 10 grade II, 3 grade III, 4 grade IV	1 chondroplasty
Cinque et al. [12]	N.A	5 MCL repair 7 FCL repair	15 meniscectomy 16 meniscal repair	N.A	20 grade[a] I 6 grade II 6 grade III 4 grade IV	N.A
Dahm et al. [17]	31 knees (89%)	N.A	13 meniscectomy 2 meniscal repair	31 knees (89%)	18 grade[a] I, 19 grade II, 8 grade III, 3 grade IV	31 chondroplasty
Figueroa et al. [22]	45 knees (90%)	N.A	38 meniscectomy	18 knees (36%)	N.A	18 chondroplasty
Iorio et al. [27]	N.A	N.A	N.A	N.A	N.A	N.A
Kinugasa et al. [31]	9 knees (81.8%)	N.A	8 meniscectomy 1 meniscus rasping	N.A	N.A	N.A
Osti et al. [44]	11 knees (55%)	0 knees	10 meniscectomy 1 meniscal repair	10 knees (50%)	1 grade[a] I 3 grade II 4 grade III 2 grade IV	4 chondroplasty 6 microfracture
Stein et al. [48]	8 knees (42.1%)	N.A	8 meniscectomy	10 knees (52.6%)	8 grade[b] I–II, 2 grade III	1 chondroplasty
Struewer et al. [50]	0 knees	0 knees	0 knees	N.A	N.A	0 knees
Toanen et al. [52]	8 knees (66%)	0 knees	8 meniscectomy	6 knees (50%)	6 grade[b] I–II	
Trojani et al. [53]	5 knees (27.8%)	N.A	5 meniscectomy	N.A	N.A	N.A
Ventura et al. [56]	10 knees (20%)	0 knees	11 meniscectomy	12 knees (24%)	N.A	12 chondroplasty
Wolfson et al. [57]	N.A	N.A	N.A	32 knees (100%)	7 grade[a] I 4 grade II 34 grade III 6 grade IV	N.A

N.A not available

[a]Outerbridge classification

[b]ICRS (International Cartilage Repair Society) classification

whereas a meniscal repair was performed in 12.2% of cases. Concomitant cartilage lesions were reported in 9 papers [4, 8, 12, 17, 22, 44, 48, 52, 57] for a total of 152 knees (57.8%), graded as severe (grade III or IV according Outerbridge [45] or ICRS [9] classification) in 40.7% of cases.

Failure rate, outcomes and radiological findings

The total failure rate, described as reoperation for revision ACL surgery and calculated from the 13 papers [4, 6–8, 17, 22, 27, 31, 44, 52, 53, 56, 57] reporting these data (for a total of 377 knees), was 2.7%, ranging from 0 to 14.3%.

The Lysholm score was the most frequently adopted scale, reported in 14 studies [4, 7, 8, 12, 17, 22, 27, 31, 44, 48, 50, 52, 56, 57] for a total of 404 patients; the average score was 89.3 (average min 82.9 – max 98.0).

Eight papers [7, 12, 17, 22, 27, 44, 52, 57] with a total of 273 patients available at the time of the latest follow-up reported the IKDC scores, with a mean average of 82.5 (average min 67.8 – max 92.0).

The Cincinnati Knee score was used in two articles [6, 8], for a total 44 patients, resulting a mean average of 85.7 (average min 78.1 – max 89).

The activity level was investigated in 9 studies [8, 12, 17, 22, 27, 31, 50, 56, 57] for a total of 319 patients. The mean Tegner Score evolved from a mean pre-injury score of 5.2 to a mean preoperative score of 2.2 to an average post-operative score of 4.8.

Manual stability testing was reported in 10 studies [4, 7, 8, 17, 31, 44, 52, 53, 56, 57]; the Lachman test at latest follow-up was considered positive in 24 out of 264 knees (9.1%), while a "glide" or "clunk" pivot-shift test was recorded in 13 knees (5.9%).

Objective stability testing with KT-1000 arthrometer device or equivalent was performed in seven studies [4, 8, 27, 31, 48, 56, 57]; one study [7] was excluded from this

Table 3 Clinical and functional scores

References	Failure rate	Radiological osteoarthritis classification		Lachman test	Pivot-shift test	KT 1000		Lysholm score		IKDC score		Cincinnati knee score		Tegner score		
		Pre operative	Post operative			Pre operative	Post operative	Pre operative	Post operative	Pre operative	Post operative	Pre operative	Post operative	Pre injury	Pre operative	Post operative
Arbuthnot et al. [4]	7.1%	N.A	N.A	Negative 11 (91.7%) positive 1 (8.3%)	Negative 11 (91.7%) positive 1 (8.3%)	4.6 mm (3–7 mm)	1.5 mm (0–4 mm)	33 (15–67)	85.5 (53–100)	N.A	N.A	N.A	N.A	N.A	N.A	N.A
Baker Jr et al. [6]	14.3%	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	78.1 (46–90)	N.A	N.A	N.A
Bali et al. [7]	0%	23.8% grade[a] 0 40.5% grade I 35.7% grade II	19.0% grade[a] 0 35.7% grade I 28.6% grade II 16.7% grade III	Negative 47 (85.5%) positive 8 (14.5%)	N.A	7.2[c] mm (5–14 mm)	2.4[c] mm (2–4 mm)	40.4 ± 10.3	85.3 ± 2.5	39.7 ± 3.3	67.8 ± 7.7	N.A	N.A	N.A	N.A	N.A
Blyth et al. [8]	0%	N.A	N.A	Negative 31 (100%) positive 0 (0%)	Negative 31 (100%) positive 0 (0%)	N.A	2.7 mm (0–7 mm)	63 (32–95)	93 (76–100)	N.A	N.A	49 (18–73)	89 (73–100)	N.A	3.7 (1–7)	5.2 (3–8)
Cinque et al. [12]	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	84.4	N.A	71.3	N.A	N.A	N.A	N.A	5
Dahm et al. [17]	8.6%	71% grade[a] 0 29% grade I	67% grade[a] 0 17% grade I 8% grade II 8% grade III	Negative 33 (97%) positive 1 (3%)	Negative 34 (97%) positive 1 (3%)	N.A	N.A	39 (23–72)	90 (33–100)	50 (18–68)	92 (28–100)	N.A	N.A	N.A	1.9 (0–7)	4.3 (2–7)
Figueroa et al. [22]	4%	N.A	N.A	N.A	N.A	N.A	N.A	50.1 (30–65)	93.7 (60–100)	42.9 (19.5–52.9)	90.9 (57.5–100)	N.A	N.A	5.8 (5–6)	N.A	5.6 (5–6)
Iorio et al. [27]	0%	17% grade[a] I 55% grade II 28% grade III	11% grade[a] I 53% grade II 36% grade III	N.A	N.A	N.A	2.7 mm ± 2.25 mm	53 ± 2.45	94.3 ± 5.14	54 ± 5.32	91.4 ± 4.78	N.A	N.A	5.8 (3–7)	N.A	5.4 (3–7)

Table 3 (continued)

References	Failure rate	Radiological osteoarthritis classification		Lachman test	Pivot-shift test	KT 1000		Lysholm score		IKDC score		Cincinnati knee score		Tegner score		
		Pre operative	Post operative			Pre operative	Post operative	Pre operative	Post operative	Pre operative	Post operative	Pre operative	Post operative	Pre injury	Pre operative	Post operative
Kinugasa et al. [31]	0%	N.A	N.A	N.A	Negative 11 (100%)	N.A	0.2 mm ± 1.0 mm	61 (52–74)	98 (93–100)	N.A	N.A	N.A	N.A	4.1 (1–6)	N.A	3.7 (1–6)
Osti et al. [44]	5%	N.A	N.A	Negative 19 (95%) positive 1 (1%)	Negative 19 (95%) positive 1 (5%)	N.A	N.A	49 (14–67)	89 (41–100)	46 (30–60)	91 (80–100)	N.A	N.A	N.A	N.A	N.A
Stein et al. [48]	N.A	N.A	N.A	N.A	N.A	N.A	2 mm (0–4 mm)	N.A	92 (61–100)	N.A	N.A	N.A	N.A	N.A	N.A	N.A
Struewer et al. [50]	N.A	41.5% grade[a] I 58.5% grade II	36.6% grade[a] I 31.7% grade II 24.4% grade III 7.3% grade IV	N.A	N.A	N.A	N.A	35 (15–69)	82.9 (25–100)	N.A	N.A	N.A	N.A	5.5 (2–8)	2.5 (2–4)	5.1 (2–8)
Toanen et al. [52]	0%	50% grade[b] 0 50% grade I	34% grade[b] 0 66 grade I	Negative 5 (42%) positive 7 (58%)	Negative 6 (50%) positive 6 (50%)	N.A	N.A	55.7 ± 12.4	93.2 ± 9.0	43.4 ± 8.4	83.8 ± 9.4	N.A	N.A	N.A	N.A	N.A
Trojani et al. [53]	0%	N.A	N.A	Negative 15 (83.3%) positive 3 (16.7%)	Negative 16 (88.9%) positive 2 (11.1%)	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
Ventura et al. [56]	0%	76% grade[b] I 24% grade II	75% grade[b] I 25% grade II	Negative 49 (98%) positive 1 (2%)	Negative 49 (98%) positive 1 (2%)	5.5 mm ± 1.3 mm	2.7 mm ± 0.8 mm	62 ± 10.4	90 ± 6.4	N.A	N.A	N.A	N.A	4 (1–8)	N.A	5 (2–8)
Wolfson et al. [57]	3%	N.A	N.A	Negative 30 (93.8%) positive 2 (6.2%)	Negative 31 (96.9%) positive 1 (3.1%)	N.A	1.2 mm (0–4.5 mm)	N.A	86.7 (45–95)	N.A	80.1 (33–100)	N.A	N.A	N.A	1.4 (0–3)	2.1 (0–3)

Lachman test: negative grade 0 or grade 1 +; positive grade 2 + (with delayed endpoint) or 3 +. Pivot shift: negative grade 0; positive grade 1 + (or glide) 2 + (or clunk). KT 1000 reports side-to-side manual maximum difference

PLC posterolateral corner, *MCL* medial collateral ligament, *LCL* lateral collateral ligament, *N.A* not available

[a] Kellgren–Lawrence classification

[b] Ahlbäck classification

[c] KT 1000 unilateral maximum translation

analysis because reporting unilateral maximal tibiofemoral translation. The mean side-to-side difference was 2.15 mm (0.2 mm – 2.7 mm).

Radiographic signs of progression of osteoarthritis were reported in all six studies investigating this aspect [7, 12, 27, 50, 52, 56]; severe signs of degeneration (grade 3 or 4 according Kellgren–Lawrence [29] or Ahlbäck [1] classification) shifted from 4 out of 216 knees (1.9%) before surgery to 28 out of 187 knees (15%) following ACL reconstruction, after a mean period of follow-up ranging from 32 to 64 months.

Level of evidence and methodological quality

Of the 16 studies selected, only one article [27] was rated as level of evidence 2, three studies [12, 31, 44] were qualified as level of evidence 3, and the remaining 12 papers were classified as level 4, (Table 1). For all papers reviewed in the analysis, the mean modified CMS was 35.4 ± 9.3 for part A and 22.3 ± 5.7 for part B, with a mean total score of 57.1 ± 11.4 (range 36–85).

Details of methodological quality assessment were shown in Table 4.

Discussion

The most important finding of the present study is that ACL reconstruction in patients older than 50 years is a satisfying procedure with good results in terms of symptomatic relief, restoration of function and return to sporting activity. A similar attempt was already performed by Brown et al. [10], but focusing on patients older than 40 years, showing good results in this cohort of patients; however, the lack of data regarding influence of ACL surgery on developmental of osteoarthritis, combined with the increasing number of papers published in recent years considering only patients older than 50 years deserves, in our opinion, new and particular consideration. Moreover, currently in Western countries, the average age and life expectancy are rising, together with physical activity level in the elderly population [21]. This has led to an increase of sport-related injuries in older populations, with high expectations concerning return to pre-injury level of activity [26]. In this context, the indication for surgical reconstruction of ACL is broadening, and patients aged more than 50 years who underwent surgical ACL reconstruction represent nowadays a significant share [34].

Limitations

Several limitations can be detected from the present review. First of all, most of studies included are case series, and the lack of a control group of concurrent conservatively managed patients was the main drawback. In this setting, however, inevitable patient selection bias would make it difficult to draw meaningful conclusions from such a comparison. Furthermore, most of the papers selected had a retrospective design, with intrinsic limitations inherent to methodologic quality. The surgical procedures were rather heterogeneous with different types of graft and different fixation techniques used. This number of variables limits the generalizability of our findings. Lastly, the relatively small sample size and the high number of patients lost to follow-up reduces the power of the study.

Clinical and functional outcomes

All papers reviewed and included in our analysis showed a statistically significant improvement of clinical and functional scores at final follow-up (Table 3), with comparable preoperative and post-operative scores to younger control group, when reported ($p > 0.05$) [12, 27, 31, 44]. The only age influence on clinical outcomes detected in two studies [31, 44] concerns the Tegner activity scale. Rates of return to sports and recreational activities after ACL reconstruction in patients over 50 was satisfying, ranging from 60% [44] to 86% [17], but, comparing with younger patients, a lower return to pre-injury sport activity level was evident. However, the observation that the two groups had a different age-related pre-injury level and different surgical expectation could mislead these outcomes. Indeed, a tendency for higher satisfaction in the older group compared with the younger group was described [12, 44]. Osti et al. [44] found a correlation between associated injuries, particularly meniscal tears and cartilage damages, and lower return rate to pre-injury recreational level, more evident in patients older than 50 years who underwent microfractures, compared to patients younger than 30 years. Since likelihood of meniscal tears and high grade chondral lesions seems to be increased as years go by [51, 58], it could represent an unavoidable bias of the present systematic review related to patient selection criteria.

Objective assessment of anteroposterior stability using the KT-100 arthrometer or equivalent showed satisfying findings, with a mean differential laxity under 3 mm reported in all studies selected [4, 8, 27, 31, 48, 56, 57]. However, a side-to-side difference of 3 mm or more was recorded in 45 knees out of 230 (19.6%) [8, 27, 44, 48, 50, 56, 57], ranging from 4% [56] to 59% [8]. Anyway, these results are superior to those obtained with non-operative treatment of ACL tears reported by Cicotti et al. [11] who recorded, in a large cohort of 52 patients aged between 40 and 60 years, a mean difference in anterior-posterior laxity between the injured knee and the normal, contralateral knee of 5 mm.

Table 4 Study quality of literature included in the systematic review, according modified Coleman Methodology Score

	Part A								Part B			
	Study size	Mean follow-up	Percent of patients with follow-up	Number of interventions per group	Type of study	Other injury included	Description of surgical technique	Description of post-operative rehabilitation	Out-come criteria	Procedure for assessing outcomes	Description of subject selec-tion process	Total
Arbuthnot et al. [4]	0	5	3	5	0	3	5	0	7	7	15	50
Baker Jr et al. [6]	0	5	3	5	0	3	3	5	3	4	5	36
Bali et al. [7]	7	3	5	5	0	5	3	3	9	7	5	52
Blyth et al. [8]	4	3	5	5	0	5	5	5	10	7	5	54
Cinque et al. [12]	10	3	3	5	10	5	5	3	5	5	5	59
Dahm et al. [17]	4	5	5	5	0	3	5	3	6	4	5	45
Figueroa et al. [22]	7	5	5	5	0	5	5	0	7	9	15	63
Iorio et al. [27]	10	5	5	10	15	5	5	3	10	12	5	85
Kinugasa et al. [31]	10	0	5	10	10	0	5	5	8	7	10	60
Osti et al. [44]	4	3	5	10	10	5	5	5	10	7	10	74
Stein et al. [48]	4	3	3	5	0	3	5	5	9	7	5	49
Struewer et al. [50]	4	3	5	5	0	5	5	5	10	7	10	59
Toanen et al. [52]	4	5	5	10	0	5	5	5	7	4	10	60
Trojani et al. [53]	0	3	5	10	0	5	5	5	6	4	5	48
Ventura et al. [56]	7	5	5	5	0	5	5	5	10	7	5	59
Wolfson et al. [57]	4	5	5	5	0	5	5	5	10	7	10	61

Graft choice

Graft failure rates in patients included in the present review are reported between 0% [7, 8, 27, 31, 52, 53, 56] and 14.3% [6] regardless graft choice, since good results of ACL reconstruction have been achieved with all graft types: BPTB [4, 6–8, 12, 17, 50, 57], quadrupled hamstrings [4, 6–8, 22, 27, 31, 50, 52, 53, 56, 57] or with allograft [6, 17, 22, 57]; these results are comparable to the published values in younger patients that range from 0 to 13.4% [16]. In literature, several authors proposed the use of hamstring autograft or allograft tissue for reconstructions in older individuals with lower demand, because of reduced donor-site morbidity and potentially fewer problems with the extensor mechanism in secondary knee arthroplasty [8, 30, 35, 39]. Particularly, the use of allograft for primary ACL reconstructions are increasingly performed by surgeons, encouraged by comparable outcomes published in literature to those with autograft, although affected by an higher risk of graft failure [24]. It could be possible that the sub-optimal physical requests of patients aged 50 or more does not push to the limit the inherent graft properties, and the benefit of decreased donor-site pain could be greater than the small risks of disease transmission and slower tissue incorporation.

Based on the present data, satisfactory results in terms of clinical and functional outcomes [50] return to sport rate [8] or progression of osteoarthritis [50] were achieved using either a standard BPTB graft, a four-stranded hamstring graft or allograft, without significant inter-group differences. Since allograft did not show any beneficial effects on clinical and functional outcomes, when directly compared to autografts [17, 22, 57], and taking into account their low biomechanical properties [24], actually a widespread use of this technique for primary ACL reconstruction in these patients cannot be justified. It can be deduced that is more important to restore and conserve knee joint stability than to focus on graft choice.

Progression of osteoarthritis

The debate regarding a possible correlation between ACL surgery and progression of osteoarthritis is ongoing [13, 46].

The prevalence of osteoarthritis progression following ACL reconstruction of 15% (28 out of 187 knees), after a mean period of follow-up ranging from 32 to 64 months, is consistent with the model-estimated proportion of OA at 5 years after surgery of 11.3% (6.4–19.1%) reported by Cinque et al. [13] in a cohort of more than 4000 patients with a significant lower weighted mean age at surgery of 30.5 years old (range of reported means 23–45.2 years old).

It is difficult to determine whether arthritis progression is related to the soft tissue surgery or the natural history of cartilage degeneration. Although some reports seems to found a significant correlation between age, radiological degeneration and ACL reconstruction, [19, 47], the intrinsic patient selection bias of those study designs not allow to clearly establish if surgery protects the unstable knee from degenerative change or not.

Possible explanations for the development of osteoarthritis in the reconstructed knee include joint injury occurring at the time of surgery, prolonged joint inflammation after surgery and abnormal joint mechanics after surgery [19, 55]. However some advocates claim the role of potential bias such as general greater trauma in the reconstructed knee before surgery than in the patients who did not choose reconstruction [55] or prolonged time before decision to underwent surgical reconstruction [13, 28]. In our series, one article [8] focused on this question, finding a longer mean time of 113 months from injury to surgery in patients in whom changes were observed, compared to 80 months in those with no radiological changes.

It has been previously well-established that preservation of the medial meniscus is a significant protective factor of arthritis progression [2, 14, 59] as well as body mass index [32]. Furthermore, chondral injury noted at the time of ACL reconstruction may be associated with higher risk of osteoarthritis progression [2]. The high occurrence of associate meniscal and chondral injury observed in the present analysis does not allow us to draw conclusive findings. It is important to underline that, in the only study where exclusion criteria involved also all patients with concomitant meniscal injuries [50], some degrees of radiographic change were observed anyway in 31.7% of knees examined at final follow-up. However, time from injury to surgical management was not reported, as well as associated chondral injuries noted at time of surgery, maintaining partial the aforementioned findings.

Conclusion

In conclusion, the data of the present study confirm that ACL reconstruction in patients older than 50 years offers good results that are comparable to those of younger patients previously reported. Age itself is not a contraindication to ACL surgery because physiological age, clinical symptoms and functional requests are more important than chronological age in decision process.

Since cohort size in the present study is not large enough, and taking into account the high occurrence of concomitant meniscal and chondral lesions, more studies with higher methodologic quality, strict inclusion criteria and larger number of patients included would be needed to make more definite recommendations.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval An institutional review board was not obtained because all data were extracted from previously published studies.

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