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ORIGINAL STUDY

Efficacy of total knee arthroplasty (TKA) revision surgery depends upon the indication for revision : a systematic review

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The number of revision total knee arthroplasty (TKA) surgeries has increased over the years and it is expected that its number will keep rising. Most frequent reasons for revision are known to be aseptic loosening, infection, instability, periprosthetic fracture, arthrofibrosis and component malposition. The influence of the indication for revision on the outcome scores is not fully understood. Therefore, this work will evaluate and review the existing literature regarding outcome scores after revision TKA surgery. We conducted a sensitive and comprehensive search for published and unpublished studies relevant to the review question. We restricted our search to English studies published between January 2008 and December 2018. Our systematic review was done according to PRISMA guidelines.

We withheld 19 studies (1419 knees) for inclusion. Of these, 9 papers reported outcome scores after TKA revision for aseptic loosening, 10 reported on revision for instability, 10 reported on stiffness or arthrofibrosis and 4 papers reported on component malposition.

Although we found some papers suggesting that there is no difference in postoperative outcome scores depending on the aetiology of revision surgery, the majority of the included studies suggest differently. This review suggests there is a tendency for relative higher outcome scores after revision for aseptic loosening. Revision for malrotation might give comparable postoperative outcome scores and satisfaction ratios. Revision for instability tends to give lower postoperative outcome scores than aseptic loosening, although certain subgroups of instability show comparable results. Lowest postoperative scores might be found after revision for stiffness and arthrofibrosis.

Keywords : Knee surgery ; total knee arthroplasty ; revision surgery ; TKA revision ; outcomes ; PROMS ; systematic review.

INTRODUCTION

The number of revision total knee arthroplasty (TKA) surgeries has increased over the years and with changing demographics it is expected that its number will keep rising *(1-3)*. It is known that the outcomes of revision TKA surgery are worse compared to a primary procedure *(4,5)*.

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Besides the poorer outcomes, revision TKA is also associated with a higher cost due to longer operating time, extensive perioperative testing, increased length of stay and more expensive implants *(4,5)*. Previous papers have identified the main reasons for failure of TKA *(6,7)*. The current failure mechanisms are aseptic loosening, infection, instability, periprosthetic fracture, arthrofibrosis and malalignment. In order to be able to create realistic preoperative expectations for patients undergoing revision TKA, this work will address the major reasons for revision, with the exclusion of infection and periprosthetic fractures, and will evaluate the outcome for each of them. Knowledge about the outcome scores after revision will help to create realistic expectations. Such expectations relate to higher patient satisfaction with the clinical outcome postoperatively after total knee arthroplasty *(5,8,9)*.

The aim of the current study is to evaluate and review the existing literature concerning patient reported outcome and satisfaction after revision total knee arthroplasty. As the influence of the indication for revision on the outcome is not fully understood, this work will evaluate and review the existing literature regarding outcome scores and range of motion after revision TKA surgery.

MATERIALS AND METHODS

Before conducting this review PubMed, EMBASE and the Cochrane library were screened for published reviews related to our topic of interest. None were identified. Relevant literature published between 2008 and 2018 reporting patient reported outcome scores and clinical outcome scores after revision TKA with a specific reason for failure was collected. The review was performed using the 'Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines *(10)*.

We conducted a sensitive and comprehensive search for published and unpublished studies relevant to the review question. We restricted our search to English studies published between January 2008 and December 2018.

Before developing a search strategy, we conducted a preliminary search for identification of relevant Medical Subject Headings (MeSH) and a wide range of synonymous text-words.

A detailed, sensitive search strategy was then developed in The US National Library of Medicine (PubMed/MEDLINE) and EMBASE. We performed a wide search strategy, including all relevant literature.

Search Terms :

1. ("Arthroplasty, Replacement, Knee"[Mesh] OR "total knee arthroplasty" OR "TKA" OR "total knee replacement" OR "total knee prosthesis")
2. AND ("stiffness" OR "instability" OR "pain" OR "strength" OR "hydrops" OR "Effusion" OR "oversizing" OR "overstuffing" OR "patellar indication" OR "malalignment" OR "malrotation" OR "loosening")
3. AND ("revision" OR "failed")
4. AND ("Patient Reported Outcome Measures" [Mesh] OR "outcome" OR "PROM")

An additional search with variations of this search strategy literature was performed using web search with google scholar. We completed our data by performing a search through citation list and bibliography of relevant studies to our study.

Inclusion criteria :

(1) Articles concerning revision total knee arthroplasty due to different aetiology : stiffness, instability, pain, strength, hydrops, effusion, oversizing, overstuffing, patellar problems, malalignment, malrotation or loosening ; (2) Articles concerning patients of any age and gender ; (3) Articles published between January 2008 and December 2018 ; (4) Studies with a minimal cohort of 30 patients ; (5) Minimal follow-up of 12 months.

Exclusion criteria :

(1) Review articles ; (2) Case studies ; (3) Studies stratifying patients based on perioperative management (anaesthesia protocol) ; (4) Studies including patients with multiple revisions ; (5) Revisions for fracture ; (6) Revision for infection ; (7) Studies conducted in a cohort with neuromotor conditions ; (8) Studies conducted in a cohort with psychiatric conditions ; (9) Studies concerning partial knee implants.

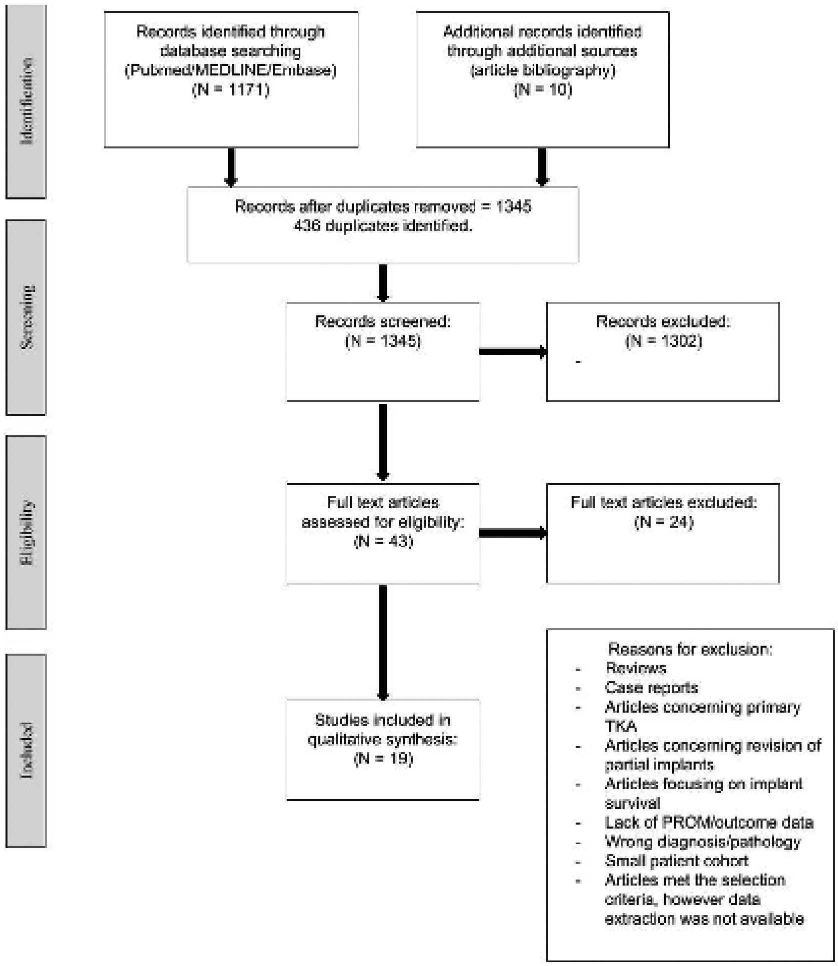

Figure 1. — PRISMA flow diagram for study selection.

All search results were all merged in the reference management software Mendeley Desktop Software (V-1.17.13) and the Mendeley Web Importer. Duplicates were removed automatically. All titles and abstracts were screened by two separate authors (M.C. and M.M.) based on our inclusion criteria. In case of doubt or disagree, articles were assessed by both authors together with a third author (S.V.O.) until consensus was reached. Figure 1 shows the selection process of the articles retrieved. Our systematic review was done according to PRISMA guidelines (Figure 1) *(10)*. The initial extensive database research retrieved 1771 studies and was completed with 10 additional articles, found by bibliography analysis of related articles. 436 duplicates were automatically excluded. The remaining 1345 studies were screened as described above according our inclusion and exclusion criteria based upon the study title and abstract. After this screening process 1302 studies were excluded. Main reasons for exclusion can be found in Figure 1. The remaining 43 articles were assessed for eligibility. We withheld 19 studies for inclusion in this systematic review.

We extracted the following key characteristics of the studies : lead author and country, year published, study design and level of evidence. All primary outcome data were indexed in google sheets. Data extracted included : *Number of patients, follow up time, average age, Male/Female distribution, body mass index, range of motion and Proms/outcome scores.* Disparities in data extraction were discussed, reviewed and resolved.

Table I. — Overview of the selected articles

Year	Author	Journal	OCEBM Levels of Evidence	Patient Count	Age	BMI	Follow up (months)	Scores	Subgroups studied
2010	Lakstein et al. (11)	J of Arthroplasty	III - Case-matched control study	48	68	-	37	KSS	malrotation (50%) - aseptic loosening (50%)
2010	Patil et al. (12)	The knee	II – Prospective cohort	45	63.4	-	40	KSS - SF-36	stiffness (25%) - aseptic loosening (29%) - maltracking (13%) - septic loosening (33%)
2010	Hartman et al. (13)	J of Arthroplasty	III – Retro-spective cohort	35	62	-	54.5	KSS - ROM	Stiffness (100%)
2011	Hardeman et al. (14)	KSSTA	III –Retro-spective cohort	129	67.7	-	56	KSS - ROM	aseptic loosening (25%) - instability (23%) - infection (14%) - malalginement (11%) - wear (10%) - patella (6%) - artrofibrosis (4%) - fracture (3%)
2011	Azzam et al. (15)	J of Arthroplasty	III – Retro-spective cohort	67	66	-	36	KSS - SF-36	instabiliity: PS failure (75%) - CR (19%) - semi-constrained (6%)
2012	Malviya et al. (16)	KSSTA	II - Prospective cohort	120	69	28.5	24	WOMAC - SF-36	Aseptic loosening (46%) - Instability (27%) - Unexplained pain (9%) - Polyethylene wear (13%) - Others (5%)
2012	Kim et al. (17)	The Knee	II –Prospective cohort	37	60.8	30.7	74.4	KSS - ROM	Stiffness (100%)
2012	Sternheim et al. (18)	Int orthopaedics	III - Case-matched control study	102	68	-	42	KSS - VAS	Malrotation (50%) - Aseptic loosening (50%)
2013	Van Kempen et al. (19)	COOR	II –Prospective cohort	150	66	-	24	KSS - VAS - ROM	Septic loosening (23%) - Aseptic loosening (27%) - Component malposition (25%) - Instability (15%) - Stiffness (10%)
2013	Bieger et al. (20)	Arch Orthop Trauma Surg	II - Prospective cohort	97	68	30.3	29	KSS	Aseptic loosening (57%) - Infection (22%) - Instability (13%) - Arthrofibrosis (7%)
2014	Abdel et al. (21)	Bone Joint J	III - Retrospective cohort	60	65	-	42	KSS	Flexion instability (100%)
2015	Kannan et al. (22)	J of Arthroplasty	III – Retrospective cohort	37	62	-	12	KSS - Satisfaction	Midflexion instability (100%)
2016	Donaldson et al. (23)	Bone joint journal	III - Retrospective cohort	48	65.5	-	59,9	WOMAC - ROM	Stiffness (100%) with reasons: Internal rotation (42%) - Artrofibrosis (13%) - Overstuffing (21%) - Malalignement (12%) - Instability (12%)
2016	Luttjeboer et al. (24)	J of Arthroplasty	III - Retrospective cohort	77	66.7	-	24	KSS - ROM - VAS	Instability (100%) with reasons: AP instability (38%) - ML instability (20%) - Multiplane instability (42%)
2016	Heesterbeek et al. (25)	KSSTA	II – Prospective cohort	35	64	-	24	nKSS - ROM - VAS	Stiffness (100%) with reasons: Malpositioning (67%) - Aseptic loosening (12.5%) - Instability (12.5%) - Stiffness e.c.i. (18%)
2016	Grayson et al. (26)	J of Arthroplasty	III - Retrospective cohort	92	65.2	34.1	21	KSS - UCLA	Flexion instability (38%) - Infec-tion (26%) - Aseptic loosening (36%)
2017	Moya-Angeler et al. (27)	J of Arthroplasty	III - Retrospective cohort	42	61	33	24	KSS - ROM	Stiffness (100%) with reasons - Artrofibrosis (81%) - Malrotation (19%) - Overstuffing (31%) - F/E mismatch (16.5%) - Poly wear (19%) - Aseptic loosening (28.5%) - Patella (14%)
2017	Rajgopal et al. (28)	J of Arthroplasty	III -Retrospective cohort	146	71.2	32.5	18	KSS - WOMAC - VAS	Flexion instability (31%) - Septic loosening (33%) - Aseptic loosening (36%)
2018	Rutherford et al. (29)	J of Arthroplasty	III - Retrospective cohort	46	61.4	28.4	59	KSS - ROM	Arthrofibrosis/stiffness (100%) with reasons: Internal rotation (26%) - Overstuffing (21%) - Instability (16.9%) - Malalignement (16.9%) - Stiffness e.c.i. (9%)

RESULTS

After full-text review, 19 studies were found to fulfill all inclusion and exclusion criteria *(11,12,21-29,13-20)*. Overview of the study characteristics can be found in table I.

There were 9 studies included reporting clinical and functional outcome scores after revision for

Table II. — Outcome scores after revision for aseptic loosening

Article	N	Age (y)	FU (mo)	KSS pre-revision	KSS post-revision	KSS Improvement	KSS Functional pre-revision	KSS Functional post-revision	KSS Functional Improvement	VAS pre-revision	VAS post-revision	VAS improvement
Lakstein, 2010	24	68	42	39	75	× 36	-	-	-	-	-	-
Patil, 2010	13	63.4	40	41.3	72.4	× 31.1	27.5	51.3	× 23.8	-	-	-
Hardeman, 2011	37	67.7	56	-	74.6	-	50.8	-	-	-	-	-
Sternheim, 2012	51	68	42	44	76	** 32	47	57	** 10	61	25	** 36
Van Kempen, 2013	40	-	24	52	85	** 33	39	69	** 30	58	17	** 41
Bieger, 2013	55	68	28	°107.8	°165.0	**°57.2	-	-	-	-	-	-
Grayson, 2016	32	65.2	21	°KSS Objective score 61.5 °KSS satisfaction 10 °KSS expectation 13.5	°KSS Objective score 94 °KSS satisfaction score 34 °KSS expectation score 9	°KSS Objective score × 32.5 °KSS satisfaction score × 24 °KSS expectation score × 4.5	°24	°69.5	× °45.5	-	-	-
Rajgopal, 2017	53	71.2	40.5	52	69	** 18	43	74	** 30	-	-	-
				WOMAC pre-revision	**WOMAC post-revision**	**WOMAC pain pre-revision**	**WOMAC pain post-revision**	**WOMAC function pre-revision**	**WOMAC function post-revision**			
Malviya, 2012	56	66.9	24	-	-	34.8	** 66.8	34.7	** 57.4			
Rajgopal, 2017	53	71.2	40.5	79	24	-	-	-	-			

(° = 2011 Knee Society Scores, * = P<0.05, ** = P<0.001, x = level of significance not given).

aseptic loosening *(11,12,14,16,18-20,26,28)* (Table II). All studies reported an improvement in reported scores after revision for aseptic loosening. When provided, all studies report a significant improvement Some studies only compared significance levels between different included revision groups. Preoperative Knee Society Scores (KSS) were between 39-52 points. Postoperative KSS improved to 69-85 points *(11,12,14,18,19,28)*. Improvement was between 31 and 36 points. Only Rajgopal et al. reported less improvement in KSS (18 points). Improvement in 2011 KSS score was between 57.2 and 61 points *(20,26)*. Pre-revision functional scores were between 27.5 and 50.8 points. These improved between 51.3 and 74 points. We identified 3 articles reporting range of motion (ROM) (Appendix A). The ROM at final follow-up appeared to be between 105-112°. Although not the reason for revision, there was a small improvement in ROM of 6° to 10° reported after revision for aseptic loosening *(18,19)*.

We included 10 studies reporting functional outcome scores after revision for instability *(14-16,19-22,24,26,28)* (Table III). Some studies make distinction between different types of instability, others report on a mixed group of instability cases. We make distinction between mixed/multiplane instability groups and isolated flexion instability. Nearly all studies report significant improvement of the reported outcome scores *(15,19,20,24)*, in all the others levels of significance were not given. Two studies with multiplane or mixed instability groups report preoperative KSS between 43 and 55 points *(15,19,24)*. Three studies report postoperative KSS between 68 and 77 points *(14,15,19,24)*. Average KSS improvement is between 25 and 33 points. Reported preoperative functional scores were between 35 and 47 points and improved to a score between 53 and 64 points. Average KSS functional improvement was between 17 and 18 points.

We identified two articles reporting range of motion after revision for instability *(14,19)*. One reports preoperative ROM of 102°, increasing to 116° *(19)*. The second reports postoperative ROM of 106° *(14)*.

Flexion instability was studied as a separate revision group in 4 included studies (Table III) *(21,22,24,26,28)*. Studies reporting on revision for flexion instability report preoperative KSS between 34 and 56 points *(21,22,24,28)*. Postoperative KSS was between 61.8 and 82 points and functional scores between 55 and 84 *(21,22,24,26,28)*. Average increase in KSS was 13 and 48 points. We see significant improvements in nearly all included studies for KSS and functional outcome scores. There is an important discrepancy in improvement described by different authors. This might be due to the reason of flexion instability. In two studies flexion instability was explained by a failure of the posterior cruciate ligament (PCL) in a cruciate retaining (CR) implant in the majority of the cases *(21,22)*. In these series KSS improvement between 27.3 and 48 points was reported. When flexion instability was due to undersizing of the femoral component or overresection of the posterior condyle, improvement of KSS was 13 points *(28)*.

There were 10 studies included reporting outcome scores after revision for stiffness or arthrofibrosis *(12-14,17,19,20,23,25,27,29)* (Table IV). Most papers define stiffness as a total arc of motion of 70° or less. Not all papers are clear about the underlying reason for stiffness or failure. Underlying reasons such as component malposition, overstuffing, loosening, instability or others are given *(12,19,23,25,27,29)*. There is also confusion in the use of the terms stiffness and arthrofibrosis. This paper makes distinction between stiffness, with underlying reasons and primary arthrofibrosis or unexplained stiffness.

Revision for stiffness shows preoperative KSS between 32.2 and 43.9 points. Postoperative KSS outcome scores were ranging between 57 and 72 points *(12,13,23,25,27)*. Average improvement in KSS was between 16.8 and 28 points. Postoperative functional KSS scores were between 45 and 70 points *(12,13,23,25,27)*. Most studies report a trend towards moderate functional results and satisfaction ratios after revision for Stiffness *(12,14,19,20,25)*. Revision for primary arthrofibrosis shows preoperative KSS of 45.7 *(17)* and an average postoperative KSS between 48.7 and 67.9 points *(14,17)*. Postoperative functional scores were between 50 and 62.9 points. Improvement in KSS was 22.2 points. Two studies report preoperative KSSs between 84.6 and 100.17 points and postoperative KSS between 140 and

Table III. — Outcome scores after revision for instability

Article	Type of instability	N	Age (y)	FU (mo)	KSS pre-revision	KSS post-revision	KSS Impro-vement	KSS Functional pre-revision	KSS Functional post-revision	KSS Functional Improvement	Other
Hardeman, 2011	Mixed	33	-	-	-	68.2	-	-	51.3	-	-
Azzam, 2011	Coronal (45%) Flexion instabi-lity (12%)Com-bined (43%)	67	66	39	43	76	** 33	47	64	* 17	Improvement in 78%
Van Kempen, 2013	Mixed	38	-	24	55	77	* 25	35	53	* 18	VAS preop 63 - postop 36 Impro-vement 27
Bieger, 2013	Mixed	13	67	34	°84.2	°157.7	** °73.5	-	-	-	
Abdel, 2014	AP Flexion instability (41/60 failure CR implant)	60	65	42	34	82	** 48	37	84	** 47	
Kannan, 2015	Flexion instability (20/24 failure CR implant)	37	62	32	34.5	61.8	** 27.3	39.5	60.3	** 20.8	Likert scale 26/37 Improvement 20/37 good result
Luttjeboer, 2016	3 subgroups	77	66.7	24	-	-	-	-	-	-	
	AP instability	29	-	-	45.5	81	** 35.5	45	60	** 15	VAS preop 70.5 - postop 41 Improvement ** 29.5
	Flexion instability	16	-	-	51	80	** 29	45	55	** 10	VAS preop 61.5 - postop 49 Improvement: ** 11.5
	Multiplane instabiliy	32	-	-	52	70	** 18	42.5	60	** 17.5	VAS preop 74 - postop 43.5 Improvement: ** 30.5
Grayson, 2016	Flexion instability	35	-	21	°KSS Objective 62.5 °KSS Satisfaction10 °KSS expectation 15	°KSS objective 91 °KSS satisfaction 28 °KSS expectation 8	°KSS objective 28.5 °KSS satisfaction 18 °KSS expectation 7	°34	°61	°27	
Rajgopal , 2017	Flexion instability	45	71.2	40.5	56	67	13	58	72	16	
					WOMAC pre-revision	WOMAC Post-revision	WOMAC pain pre-revision	WOMAC pain Post-revision	WOMAC function pre-revision	WOMAC function Post-revision	
Malviya, 2012	Coronal Instability	32 (27%)	64.8	24	-	-	33.8	53.4	36.2	49.5	
Rajgopal, 2017	Flexion instability	45	71.2	40.5	71 (SD 8)	23 (SD 3)	-	-	-	-	

(° = 2011 Knee Society Scores, * = P<0.05, ** = P<0.001, x = level of significance not given).

Table IV. — Outcome scores after revision for Stiffness or arthrofibrosis

Article	Diagnosis	Underlying diagnosis	N	Age (y)	FU (mo)	KSS pre-revision	KSS post-revision	KSS Improvement	KSS Functional pre-revision	KSS Functional post-revision	KSS Functional Improvement	Other scores
Patil, 2010	stiffness	-	11	-	40	41.3	58.1	16.8	41.2	52.7	* 10.9	-
Hartman, 2010	Stiffness	-	35	62	54.5	32.2	60.9	** 28.7	41.6	56.3	* 14,7	
Van Kempen, 2013	Stiffness	- malrotation (53.3%) - aseptic loosening (20%)	15	-	24	34	57	* 24	42	45	3	VAS preop 62 - postop 53 Impovement: * 19
Donaldson, 2016	Stiffness	- Internal rotation (42%) - Primary Arthrofibrosis (12.5%) - Overstuffing (20.8%) - Malalignement (12.5%) - Instability (12.5%)	48	65.5	59.9	-	-	-	-	-	-	WOMAC preop 58.3 - postop 36.9 Impovement: ** 21.4
Heesterbeek, 2016	Stiffness	- Malrotation (77.1%) - Aseptic loosening (14.2%) - Instability (8.6%) - Unknown (8.6%)	35	64	24	43	61	** 18	45	60	** 15	VAS preop 66 - Postop 49 Improvement * 17
Moya – Angeler, 2017	Stiffness	- Malrotation (19%) - oversizing (30%) - gap mismatch (16%) - wear (19%) - loosening (28%) - maltracking (14%) - artrofibrosis (80%)	42	61	47	43.9	72	* 28	48.7	70.1	* 20.4	VAS Improvement in 73%
Rutherford, 2018	Arthrofibrosis (functional stiffness)	- Internal rotation (39%) - Overstuffed (21%) - Instability (7%) - Malalignement (8%) - Unexplained (17%)	46	61.4	59	°100.17	°140.07	** °40	°57.17	°70.98	** °14	-
Hardeman, 2011	Arthrofibrosis	-	5	67.7	56	-	48.7	-	-	50	-	-
Kim, 2012	Arthrofibrosis	Excluded	37	60.8	74.7	45.7	67.9	** 22.2	41.8	62.9	** 21.1	-
Bieger, 2013	Arthrofibrosis	Excluded	7	61	27	84.6 °	143.7°	** 59.1 °	-	-	-	-

(°= 2011 Knee Society Scores, * = P<0.05, ** = P<0.001, x = level of significance not given).

Table V. — Outcome scores after revision for component malposition

Article	Subgroup	N	Age (y)	FU (mo)	KSS pre-revision	KSS post-revision	KSS Impro-vement	KSS Functional pre-revision	KSS Functional post-revision	KSS Functional Impro-vement	Other
Lakstein, 2010	Malrotation	24	68	37	33	80	47	-	-	-	-
Patil et al, 2010	Patella maltracking	6	63	40	44.8	82.2	37.3	44.2	72.5	28.3	-
Sternheim, 2012	Malrotation	51	69	40	44	75	** 31	49	60	** 11	Vas preop: 71 - postop: 36 Improvement: 44
Van Kempen, 2013	Malpositioning/ Malrotation	38	-	24	50	77	27	47	62	15	VAS preop: 61 - postop: 36 Improvement: 25

(* = P<0.05, ** = P<0.001, x = level of significance not given).

Table VI. — Overview of the collected results

	Postoperative			Improvement				
Indication	KSS	fKSS	ROM	KSS	fKSS	ROM	Complications	Reinterventions
Aseptic loosening	69 - 85	51.3 - 74	105° - 112°	31 - 36	10 - 30	6° - 10°	10% - 23.6%	2.5%
Instability	68 - 77	53 - 64	106° - 116°	25 - 33	17 - 18	14°	10% - 46.6%	18% - 23%
Flexion instability	61.8 - 82	55 - 84	/	13 - 48	10 - 47	/	10% - 27%	18.9%
Stiffness	57 - 72	45 - 70	83° - 98.1°	16.8 - 28	3 - 20.4	20° - 45°	33% - 49%	14.2 - 30%
Arthrofibrosis	48.7 - 67.9	50 - 62.9	85° - 99°	22.2	21.1	18° - 21°	28%	17%
Component malposition	75 - 82.2	44.2 - 49	102° - 110°	27 - 47	11 - 28.3	9° - 21°	24% - 29%	0 - 8%

(Mobilisation under narcosis was not included in reinterventions).

143.7 points *(20,29)*. It is important to note that in most series pain scores stayed high postoperative. Postoperative VAS scores were reported to be between 36.9 and 53 points *(19,23,25)*.

Range of motion (ROM) is also considered a major outcome parameter after revision for stiffness or arthrofibrosis (Appendix A). Five studies report postoperative ROM between 83° and 98.1° after revision for stiffness *(13,19,23,27,30)* (Appendix A). Average improvement in ROM was between 20° and 45°. Considering arthrofibrosis, three studies report postoperative ROM between 85° and 99° *(14,17,29)*. Average improvement in ROM was between 18° and 21°. Only 50% of the included articles reported an average ROM over 90° after revision for stiffness and arthrofibrosis at final follow-up.

There were 3 articles found that evaluated component rotation and one evaluating patellar maltracking *(11,12,18,19)* (Table V). There might be overlap between revisions for patella maltracking and revision for component positioning. Also, there might be overlap between cases of malrotation and stiffness in some studies. The included studies report preoperative KSS between 33 and 50 points. Postoperative KSS scores are between 75 and 82.2 points *(11,12,18,19)*. Gain in KSS is between 27 and 47 points. Postoperative functional scores were found to be between 44.2 and 49 points, with an improvement between 11 and 28.3 points. Considering range of motion, three studies report average preoperative ROM between 81° and 101°, postoperative ROM between 102° and 110° and average gain between 9° and 21° *(11,18,19)* (Appendix A).

DISCUSSION

In recent years, more and more papers papers have been published concerning the results after revision for TKA failure. However, the influence of the indication for revision on the outcome is not fully understood. The performed systematic review reports on 19 papers that met the inclusion criteria and provide insight into this complex matter. This paper provides a descriptive review of their findings based on the reported functional outcome scores, range of motion and remarks. Table VI provides an overview of the collected findings. Although we found some papers suggesting that there is no difference in postoperative outcome scores depending on the aetiology of revision surgery *(14,20)*, the majority of the included studies suggests differently.

Most included studies show a trend towards good clinical and functional results after revision for aseptic loosening. For this reason, revision for aseptic loosening is often used as a golden standard for comparing outcome scores. Three studies compared the functional outcome scores after revision for aseptic loosening against revision for instability *(16,19,26)*. Two studies showed significant better results for the aseptic loosening group *(16,19)*. A significant higher proportion of patients in the aseptic loosening group were satisfied, had a better quality of life and would have the surgery again *(16)*. One study failed to show significant differences in KSS or satisfaction at final follow-up *(26)*. When considering the expectation scores, it seemed that patients with aseptic loosening were more likely to have their expectations met compared to revision for instability or arthrofibrosis. Compared to revision for malrotation, no significant difference was found between both groups *(11,19)*. One study did show a clear trend towards better postoperative KSS scores in revision for aseptic loosening and showed significantly lower postoperative VAS pain scores compared to other indications *(19)*. In contrast, another study showed better results after revision for maltracking compared to aseptic loosening *(12)*. Two included studies showed better postoperative clinical outcome scores after revision for aseptic loosening compared to revision for stiffness *(12,19)*. One of these didn't show significant differences concerning functional scores *(12)*. Hardeman et al. found no differences in the functional outcome scores depending upon the aetiology for revision, but revisions for arthrofibrosis tended to have worse results *(14)*.

As mentioned earlier, some articles show better results for aseptic loosening compared to instability (16,19). One study did not show differences in KSS or satisfaction at final follow-up *(26)*. Outcome also depends upon the type of instability. Revision for anteroposterior instability after failed CR implants tends to have very good outcome scores *(15,21)*. Revision for non-CR failure related flexion instability also gives adequate results, but appears to give less patient satisfaction. Probably because of higher preoperative functional scores *(20,26)*. Grayson et al. showed that patients revised for flexion instability started with the highest function scores preoperatively and improved the least from the baseline, compared with patients revised for infection and aseptic loosening *(26)*. Similarly, patients with revision for flexion instability were less likely to report their expectations were met in this study cohort. Raigopal et al. reported similar findings *(28)*. Interestingly the patients of the aseptic loosening group reported better subjective outcome scores than those in the flexion instability group. Also, there is a trend towards better results and less complications when adding more constraint in revision for instability. Malviya et al. reported a trend towards better outcome scores when using a linked implant for revision for instability *(16)*. Another included study reported a tendency for lower functional outcome scores, but satisfaction rates were the same for hinged and condylar implants *(24)*. Also failure rates are markedly lower when using hinged implants *(24)*. This is in line with other studies published concerning revision TKA. Hossain et al. published a retrospective study in 2008 concerning 349 revision cases for various indications *(31)*. They report highest satisfaction ratios (88%) for hinged implants compared to PS and CCK implants. The rotating hinge group also showed the highest 10-year survival rates. Luttjeboer et al. stated 3 clear recommendations for determining constrained in revision for instability *(24)*. They suggest using hinged implants in cases with severe ligament instability or bone loss, and only to use posterior stabilised implants in cases of PCL insufficiency. They suggest using condylar constraint implants in all other cases.

Causes for stiffness following TKA are numerous and often multifactorial. Analysing the underlying reasons for stiffness, malrotation of the components appears to be the most frequent underlying reason for stiffness. It accounts for 39 to 77% of all cases of TKA stiffness *(19,23,29,30)*. Other common underlying reasons are overstuffing or oversizing in 21% to 31% *(23,27,29)*, and instability in 12% to 16.9% of the cases *(23,29,30)*. Unexplained pain or stiffness should therefore be considered as a diagnosis of exclusion. When revising for stiffness it is important that there seems to be no difference in outcome scores depending the underlying reason for stiffness *(25,29)*. This is in contrast to common belief that outcome after revision is better when an underlying cause for stiffness is identified *(32)*.

Concerning the outcome scores, most publications tend to report moderate improvement in outcome scores after revision for stiffness. It seems that residual VAS scale for pain stays relative high in most included studies *(19,23,25)*. Up to 9.5% of their patients continued to have severe pain at final follow-up in one study *(27)*. Better pain scores after revision for instability and aseptic loosening were shown compared to stiffness *(33)*. Two included studies report inferior results after revision for stiffness compared to aseptic loosening and malrotation *(12,19)*. A study, that did not meet our inclusion criteria, revision TKA in 67 revisions. They concluded that postoperative pain scores were better for revision after instability and loosening compared to arthrofibrosis. Postoperative function scores were also better for revision after instability *(33)*. When analysing postoperative range of motion there was an average gain of 20° to 45°, with only 50% of the articles reporting an average ROM over 90° at final follow up *(13,14,17,19,23,25,29)*. Up to 90% of the cases achieve a ROM over 70° *(25)*. Hartman et al. found no correlation for time interval between index and revision surgery and the postoperative arc of motion *(13)*. Likewise Rutherford et al. found no impact on the outcome scores comparing early and late revisions *(29)*. Similarly, Kim et al. found no statistical significant difference in surgical timing between the more successful and the failure group *(17)*.

This small improvement in ROM could be sufficient for walking and daily life activities *(30)*. It is known that walking on a flat surface requires 65° of knee flexion, arising from the seated position or climbing stairs requires 70° of knee flexion, and descending stairs needs 90° of flexion *(34)*. Preoperative stiffness appears to be a moderate predictor for postoperative range of motion *(17,25)*. The indication for revision does not seem to influence postoperative range of motion. Interesting advice was provided by Donaldson et al. purposes to perform a sloppy revision for severe stiffness. The knee is first balanced in flexion and extension after which the liner is downsized by 2-4 mm. Additional stability is obtained by using a constrained liner *(23)*. They performed a sloppy revision in severe stiffness, with similar results as in a less severe stiffness group, without additional complications. A more recent study from Van Rensch et al. showed the results of a more extensive release when revising severely stiff TKA in combination with using rotating hinged implants *(30)* They reported acceptable results for revision of severe stiffness with improvement of average ROM from 45° to 90° and KSS from 43 to 76 points at 2 years follow-up. They also suggest taking care in evaluating potential comorbidities associated with arthrofibrosis. Although outcomes and functional scores are moderate and pain scores remain relatively high, the gain in ROM can be of significant importance for our patients. We should warn our patients to lower their expectations for pain relief, as pain scores tend to stay high. The use of specific revision strategies could improve our results.

Revision for malrotation shows relative good results comparable to those after revision for aseptic loosening *(11,18,19)*. Though Lakstein et al. reported no differences in outcome scores after revision for malrotation compared to revision for aseptic loosening, they did report a trend towards faster recovery after revision for malrotation during the first 6 months *(11)* Satisfaction ratios also reported to be comparable. A 75% satisfaction ratio was found , compared to 79% satisfaction ratio in the aseptic loosening group *(18)*. Malrotation is beneficial for increasing range of motion (Appendix A). Three included articles reported an improvement in ROM *(11,18,19)*. Based upon these findings, revision TKA for malrotation can be considered as highly beneficial. Typically, patients with malrotation of the components never experienced a pain free period after primary arthroplasty. In those cases evidence supports the use of early CT evaluation after exclusion of infection in painful TKA *(11,18)*. Malrotation is suggested as a diagnosis to consider when being confronted with the so called 'mystery knee'.

When considering comorbidities, there might be a correlation with outcome scores. Studies included in our review failed to show clear association between these comorbidities and outcome scores after revision TKA *(13,15-17,22,26,27,29)*. Only 2 studies managed to show a relationship with age *(14,23)*. One study reported a tendency to worse physical scores and better functional scores in younger patients *(14)*, the other reported lower improvement in range of motion in patients under 60 years revised for stiffness *(23)*. Other studies reporting on age fail to show any correlation with age *(13,15,16,26,27,29)*. Pun et al. report similar postoperative results in males and females after revision TKA *(33)*. Interesting recent work by Clement et al. investigated a retrospective cohort of 2589 patients with primary TKA *(35)*. They investigated risk factors for developing stiffness, and found following odds ratios : 1.66 for patients of the male gender, 2.06 for lung disease, 1.82 for diabetes, 1.81 for back pain and 5.79 for preoperative stiffness *(35)*. Another recent publication by Verbeek et al. was the first to make predictive model for beneficial postoperative functional outcome scores. Following odds ratios were fitted into the model : 1.59 for male gender, 0.44 for major bone defects, 0.39 for higher age, 0.42 for higher preoperative fKSS and 0.48 for preoperative severe stiffness *(36)*. Both studies report a contrasting influence by gender, but the first focusses on developing stiffness in males with primary TKA, while the latter shows a higher possibility of achieving beneficial functional scores after revision TKA. The finding of higher functional scores in younger patients, is in line with the findings of Hardeman et al. *(14)*.

Some limitations have to be mentioned. For instance, it was impossible to find level I randomized controlled trials. Most included studies are based on prospective and retrospective cohorts. Secondly it is also very important to mention the difficulties in comparing inhomogeneous study groups. Differences in reporting results and outcome scores used as evaluation pose problems comparing these studies. A third major difficulty was stratifying patients into separate groups based on the reason for revision. As it is also noted by other studies, in patients with a non-functioning TKA there is often a combination of problems *(19)*. Some studies also try to make further diversification into subgroups, as is done for instability and stiffness.

CONCLUSION

As the number of revision TKA surgery is rising, it is important to know what the outcome of this surgery can be. This review suggests there is a tendency for relative higher outcome scores after revision for aseptic loosening. Revision for malrotation might give comparable postoperative outcome scores and satisfaction ratios. Early revision for clear malrotation problems seems beneficial. Revision for instability tends to give lower postoperative outcome scores than aseptic loosening, although certain subgroups of instability show comparable results. There also seems to be a trend towards higher outcome scores and less failures when adding more constraint in revision for instability. Lowest postoperative scores might be found after revision for stiffness and arthrofibrosis. Pain scores also tend to remain high. Although improvement in outcome scores of these patient populations are only moderate, they can be important enough for improving quality in life. Specific revision strategies could also improve outcome scores and decrease failure rate of revision. It is clear that there is a lack of strong prospective studies that evaluate the influence of indication of revision on the outcome. The information provided can be used as a basis to perform further prospective studies.

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Appendix A. — Range of motion after revision TKA surgery

Article	Indication	N	Age (y)	FU (mo)	M/F	ROM pre-revision	ROM at final follow-up	ROM Improvement
Hardeman, 2011	Aseptic loosening	37	67.7	56	-	-	105.6°	-
Sternheim, 2012	Aseptic loosening	51	68	42	22/29	95°	106°	10°
Van Kempen, 2013	Aseptic loosening	40	-	24	-	106°	112°	6°
Hardeman, 2011	Instability	33	-	-	-	-	106°	-
Van Kempen, 2013	Instability	38	-	24	-	102°	116°	14°
Lakstein, 2010	Malrotation	24	68	37	9/15	81°	102°	* 21°
Sternheim, 2012	Malrotation	51	69	40	22/29	93°	103°	10°
Van Kempen, 2013	Malpositioning - Malrotation	38	-	24	-	101°	110°	9°
Hartman, 2010	Stiffness		62	54.5 mo	20/15	53.6°	98.1°	** 44.5°
Van Kempen, 2013	Stiffness	15	-	24	-	55°	83°	28°
Donaldson, 2015	Stiffness	48	65.5	59.9	13/35	42.4°	87.4°	* 45°
Heesterbeek, 2016	Stiffness	35	64	24	9/31	60°	85°	** 25°
Moya-Angeler, 2017	Stiffness	42	61	47	-	72°	92°	* 20°
Rutherford, 2018	Arthrofibrosis (functional stiffness)	46	61.4	59	-	ROM: 78° Flexion: 88° Extension: 10.5°	ROM: 99° Flexion: 102° Extension: 3°	** ROM: 21° ** Flexion: 14° ** Extension: 7°
Hardeman, 2011	Arthrofibrosis	5	67.7	56	-	-	98.3°	-
Kim, 2012	Arthrofibrosis	37	60.8	74.7	15/24	ROM 67° Extension: 12°	ROM: 85° Extension: 5°	** ROM: 18° ** Extension: 7°