Complications and outcomes of trochleoplasty for patellofemoral instability: A systematic review and meta-analysis of 1000 trochleoplasties.

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Original article (Systematic review)

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Abstract

Background

Trochleoplasty is an effective patellar stabilization procedure; however, it is associated with a risk of complications that cannot be ignored. Prior systematic reviews on this topic did not include more recent studies reporting important outcomes, particularly the long-term results of lateral elevation trochleoplasty. This led us to carry out a new meta-analysis of the various trochleoplasty procedures to specify: 1) the recurrence rate of patellofemoral dislocation, 2) the complication rates and 3) the clinical outcomes.

Patients and Methods

Studies reporting complications and clinical outcomes of trochleoplasty, whether or not it was combined with other procedures for patellofemoral instability, were identified in the MEDLINE, Embase, Scopus, Cochrane Library, Web of Science databases and by searching the grey literature. The primary endpoint was the recurrence of patellofemoral dislocation while the secondary endpoints were objective patellofemoral instability without dislocation, stiffness, patellofemoral osteoarthritis, subsequent surgeries and various clinical outcome scores. The results were combined in a random-effects model (weighing factor: inverse variance) when the heterogeneity was less than 80%.

Results

Twenty-eight studies were included: 5 featured lateral elevation trochleoplasty, 10 about the Dejour deepening trochleoplasty, 12 about the Bereiter deepening trochleoplasty and 1 about the recession wedge trochleoplasty. A total of 1000 trochleoplasty procedures were done in 890 patients who had a follow-up of 1 to 25 years. There were 24 cases of recurrent dislocation (24/994 [2.4%]; this outcome was not reported for 6 trochleoplasties). The Dejour deepening trochleoplasty was the most effective with only 1 recurrence in 349 knees (0.28%). For the other complications, residual patellar instability without dislocation occurred in 82 of 754 knees (8% [95% CI: 3-14%]), patellofemoral osteoarthritis in 117 of 431 knees (27%), stiffness in 59 of 642 knees (7% [95% CI: 3-12%]) and the need for subsequent surgery in 151 of 904 knees (17%).

Discussion

This study found a low recurrence rate for patellofemoral dislocation and residual instability. The incidence of stiffness, patellofemoral osteoarthritis and subsequent surgery remains high but differs greatly between studies. This meta-analysis showed a very large disparity between studies for most complications, which justifies the need for randomized and comparative studies to establish the role of trochleoplasty procedures in the treatment algorithm for patellar instability.

Level of evidence: IV; systematic review and meta-analysis

Keywords: Patellofemoral instability, Trochleoplasty, Complications, Patellar dislocation, Trochlear osteotomy

1. Introduction

Recurrent patellofemoral instability (RPFI) is more likely to occur in persons with abnormal morphology. Trochlear dysplasia is present in 68% to 85% of RPFI cases [1,2]. Trochleoplasty was developed specifically to manage this anatomical variation. It can be combined with other patellar stabilization procedures (reconstruction of the medial patellofemoral ligament [MPFL], tibial tubercle transfer [TTT], lateral retinaculum release, procedure on medial soft tissues). Four trochleoplasty procedures have been described to correct trochlear dysplasia: elevation trochleoplasty of the lateral trochlear condyle [3], Dejour sulcus deepening trochleoplasty [4,5], Bereiter thin-flap deepening trochleoplasty [6] and recession wedge trochleoplasty [7]. The appropriate surgical procedure depends on the exact type of dysplasia. The indications are rare although the clinical results appear satisfactory overall [8]. The complications from these procedures also vary, meaning that we cannot draw any conclusions about the best procedure or the indications. In two systematic reviews, the authors showed the benefit of combining trochleoplasty with MPFL reconstruction in patients with trochlear dysplasia [9,10]. Two other systematic reviews highlighted the complications of trochleoplasty: Van Sambeeck et al. [11] found low and comparable complication rates for the Dejour and Bereiter deepening trochleoplasties, while Hiemstra et al. [12] showed a low rate of recurrent dislocations and complications. A new systematic review and meta-analysis is justified by the recently published articles on this topic, the lack of searches of the grey literature, the lack of articles with long-term results of elevation trochleoplasty and the application of a meta-analysis to very heterogeneous data in these studies. This led us to carry out a new meta-analysis of the various trochleoplasty techniques to specify: 1) the recurrence rate of patellofemoral dislocation 2) the rates of complications (residual patellar instability [apprehension, subluxation, clinical instability]), stiffness (clinically significant or requiring a surgical intervention), patellofemoral osteoarthritis (development or progression of osteoarthritis), need for subsequent surgery and 3) the clinical outcomes (Kujala score [13], Lille knee score [14], Lysholm score [15] or the International Knee Documentation Committee [IKDC] Subjective Knee Form [16]).

2. Methods

This systematic review was done while following the criteria on the PRISMA list [17]. The research protocol was recorded prospectively in the PROSPERO registry.

2.1 Search strategy

The search strategies were designed in collaboration with the Department of Research and Researcher Support at the University of Lille (Appendix 1). Data were extracted from the MEDLINE, Embase, Web of Science, Scopus and Cochrane Library databases. The grey literature was also searched: clinical trials via Cochrane Library, the European research thesis portal (DART), the grey literature system in Europe (Opengrey.eu), the French dissertation portal (Sudoc) and pre-print portals (MedRxiv and BioRxiv). Searches were carried out between March 9 and April 2, 2020.

2.2 Selection of studies

All the articles were sorted first based on the relevance of their title and abstract by two reviewers (JTL, JD). These two reviewers read these articles in their entirety to extract the relevant ones. In case of a different opinion on whether an article should be included or not, a third reviewer (SP) was consulted to make the final decision. The included articles referred to our primary endpoint or to one of our secondary endpoints. The articles were excluded if 1) no trochleoplasty was performed, 2) no trochleoplasty complications were reported, 3) biomechanical, cadaver or animal studies, 4) expert opinion, case report or review of literature, 5) article published in a language other than French or English, 6) articles published before 1990, or 7) trochleoplasty was performed for a reason other than patellofemoral instability. When the data were published in several articles, only the data published in the most recent one was included. When two separate follow-up periods were featured in the same article, only the longest follow-up data were included. A meta-analysis was done for complications and scores reported by three or more articles.

2.3 Data extraction

The following data were extracted from the articles by one of the authors (JTL): number of patients, number of knees, age at surgery, sex, prior surgery on the knee, surgical indication, type of trochlear dysplasia, type of trochleoplasty performed, other surgical procedures done at the same time, follow-up time, number lost to follow-up, complications related to trochleoplasty (recurrence of dislocation, residual instability without dislocation, stiffness, subsequent surgical procedure on the same knee, patellofemoral osteoarthritis), functional scores (Kujala [13], Lille [14], Lysholm [15] and IKDC [16]), and the study's level of evidence. Stiffness had to require another surgical procedure (manipulation under general anesthesia, arthroscopic or open release) or be clinically significant and impactful for the patient. For patellofemoral osteoarthritis, development or progression relative to the preoperative osteoarthritis level had to be observed. The quality of the studies was not evaluated since all the studies were of low methodological quality since no randomized clinical trials nor comparative studies were included in this systematic review.

2.4 Statistical methods

The complication rates and mean values (standard deviation) of the functional scores were extracted from the studies. When the median and range were reported in the study, the mean and standard deviation of the functional scores were estimated using the method described by Hozo et al. [18]; when the interquartile range was reported instead of the range, the standard deviation was estimated with the formula IQR/1.35. A "pseudocount” of 0.25 was used to incorporate the studies reporting no complications. The heterogeneity between the studies for each endpoint was evaluated with the Cochrane Q test and quantified by the I^2 index, measuring the proportion of heterogeneity between the studies that cannot be explained by chance alone. The results of this analysis were presented as forest plots. When the heterogeneity was less than 80%, the results were pooled in a random effects model using the inverse variance-weighted average method. To combine the complication rates, a Freeman-Tukey variance stabilizing arcsine transformation was used. The meta-analysis was done using the package meta of the R software (Version 3.6.1).

3. Results

The search strategy identified 12,094 studies, of which 28 were included in this meta-analysis (Figure 1). All studies were level IV. The characteristics of the included studies are shown in Table 1 and 2. In all, 1000 trochleoplasties were performed in 890 patients. The mean age of the patients in these studies ranged between 12.5 and 32 years. The mean duration of the follow-up was between 1 and 25 years. Thirty-eight percent of patients (328/860) had another surgery on their knee before the trochleoplasty in the 23 studies reporting this information. Among the 28 included studies, 5 featured lateral elevation trochleoplasty (with 1 modified technique), 10 about the Dejour deepening trochleoplasty (with 3 modified techniques and 1 arthroscopic technique), 12 about the Bereiter deepening trochleoplasty (with 3 modified techniques) and 1 about the recession wedge trochleoplasty. Additional procedures were done in 24 studies while trochleoplasty alone was done in one study; three studies did not report this information.

Primary endpoint

Amongst all trochleoplasty techniques pooled, there were 24 recurrent dislocations in 994 operated knees (2.4%) (Figure 2). The studies by Tigchelaar et al. [25] (4/15; lateral elevation trochleoplasty), Metcalfe et al. [26] (16/199; Bereiter deepening trochleoplasty) and Weiker and Black [47] (1/6; lateral elevation trochleoplasty) had the highest rate of recurrent dislocation. The Dejour deepening trochleoplasty appears to be the most effective at preventing recurrent dislocation (Figure 2). Only 1 dislocation was observed out of 349 knees (0.28%), in contrast to the Bereiter deepening trochleoplasty for which 18 recurrences were reported (n=18/552; 3.2%). Four recurrences (n=4/63; 6.3%) were observed for the lateral elevation trochleoplasty and 1 recurrence (n=1/19; 5.2%) for the recession wedge trochleoplasty.

Secondary endpoints

Of the 20 studies evaluating residual patellar instability without dislocation after trochleoplasty, 82 knees (n=82/754) had residual instability, which confers a combined rate of 8% [95% CI: 3% to 14%] in the meta-analysis (Figure 3). However, there was considerable heterogeneity between studies with the rate ranging from 0% to 41%. There was less residual instability without dislocation after the Bereiter deepening trochleoplasty (n=30/444; 8.7%) than after the lateral elevation trochleoplasty (n=8/46; 17.3%) and the Dejour trochleoplasty (43/245; 17.5%) (Figure 4). Patellofemoral osteoarthritis was observed in 117 of 431 knees (Figure 5): 30/58 (51.7%) for lateral elevation trochleoplasty, 51/290 (17.5%) for Bereiter trochleoplasty, 33/65 (53.8%) for Dejour trochleoplasty and 3/18 (16.6%) for recession wedge trochleoplasty (Figure 5-6).

The results were very heterogeneous with rates ranging between 0% and 97% depending on the study. When the analysis was done relative to the length of follow-up, 92% (57/62; [95% CI: 80% to 100%]) of patients who had more than 10 years of follow-up presented with patellofemoral osteoarthritis, contrary to 30 of 277 patients (10.8%) who had between 5- and 10-years of follow-up and 30 of 92 patients (32.6%) who had less than 5 years of follow-up (Figure 7). As for postoperative stiffness, 22 studies investigating the presence of knee stiffness found 59 stiff knees (n=59/642) which equals a combined rate of 7% [95% CI: 3% to 12%] (Figure 8). There was considerable heterogeneity here also, with reported rates of 0% to 100%. The studies by Rouanet et al. [31] (8/34 [23.5%]; Dejour trochleoplasty), Donell et al. [43] (5/17 [29.4%]; Dejour trochleoplasty), Verdonk et al. [45] (5/13 [38.4%]; Dejour trochleoplasty), Weiker and Black [47] (3/6 [50%]; lateral elevation trochleoplasty) and Badhe and Foster [46] (4/4 [100%]; lateral elevation trochleoplasty) had the highest stiffness rates, contrary to the other studies in the systematic review. The Bereiter deepening trochleoplasty appears to cause less stiffness (n=11/250 [4.4%]) contrary to the Dejour deepening trochleoplasty (n=40/348 [11.4%]) and the lateral elevation trochleoplasty (n=7/52 [13.4%]) (Figure 9). Repeat surgery was needed in 151 of 904 knees (16.7%) (Figure 10), with rates ranging from 0% to 83% in the 24 studies. Fifty-five subsequent surgeries (n=55/493 [11.1%]) were needed for the Bereiter trochleoplasty contrary to the Dejour trochleoplasty where 73 additional surgeries were needed (n=73/354 [20.6%]) (Figure 11). Twelve patients who underwent lateral elevation trochleoplasty ((n=12/38 [31.5%]) needed an additional surgery, as did 11 patients (11/19 [57.8%]) who had a recession wedge trochleoplasty. When the analysis was done based on the length of follow-up, 31% (22/66; [95% CI: 17% to 47%]) of patients with more than 10 years' follow-up needed another surgery, versus 93 of 597 patients (15.5%) with 5 to 10 years' follow-up and 36 of 241 patients (14.9%) with less than 5 years follow-up (Figure 12). The mean postoperative outcome scores varied greatly depending on the studies: 67 to 85.8 for the IKDC, 69.3 to 95 for the Lysholm and 66.8 to 94.9 for the Kujala (Table 2) (Figures 13, 14, 15).

4. Discussion

This systematic review exposes the significant heterogeneity of the results on trochleoplasty published in the current literature. The recurrence of patellar dislocation after trochleoplasty remains rare (24/994; 2.4%), no matter which type of trochleoplasty is performed. The Dejour trochleoplasty appears to be associated with fewer dislocation recurrences. In another meta-analysis, Van Sambeeck et al. [11] found a combined recurring dislocation rate of 2% for the Dejour trochleoplasty and 4% for the Bereiter trochleoplasty. In most studies, trochleoplasty is combined with additional patellar stabilization procedures, which showed better clinical results and fewer recurrence of dislocation and patellofemoral instability [7,8]. MPFL reconstruction is effective at preventing recurrence of dislocation in patients who have less severe trochlear dysplasia (grade A or B in the Dejour classification [19]) [10]. Moitrel et al. found no recurrent dislocations in patients who underwent only MPFL reconstruction and TTT, independent of the severity of the trochlear dysplasia [48]. Zaffagnini et al. [9] showed that combined trochleoplasty and MPFL reconstruction reduced the risk of recurrent dislocation in patients who had severe trochlear dysplasia (grade C or D in Dejour classification [19]) more than isolated MPFL reconstruction, with similar clinical outcomes. Two other systematic reviews also suggested that trochleoplasty reduced the dislocation risk in patients with severe trochlear dysplasia [8,49].

The combined rate of residual patellofemoral instability without dislocation is about 8%; it was found slightly more often in cases of lateral elevation trochleoplasty. However, the studies are very heterogeneous with rates of residual patellofemoral instability without dislocation going up to 41%. Residual patellar instability after trochleoplasty was comparable to other surgical techniques for stabilizing the patella [8].

While only three studies had a minimum follow-up of 10 years, patellofemoral osteoarthritis was common after the trochleoplasty procedures (117 of 431 knees; 27%). It was most frequent after lateral elevation trochleoplasty; however, the follow-up period was the longest in studies using this technique. The evaluation of osteoarthritis was also heterogeneous in the studies, with some studies using radiographs, others using MRI; some studies did not report preoperative data; thus, it was impossible to know if the osteoarthritis progressed after surgery. We do not known whether trochleoplasty accelerates the development of patellofemoral osteoarthritis by cartilage damage or if this is the natural history of patients who have considerable trochlear dysplasia [50,51].

The combined stiffness rate was relatively low (about 7%) and appears to be more frequent after lateral elevation trochleoplasty. However, the two largest and most recent studies on lateral elevation trochleoplasty [25,27] found no instances of stiffness while all the knees evaluated in small case series (4 and 6 patients) of lateral elevation trochleoplasty [46,47] were stiff. A surgical learning curve or inadequate postoperative mobilization protocols in these small case series may explain these differences. Stiffness remains the more commonly reported complication after trochleoplasty, contrary to other patellar stabilization procedures. In a meta-analysis comparing isolated MPFL reconstruction with trochleoplasty plus MPFL reconstruction, this intervention was associated with a higher complication rate, with the most frequent complication being postoperative stiffness [10]. The aggressive nature of the bone procedures, the substantial bone remodeling in the trochlea and the resulting postoperative limitations may explain this stiffness.

The number of subsequent surgeries was considerable (151/904), especially for lateral elevation trochleoplasty (12/38) and recession wedge trochleoplasty (11/19). By doing a sub-analysis based on the length of follow-up, we found that studies with the longest follow-up [20,25,39] increased this rate, given the higher probability of needing another procedure over time. Only 12 knees that underwent trochleoplasty (7 Dejour and 5 lateral elevation) required arthroplasty in the following years; however, the duration of follow-up was short in many studies, which may have under-estimated the number of surgical revisions for knee arthroplasty. Among the other repeat surgical procedures, most were performed for residual instability without dislocation (45 of 82 knees with residual instability without dislocation) or for stiffness (19 manipulations under general anesthesia and 39 arthroscopic releases).

The mean postoperative values of the clinical scores (IKDC, Kujala and Lysholm) were also very heterogeneous between studies; some studies reported moderate functional outcomes while other studies presented very good outcomes. In all the studies, the mean postoperative scores improved. Even in the studies reporting only moderate mean postoperative scores [23,25,26,31,37,43], the scores had improved. In their meta-analysis, Zaffagnini et al. [10] suggested a significant postoperative improvement in the Kujala score of 28.1 points for trochleoplasty combined with MPFL reconstruction. In patients who have patellar instability due to patella alta, Otsuki et al. [52] found better postoperative clinical scores (Lysholm and Kujala) in patients who had undergone trochleoplasty. We did not perform a meta-analysis on the difference between preoperative and postoperative scores because the statistical estimate would have been too inaccurate given the differences in how the results are presented (mean or median) and the vast differences in the results in the various studies.

Our study has several limitations: 1) While the most recent meta-analysis [11] reported combined rates for all the complications, the wide disparity between studies made calculating combined rates in our meta-analysis uninterpretable and unrepresentative. Thus, we did not calculate combined rates for recurrent dislocation, patellofemoral osteoarthritis, additional surgery and clinical scores. 2) Our review included only observational, non-randomized, non-comparative studies since most studies were retrospective with level IV evidence. However, trochleoplasty procedures are rare and there are no large or comparative studies in the literature. 3) No analysis of bias and study quality was done given the low level of evidence of the included studies and the lack of a quality measurement scale for observational, non-comparative studies. 4) The duration of follow-up, surgical techniques used, methods to collect complications, and trochleoplasty indications vary between studies; when possible, we performed subgroup analysis and a meta-analysis. 5) Several technical variations were used, but we chose to group these modified techniques with the original techniques to provide a summary. 6) Trochleoplasty is often combined with other surgical procedures to stabilize the patella, making it difficult to establish whether trochleoplasty explains the results found.

5. Conclusion

This is the most recent and highest evidence level review of trochleoplasty, although the included studies have a low level of proof. While trochleoplasty is often combined with other surgical procedures, low rates of dislocation recurrence and residual instability without dislocation were observed, no matter which technique was used. Stiffness, the need for another procedure and patellofemoral osteoarthritis remain the most frequent complications. This review of literature exposes the need for high-quality, comparative cohort studies to determine the indications for trochleoplasty and the type of procedure to recommend.

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Conflicts of interest: Related to this work, Henri Migaud declares being the Editor-in-Chief of Othopaedics & Traumatology: Surgery & Research. The other authors have no conflict of interest to disclose relative to this work. Outside this work, Henri Migaud is a research and educational consultant for Zimmer-Biomet, Corin, MSD and SERF. Sophie Putman is a consultant for Corin. Gilles Pasquier is a consultant for Zimmer-Biomet. The other authors have no conflict of interest to declare outside this study.

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Appendix 1: Database queries

<ins>MEDLINE query:</ins> ((Patellar Dislocation[mh]) OR ((Patella*[tiab] OR Patello*[tiab]) AND (dislocation[tiab] OR displacement[tiab] OR luxation[tiab] OR instability[tiab] OR reconstruction[tiab]) AND (trochleo*[tiab] OR trochlea*[tiab] OR sulcus[tiab] OR patellar groove[tiab] OR surgery[tiab] OR osteotomy[tiab])) OR ((Patella*[OT] OR Patello*[OT]) AND (dislocation[OT] OR displacement[OT] OR luxation[OT] OR instability[OT] OR reconstruction[OT]) AND (trochleo*[OT] OR trochlea*[OT] OR sulcus[OT] OR patellar groove[OT] OR surgery[OT] OR osteotomy[OT])))

<ins>Web of Sciences query:</ins> ((TI=("patellar dislocation") OR AB=(patellar dislocation) OR AK=(patellar dislocation)) OR (TI=(patello* OR patella*) OR AB=(patello* OR patella*) OR AK=(patello* OR patella*)) AND (TI=(dislocation OR displacement OR luxation OR instability OR reconstruction) OR AB=(dislocation OR displacement OR luxation OR instability OR reconstruction) OR AK=(dislocation OR displacement OR luxation OR instability OR reconstruction)) AND (TI=(trochle* OR sulcus OR patellar groove OR surgery OR osteotomy) OR AB=(trochle* OR sulcus OR patellar groove OR surgery OR osteotomy) OR AK=(trochle* OR sulcus OR patellar groove OR surgery OR osteotomy)))

<ins>Embase query:</ins> ('patella dislocation'/exp/dm_su OR trochleoplast*) AND ('trochlear dysplasia'/exp OR 'patella dislocation'/exp OR 'patella instability'/exp) AND [1990-2020]/py AND ([english]/lim OR [french]/lim)

Scopus query: INDEXTERMS ({Patellar Dislocation}) OR TITLE-ABS ("Patell*" AND ({dislocation} OR {displacement} OR {luxation} OR {instability} OR {reconstruction}) AND ("trochle*" OR {sulcus} OR {patellar groove} OR {surgery} OR {osteotomy})) OR AUTHKEY ("Patell*" AND ({dislocation} OR {displacement} OR {luxation} OR {instability} OR {reconstruction}) AND ("trochle*" OR {sulcus} OR {patellar groove} OR {surgery} OR {osteotomy}))

Cochrane query: (([mh "Patellar Dislocation"]) OR ((Patella*:ti,ab,kw OR Patello*:ti,ab,kw) AND (dislocation:ti,ab,kw OR displacement:ti,ab,kw OR luxation:ti,ab,kw OR instability:ti,ab,kw OR reconstruction:ti,ab,kw) AND (trochleo*:ti,ab,kw OR trochlea*:ti,ab,kw OR sulcus:ti,ab,kw OR "patellar groove":ti,ab,kw OR surgery:ti,ab,kw OR osteotomy:ti,ab,kw

Table 1: Characteristics of the studies included in this systematic review. Depending on the available data, the values are expressed as mean ± SD (Min-Mx) or *median ± SD (Q1-Q3)

Authors	Level of evidence	Number of patients	Number of knees	Women %	Mean age at surgery (Min-max)	Follow-up (years) (Min-max)	Type of trochlear dysplasia in Dejour classification [19] (number of knees)	Number of patients with prior surgery	Type of trochleoplasty	TTT	MPFL reconstruction	Medial soft tissue procedure	Other associated surgical procedures
Bauduin et al. [20]	4	13	17	62	24 (16-57)	25 (16-31)	A(3) B(13) C(1)		Lateral elevation	10	0	4	9 sartorius plasty
Carstensen et al. [21]	4	62	62	73	20.5	2.7 (0.5-6.8)	B(50) D(12)	31	Dejour				
Nelitz et al. [22]	4	18	18	67		2.3 (2-3)	B(6) C(4) D(8)		Bereiter	0	18	0	
Wind et al. [23]	4	21	22	73	*21.5 (13.8-39.8)	5			Bereiter	22	22	0	17 lateral retinaculum transections
Von Engelhardt et al. [24]	4	30	33	64	24	2.4			Modified Dejour	0	33	0	
Tigchelaar et al. [25]	4	12	15		25 (15-34)	13.6		5	Modified lateral elevation				1 Roux-Goldthwait, 1 varus-inducing osteotomy
Metcalfe et al. [26]	4	173	199		21.3 (14-38)	4.4 (1-12)		65	Bereiter	19	1	0	3 lateral retinaculum transections, 1 derotation osteotomy
Pesenti et al. [27]	4	23	27	52	12.5 (8-17)	5	B(27)	1	Lateral elevation	3	0	7	17 Roux-Goldthwait
Camathias et al. [28]	4	44	50	68	15.6 (13-20.4)	2.8	B(27) C(17) D(6)		Modified Bereiter	0	0	0	
Bering et al.	4	39	42	83	20.6	4.1	B(15) C(21)	13	Bereiter	0	0	42	

[29]					(13-41)	(1-9.1)	D(6)						
McNamara et al. [30]	4	90	107	60	23 (12-49)	6 (2-19)	B(49) C(3) D(54)	43	Modified Dejour	11	14	0	28 lateral retinaculum transections, 16 patellar microfractures 10 medial ossicle excisions
Rouanet et al. [31]	4	34	34	71	27.8 (16-49)	15.3 (12-19)		13	Dejour	17	0	34	
Neumann et al. [32]	4	42	46	72	*27.6 (16-53)	4.7 (2-9.1)	A(4) B(7) C(10) D(23)	6	Modified Bereiter	0	46	46	
Banke et al. [33]	4	17	18	65	22.2	2.5		7	Bereiter	0	18	0	
Ntagiopoulos et al. [34]	4	27	31	48	21 (14-47)	7 (2-9)	B(12) D(19)	0	Dejour	21	5	26	21 lateral retinaculum transections
Nelitz et al. [35]	4	23	26	39	19.2 (15.4-23.6)	2.5 (2-3.5)		13	Bereiter	0	26	4	6 lateral retinaculum transections, 2 Roux-Goldthwait, 2 patella microfractures
Blønd et al. [36]	4	24	29	68	*19 (12-39)	2.4 (1-4.8)	B(10) C(11) D(16)	16	Arthroscopic Bereiter	0	29	0	
Dejour et al. [37]	4	22	24	57	23 (14-33)	5.5 (2-15.9)	B(7) D(17)	24	Dejour	12	14	10	6 lateral retinacular transections, 1 patellar osteotomy, 4 patellar tendon lengthening
Faruqui et al. [38]	4	6	6	83	21.5 (15-38)	5.7		6	Dejour	3	3	2	
Thaunat et al. [39]	4	17	19	56	23 (18-45)	2.8 (1-5.9)	A(1) B(7) C(5) D(6)	7	Beaufils	18	8	0	19 lateral retinaculum transections
Fucentese et al. [40]	4	38	44	74	18 (14-40)	4 (2-7.8)	A(9) B(15) C(9) D(11)	13	Bereiter	0	0	44	
Zaki et al.		25	27	72	25 (19-36)	4.5 (1-6)		20	Modified	5	0	2	22 Roux-

[41]									Dejour				Goldthwait
Von Knoch et al. [42]	4	38	45	58	22.2 (15-31)	8.3 (4-14)		15	Bereiter	0	0	45	
Donell et al. [43]	4	15	17	80	25 (15-47)	3 (1-9)		9	Dejour	8	0	16	17 lateral retinaculum transections, 1 Roux-Goldthwait
Schöttle et al. [44]	4	16	19	81	22 (17-40)	3 (2-4)		5	Bereiter	0	0	19	19 lateral retinaculum transections
Verdonk et al. [45]	4	12	13	75	27 (14-39)	1.5 (0.7-2.8)		10	Dejour				
Badhe and Foster [46]	4	4	4	75	32 (24-38)	1 (1-3.5)		0	Lateral elevation	4	0	4	4 lateral retinaculum transections, 4 patellar osteotomies
Weiker and Black [47]	4	5	6		22.5 (16-39)	7.7 (5.4-10.3)		6	Lateral elevation				

TTT: tibial tubercle transfer
MPFL: Medial patellofemoral ligament
*Median (Q1;Q3)

Table 2: Complications and functional outcomes from the studies included in the systematic review. Depending on the available data, the values are expressed as mean ± SD (Min-Mx) or *median ± SD (Q1-Q3)

Authors	Recurrent dislocation / No. knees	Residual instability / No. knees	Patello-femoral OA / No. knees	Stiffness / No. knees	Subsequent surgery / No. knees	Types of surgery	Kujala score [13] mean preop (Min-max)	Kujala score [13] mean postop (Min-max)	Lysholm score [15] mean preop (Min-max)	Lysholm score [15] mean postop (Min-max)	IKDC score [16] mean preop (Min-max)	IKDC score [16] mean postop (Min-max)
Bauduin et al. [20]	0/17		12/13		4/17	2 PFA, 2 TKA						
Carstensen et al. [21]	0/62			11/62	11/62	2 manipulations, 9 arthrolysis						
Nelitz et al. [22]	0/18	1/18		1/18	1/18	1 arthrolysis	67 (54-75)	89.5 (78-96)				
Wind et al. [23]	0/22	3/22		3/22	6/22	3 manipulations, 2 arthrolysis, 1 MPFL revision	44 (30-85)	71 (32-93)			43±13	64±16
Von Engelhardt et al. [24]	0/33	0/33		3/33	2/33	2 arthrolysis	64 ±16	94±9	63±17	95±6	58±11	85±12
Tigchelaar et al. [25]	4/15	6/15	12/15	0/15	3/15	1 MPFL, 2 TTT		78 (40-100)	54 (27-78)	71 (35-100)		
Metcalfe et al. [26]	16/199	12/199	7/132		27/199	9 MPFL, 7 TTT, 2 manipulations, 2 implant removals, 2 arthrolysis, 5 arthroscopies	*51.5 ± 26.5	*82.5 ± 30.5			*44,3±25,3	*71,3±39,1
Pesenti et al. [27]	0/27	2/27	4/27	0/27								
Camathias et al. [28]	1/50			4/50	5/50	4 arthrolysis, 1 MPFL + trochleoplasty revision	71 ±1.1 (69 – 74.5)	92 ±0.8 (90.2 – 93.6)	71 ±1.6 (68.1 – 74.5)	95 ±0.7 (94.1 – 96.8)		
Bering et al. [29]	0/42	1/42		0/42	2/42	1 TTT, 1 arthroscopy				81.3 (39-100)		
McNamara et al. [30]	0/107	26/107		8/107	21/107	10 MPFL, 8 arthrolysis, 2 implant removals, 1 arthroscopy	*63 (IQR 47-75)	*84 (73-92)				
Rouanet et al. [31]	0/34	11/27	33/34	8/34	15/34	3 PFA, 3 TKA, 1 TTT, 6 manipulations, 2 arthrolysis	55 (13-75)	76 (51-94)				
Neumann et al. [32]	0/46		3/46				*62 (9-96)	*88 (47-100)				
Banke et al.	0/18		0/18	2/18	3/18	2 arthrolysis, 1 MPFL	51.1	87.9			49,5	80,2

[33]						revision	± 22.9 (7 – 86)	± 12.9 (59 – 103)			$\pm 20{,}7$ (11,5 – 81,6)	$\pm 13{,}7$ (49,4 – 98,9)
Ntagiopoulos et al. [34]	0/31	0/31	0/31	0/31	2/31	2 implant removals	59 (28-81)	87 (49-100)			51,2 $\pm 22{,}9$ (25 – 80)	82,5 $\pm 17{,}9$ (40 – 100)
Nelitz et al. [35]	0/26	0/26		1/26	0/26		79 (21-100)	96 (74-100)			74 (32-95)	90 (65-98)
Blønd et al. [36]	0/29	2/29		0/29	5/29	3 lateral retinaculum transections, 2 TTT	*64 (12-90)	*95 (47-100)				
Dejour et al. [37]	0/24	0/24		0/24	1/24	1 implant removal	44.8 ± 15 (25 – 73)	81.7 ± 13.9 (61 – 100)			51,4 $\pm 21{,}8$ (23 – 75)	76,7± 13 (53 – 100)
Faruqui et al. [38]	0/6	0/6			0/6							
Thaunat et al. [39]	1/19	1/19	3/18	1/19	11/19	1 arthrolysis, 8 implant removals, 1 TTT revision, 1 bony protuberance excision		80$\pm$17				67$\pm$17
Fucentese et al. [40]	1/44	6/44	16/44		5/44	1 MPFL, 1 TTT, 3 arthroscopies	68 (29-84)	90 (42-100)				
Zaki et al. [41]	0/27			0/27	0/27				54 (32-61)	70 % > 83 and 30 % between 65-83		
Von Knoch et al. [42]	0/45	1/45	24/31	0/45	1/45	1 Emslie-Trillat		94.9 (80-100)				
Donell et al. [43]		6/17		5/17	12/17	5 implant removals, 5 arthrolysis, 1 medial reconstruction, 1 patellar chondroplasty	48 (13-75)	75 (51-98)				
Schöttle et al. [44]	0/19	4/19	1/19				56 (27-67)	80 (43-99)				
Verdonk et al. [45]	0/13			5/13	9/13	1 TKA, 5 manipulations, 3 metal implant removal						
Badhe et Foster [46]	0/4	0/4		4/4								
Weiker et Black [47]	1/6		2/3	3/6	5/6	1 manipulation, 1 arthrolysis, 1 patellectomy, 1 TKA, 1 medial reconstruction			53 (29-65)			

IKDC: International Knee Documentation Committee, PFA: Patellofemoral arthroplasty, TKA: Total knee arthroplasty
MPFL: Medial patellofemoral ligament, TTT Tibial tubercle transfer, *median (Q1-Q3)

Figure legends

Figure 1: Flow chart summarizing the inclusion of studies

Figure 2: Recurrence of patellar dislocation – Forest plot. 24 recurrent dislocations out of 994 (2.4%) knees operated

Figure 3: Recurrence of patellofemoral instability without dislocation – Forest plot. 82 of 754 knees has residual instability

Figure 4: Recurrence of patellofemoral instability without dislocation by type of trochleoplasty – Forest plot. The Bereiter deepening trochleoplasty had the least residual instability without dislocation

Figure 5: Patellofemoral osteoarthritis – Forest plot. Patellofemoral osteoarthritis was found in 117 of 431 knees

Figure 6: Patellofemoral osteoarthritis by type of trochleoplasty – Forest plot. Lateral elevation trochleoplasty was associated with the highest incidence of patellofemoral osteoarthritis

Figure 7: Patellofemoral osteoarthritis by duration of follow-up – Forest plot. 92% of patients with more than 10 years' follow-up had patellofemoral osteoarthritis

Figure 8: Postoperative stiffness – Forest plot. Stiffness was identified in 59 of 642 knees

Figure 9: Stiffness by type of trochleoplasty – Forest plot. The Bereiter techniques was associated with less stiffness

Figure 10: Number of subsequent surgeries – Forest plot. Additional surgery was done on 151 of 904 knees

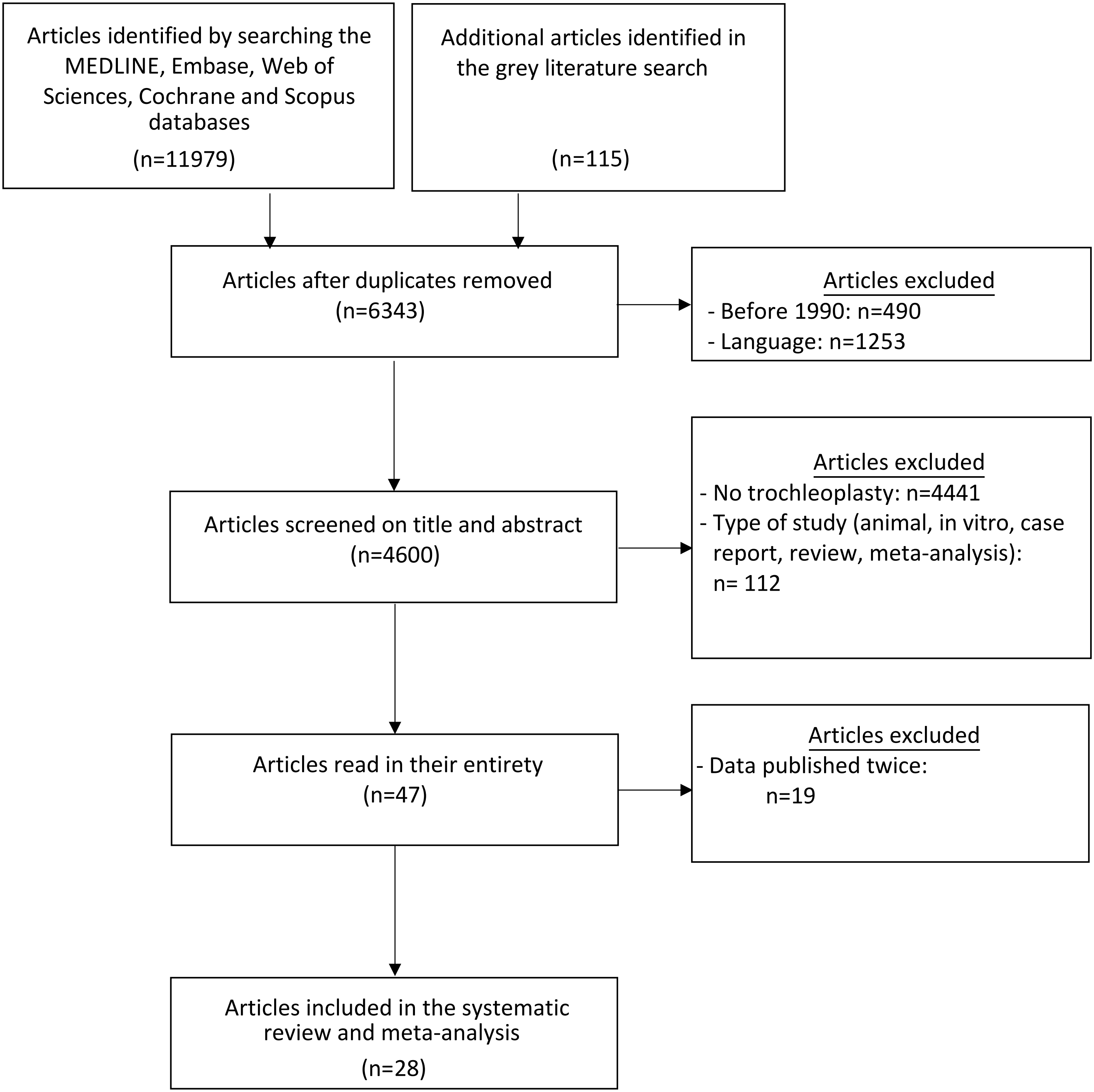
Figure 11: Number of subsequent surgeries by type of trochleoplasty – Forest plot. The Bereiter trochleoplasty was associated with fewer additional surgeries

Figure 12: Number of subsequent studies by duration of follow-up – Forest plot. 31% of patients with more than 10 years' follow-up required another surgery

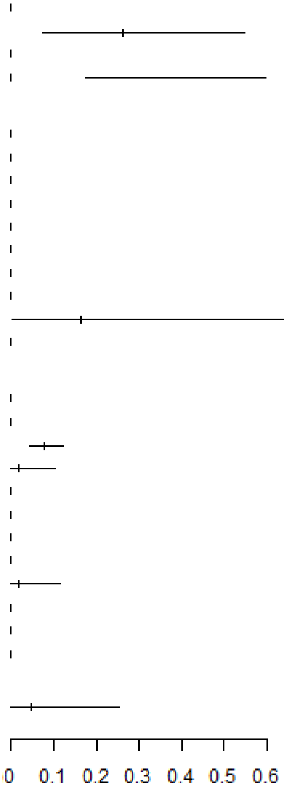
Figure 13: Mean postoperative value of the IKDC score [16] – Forest plot

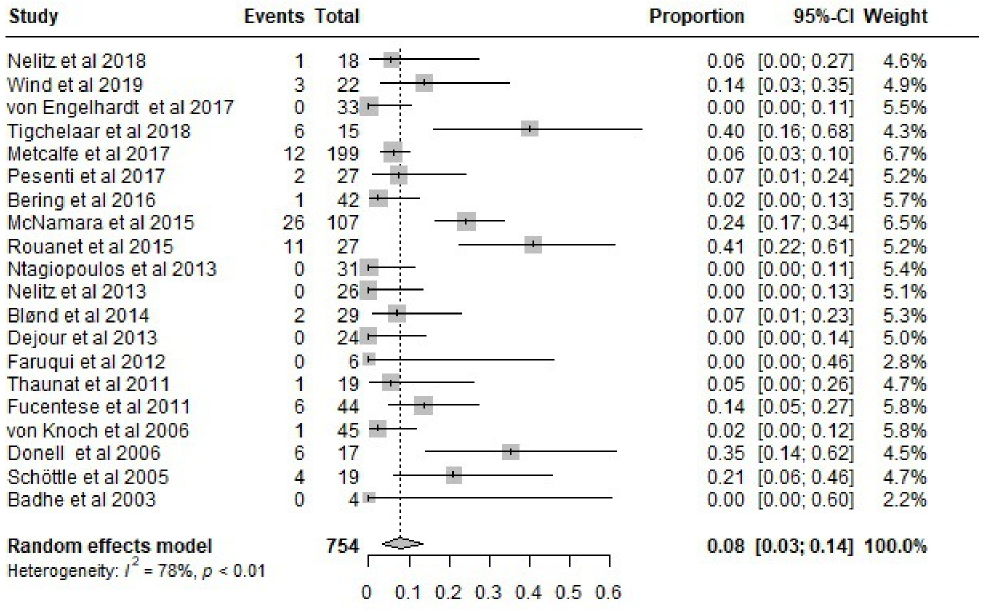
Figure 14: Mean postoperative value of the Lysholm score [15] – Forest plot

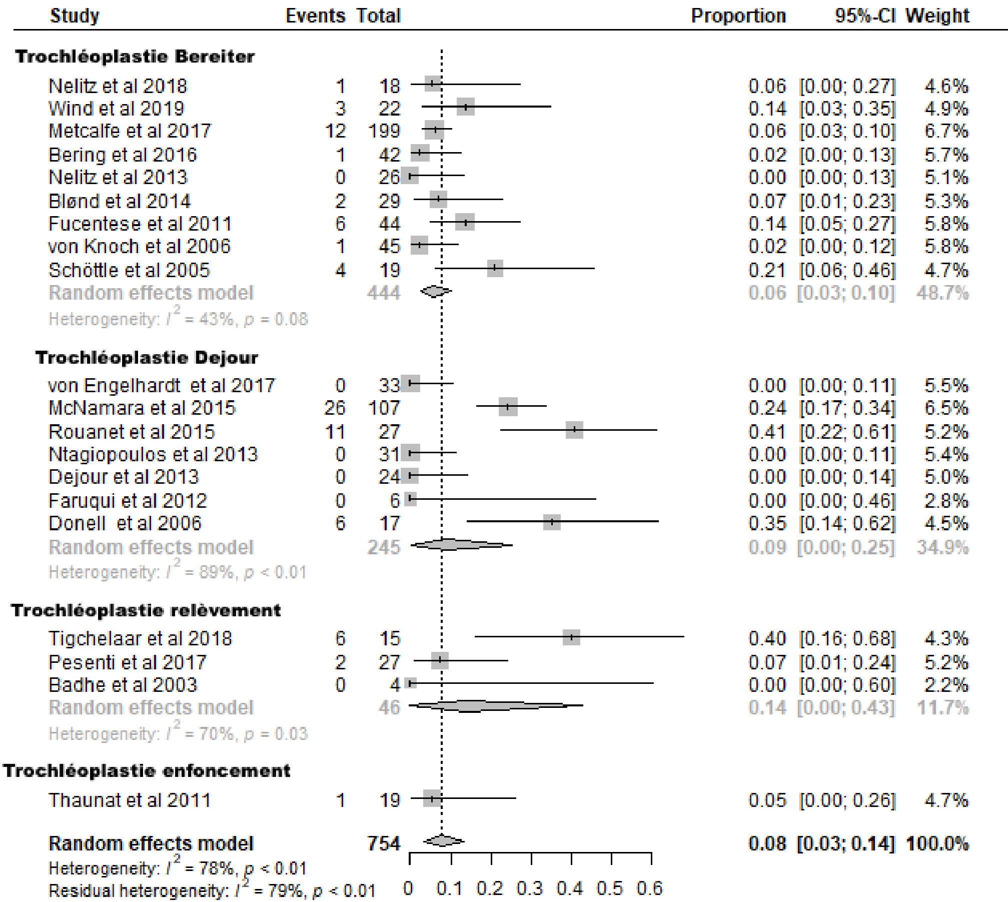
Figure 15: Mean postoperative value of the Kujala score [13] by type of trochleoplasty – Forest plot


Articles identified by searching the MEDLINE, Embase, Web of Sciences, Cochrane and Scopus databases
(n=11979)
Additional articles identified in the grey literature search
(n=115)
Articles after duplicates removed
(n=6343)
Articles excluded
- Before 1990: n=490
- Language: n=1253
Articles screened on title and abstract
(n=4600)
Articles excluded
- No trochleoplasty: n=4441
- Type of study (animal, in vitro, case report, review, meta-analysis): n= 112
Articles read in their entirety
(n=47)
Articles excluded
- Data published twice:
n=19
Articles included in the systematic review and meta-analysis
(n=28)

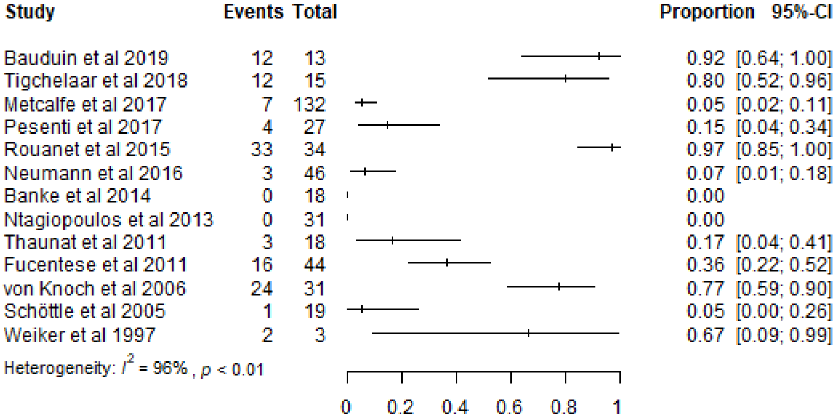
Study	Events	Total	Proportion	95%-CI
Lateral elevation trochleoplasty				
Bauduin et al 2019	0	17	0.00	
Tigchelaar et al 2018	4	15	0.27	[0.08; 0.55]
Pesenti et al 2017	0	27	0.00	
Badhe et al 2003	0	4	0.00	
Dejour deepening trochleoplasty				
Carstensen et al 2019	0	62	0.00	
von Engelhardt et al 2017	0	33	0.00	
McNamara et al 2015	0	107	0.00	
Rouanet et al 2015	0	34	0.00	
Ntagiopoulos et al 2013	0	31	0.00	
Dejour et al 2013	0	24	0.00	
Faruqui et al 2012	0	6	0.00	
Schöttle et al 2005	0	19	0.00	
Weiker et al 1997	1	6	0.17	[0.00; 0.64]
Zaki et al 2010	0	27	0.00	
Bereiter deepening trochleoplasty				
Nelitz et al 2018	0	18	0.00	
Wind et al 2019	0	22	0.00	
Metcalfe et al 2017	16	199	0.08	[0.05; 0.13]
Camathias et al 2016	1	50	0.02	[0.00; 0.11]
Neumann et al 2016	0	46	0.00	
Banke et al 2014	0	18	0.00	
Nelitz et al 2013	0	26	0.00	
Blønd et al 2014	0	29	0.00	
Fucentese et al 2011	1	44	0.02	[0.00; 0.12]
von Knoch et al 2006	0	45	0.00	
Verdonk et al 2005	0	13	0.00	
Bering et al 2016	0	42	0.00	
Recession wedge trochleoplasty				
Thaunat et al 2011	1	19	0.05	[0.00; 0.26]

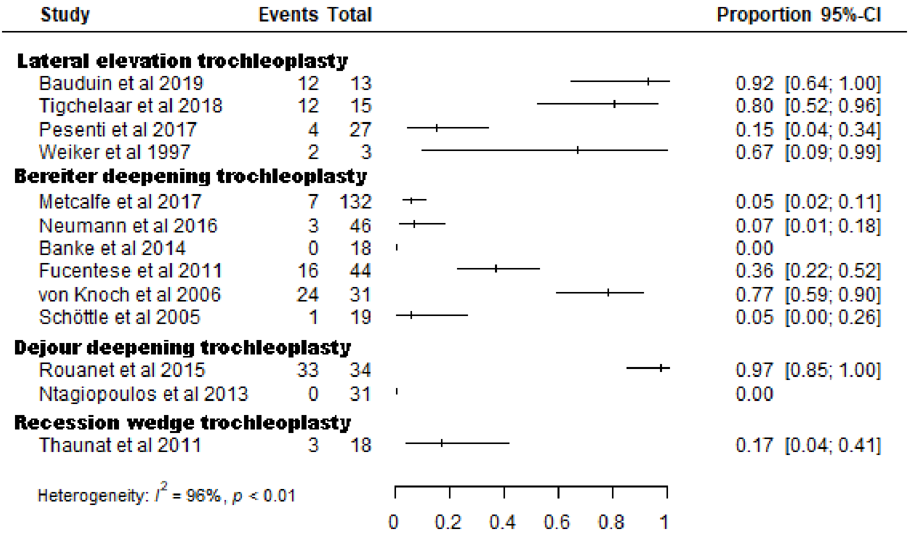



Study Events Total Proportion 95%-CI Weight
Nelitz et al 2018 1 18 0.06 [0.00; 0.27] 4.6%
Wind et al 2019 3 22 0.14 [0.03; 0.35] 4.9%
von Engelhardt et al 2017 0 33 0.00 [0.00; 0.11] 5.5%
Tigchelaar et al 2018 6 15 0.40 [0.16; 0.68] 4.3%
Metcalfe et al 2017 12 199 0.06 [0.03; 0.10] 6.7%
Pesenti et al 2017 2 27 0.07 [0.01; 0.24] 5.2%
Bering et al 2016 1 42 0.02 [0.00; 0.13] 5.7%
McNamara et al 2015 26 107 0.24 [0.17; 0.34] 6.5%
Rouanet et al 2015 11 27 0.41 [0.22; 0.61] 5.2%
Ntagiopoulos et al 2013 0 31 0.00 [0.00; 0.11] 5.4%
Nelitz et al 2013 0 26 0.00 [0.00; 0.13] 5.1%
Blønd et al 2014 2 29 0.07 [0.01; 0.23] 5.3%
Dejour et al 2013 0 24 0.00 [0.00; 0.14] 5.0%
Faruqui et al 2012 0 6 0.00 [0.00; 0.46] 2.8%
Thaunat et al 2011 1 19 0.05 [0.00; 0.26] 4.7%
Fucentese et al 2011 6 44 0.14 [0.05; 0.27] 5.8%
von Knoch et al 2006 1 45 0.02 [0.00; 0.12] 5.8%
Donell et al 2006 6 17 0.35 [0.14; 0.62] 4.5%
Schöttle et al 2005 4 19 0.21 [0.06; 0.46] 4.7%
Badhe et al 2003 0 4 0.00 [0.00; 0.60] 2.2%
Random effects model 754 0.08 [0.03; 0.14] 100.0%
Heterogeneity: I^2 = 78%, p < 0.01
0 0.1 0.2 0.3 0.4 0.5 0.6



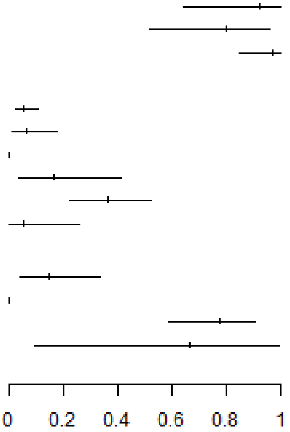
Study
Events
Total
Proportion
95%-CI
Weight
Trochléoplastie Bereiter
Nelitz et al 2018 1 18 0.06 [0.00; 0.27] 4.6%
Wind et al 2019 3 22 0.14 [0.03; 0.35] 4.9%
Metcalfe et al 2017 12 199 0.06 [0.03; 0.10] 6.7%
Bering et al 2016 1 42 0.02 [0.00; 0.13] 5.7%
Nelitz et al 2013 0 26 0.00 [0.00; 0.13] 5.1%
Blønd et al 2014 2 29 0.07 [0.01; 0.23] 5.3%
Fucentese et al 2011 6 44 0.14 [0.05; 0.27] 5.8%
von Knoch et al 2006 1 45 0.02 [0.00; 0.12] 5.8%
Schöttle et al 2005 4 19 0.21 [0.06; 0.46] 4.7%
Random effects model 444 0.06 [0.03; 0.10] 48.7%
Heterogeneity: I^2 = 43%, p = 0.08
Trochléoplastie Dejour
von Engelhardt et al 2017 0 33 0.00 [0.00; 0.11] 5.5%
McNamara et al 2015 26 107 0.24 [0.17; 0.34] 6.5%
Rouanet et al 2015 11 27 0.41 [0.22; 0.61] 5.2%
Ntagiopoulos et al 2013 0 31 0.00 [0.00; 0.11] 5.4%
Dejour et al 2013 0 24 0.00 [0.00; 0.14] 5.0%
Faruqui et al 2012 0 6 0.00 [0.00; 0.46] 2.8%
Donell et al 2006 6 17 0.35 [0.14; 0.62] 4.5%
Random effects model 245 0.09 [0.00; 0.25] 34.9%
Heterogeneity: I^2 = 89%, p < 0.01
Trochléoplastie relèvement
Tigchelaar et al 2018 6 15 0.40 [0.16; 0.68] 4.3%
Pesenti et al 2017 2 27 0.07 [0.01; 0.24] 5.2%
Badhe et al 2003 0 4 0.00 [0.00; 0.60] 2.2%
Random effects model 46 0.14 [0.00; 0.43] 11.7%
Heterogeneity: I^2 = 70%, p = 0.03
Trochléoplastie enfoncement
Thaunat et al 2011 1 19 0.05 [0.00; 0.26] 4.7%
Random effects model 754 0.08 [0.03; 0.14] 100.0%
Heterogeneity: I^2 = 78%, p < 0.01
Residual heterogeneity: I^2 = 79%, p < 0.01
0 0.1 0.2 0.3 0.4 0.5 0.6

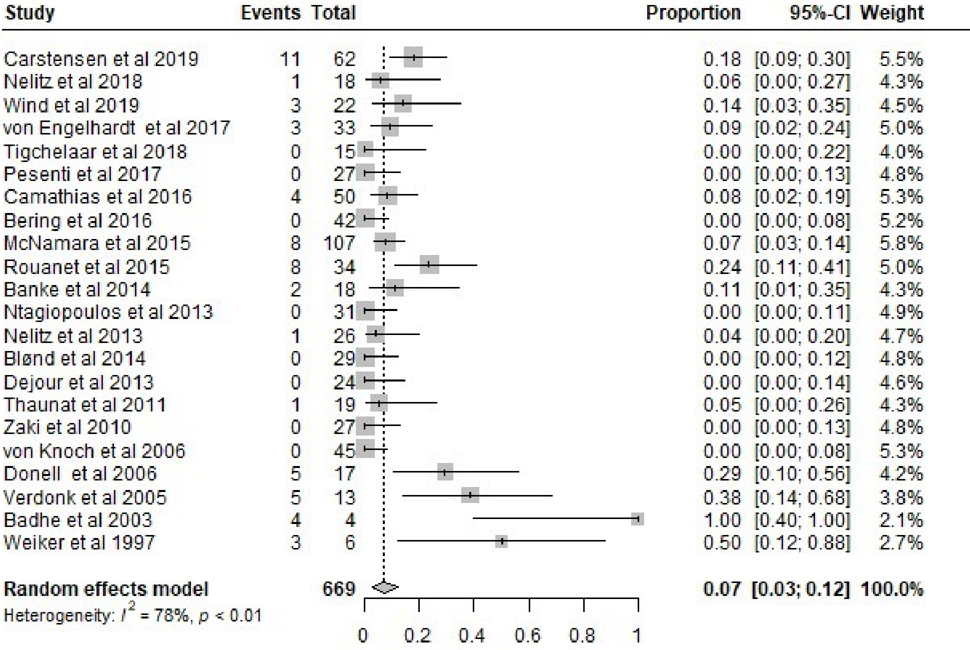

Study Events Total Proportion 95%-CI
Bauduin et al 2019 12 13 0.92 [0.64; 1.00]
Tigchelaar et al 2018 12 15 0.80 [0.52; 0.96]
Metcalfe et al 2017 7 132 0.05 [0.02; 0.11]
Pesenti et al 2017 4 27 0.15 [0.04; 0.34]
Rouanet et al 2015 33 34 0.97 [0.85; 1.00]
Neumann et al 2016 3 46 0.07 [0.01; 0.18]
Banke et al 2014 0 18 0.00
Ntagiopoulos et al 2013 0 31 0.00
Thaunat et al 2011 3 18 0.17 [0.04; 0.41]
Fucentese et al 2011 16 44 0.36 [0.22; 0.52]
von Knoch et al 2006 24 31 0.77 [0.59; 0.90]
Schöttle et al 2005 1 19 0.05 [0.00; 0.26]
Weiker et al 1997 2 3 0.67 [0.09; 0.99]
Heterogeneity: I^2 = 96% , p < 0.01
0 0.2 0.4 0.6 0.8 1



Study
Events Total
Proportion 95%-CI
Lateral elevation trochleoplasty
Bauduin et al 2019 12 13 0.92 [0.64; 1.00]
Tigchelaar et al 2018 12 15 0.80 [0.52; 0.96]
Pesenti et al 2017 4 27 0.15 [0.04; 0.34]
Weiker et al 1997 2 3 0.67 [0.09; 0.99]
Bereiter deepening trochleoplasty
Metcalfe et al 2017 7 132 0.05 [0.02; 0.11]
Neumann et al 2016 3 46 0.07 [0.01; 0.18]
Banke et al 2014 0 18 0.00
Fucentese et al 2011 16 44 0.36 [0.22; 0.52]
von Knoch et al 2006 24 31 0.77 [0.59; 0.90]
Schöttle et al 2005 1 19 0.05 [0.00; 0.26]
Dejour deepening trochleoplasty
Rouanet et al 2015 33 34 0.97 [0.85; 1.00]
Ntagiopoulos et al 2013 0 31 0.00
Recession wedge trochleoplasty
Thaunat et al 2011 3 18 0.17 [0.04; 0.41]
Heterogeneity: I^2 = 96%, p < 0.01
0 0.2 0.4 0.6 0.8 1

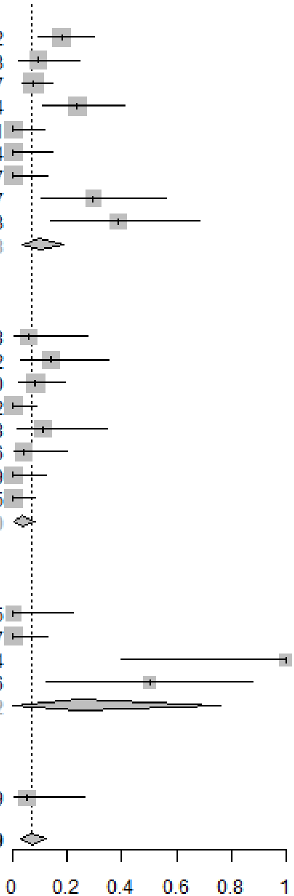
Study	Events	Total	Proportion	95%-CI
Follow-up > 10 years				
Bauduin et al 2019	12	13	0.92	[0.64; 1.00]
Tigchelaar et al 2018	12	15	0.80	[0.52; 0.96]
Rouanet et al 2015	33	34	0.97	[0.85; 1.00]
Follow-up < 5 years				
Metcalfe et al 2017	7	132	0.05	[0.02; 0.11]
Neumann et al 2016	3	46	0.07	[0.01; 0.18]
Banke et al 2014	0	18	0.00	
Thaunat et al 2011	3	18	0.17	[0.04; 0.41]
Fucentese et al 2011	16	44	0.36	[0.22; 0.52]
Schöttle et al 2005	1	19	0.05	[0.00; 0.26]
Follow-up 5 to 10 years				
Pesenti et al 2017	4	27	0.15	[0.04; 0.34]
Ntagiopoulos et al 2013	0	31	0.00	
von Knoch et al 2006	24	31	0.77	[0.59; 0.90]
Weiker et al 1997	2	3	0.67	[0.09; 0.99]



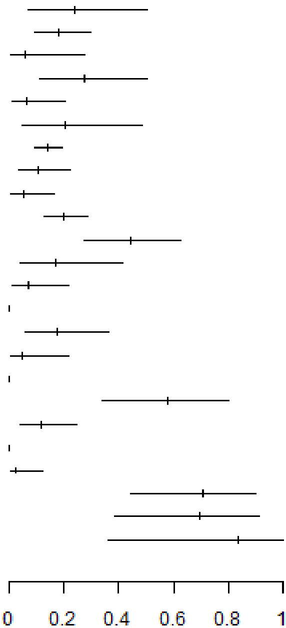


Study
Events
Total
Proportion
95%-CI
Weight
Carstensen et al 2019 11 62 0.18 [0.09; 0.30] 5.5%
Nelitz et al 2018 1 18 0.06 [0.00; 0.27] 4.3%
Wind et al 2019 3 22 0.14 [0.03; 0.35] 4.5%
von Engelhardt et al 2017 3 33 0.09 [0.02; 0.24] 5.0%
Tigchelaar et al 2018 0 15 0.00 [0.00; 0.22] 4.0%
Pesenti et al 2017 0 27 0.00 [0.00; 0.13] 4.8%
Camathias et al 2016 4 50 0.08 [0.02; 0.19] 5.3%
Bering et al 2016 0 42 0.00 [0.00; 0.08] 5.2%
McNamara et al 2015 8 107 0.07 [0.03; 0.14] 5.8%
Rouanet et al 2015 8 34 0.24 [0.11; 0.41] 5.0%
Banke et al 2014 2 18 0.11 [0.01; 0.35] 4.3%
Ntagiopoulos et al 2013 0 31 0.00 [0.00; 0.11] 4.9%
Nelitz et al 2013 1 26 0.04 [0.00; 0.20] 4.7%
Blønd et al 2014 0 29 0.00 [0.00; 0.12] 4.8%
Dejour et al 2013 0 24 0.00 [0.00; 0.14] 4.6%
Thaunat et al 2011 1 19 0.05 [0.00; 0.26] 4.3%
Zaki et al 2010 0 27 0.00 [0.00; 0.13] 4.8%
von Knoch et al 2006 0 45 0.00 [0.00; 0.08] 5.3%
Donell et al 2006 5 17 0.29 [0.10; 0.56] 4.2%
Verdonk et al 2005 5 13 0.38 [0.14; 0.68] 3.8%
Badhe et al 2003 4 4 1.00 [0.40; 1.00] 2.1%
Weiker et al 1997 3 6 0.50 [0.12; 0.88] 2.7%
Random effects model 669 0.07 [0.03; 0.12] 100.0%
Heterogeneity: I^2 = 78%, p < 0.01
0
0.2
0.4
0.6
0.8
1

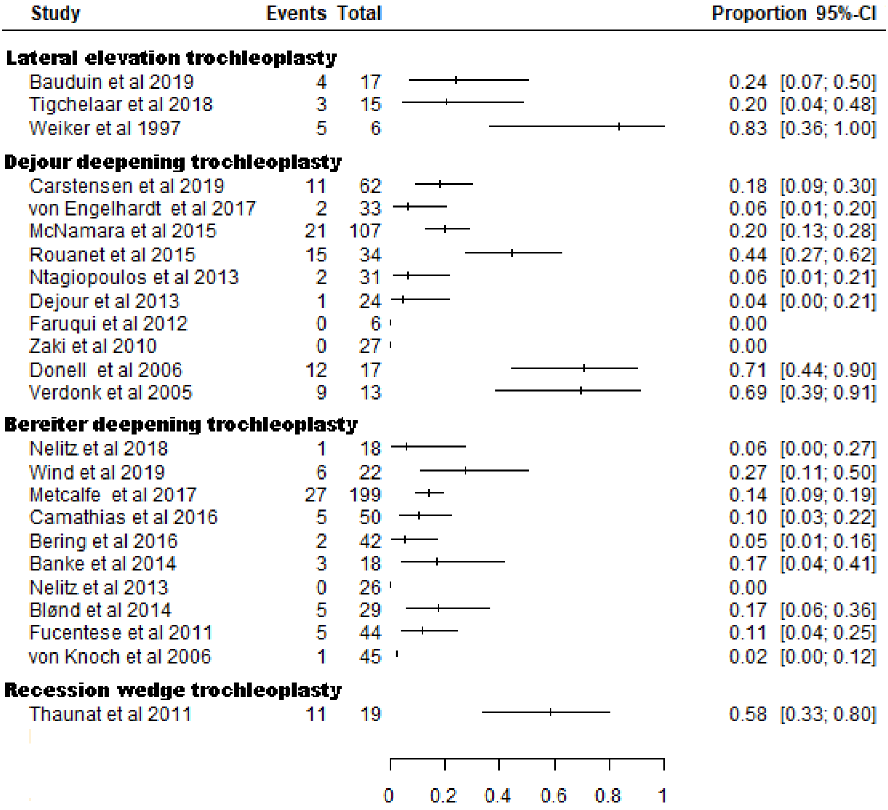
Study	Events	Total	Proportion	95%-CI	Weight
Dejour deepening trochleoplasty					
Carstensen et al 2019	11	62	0.18	[0.09; 0.30]	5.5%
von Engelhardt et al 2017	3	33	0.09	[0.02; 0.24]	5.0%
McNamara et al 2015	8	107	0.07	[0.03; 0.14]	5.8%
Rouanet et al 2015	8	34	0.24	[0.11; 0.41]	5.0%
Ntagiopoulos et al 2013	0	31	0.00	[0.00; 0.11]	4.9%
Dejour et al 2013	0	24	0.00	[0.00; 0.14]	4.6%
Zaki et al 2010	0	27	0.00	[0.00; 0.13]	4.8%
Donell et al 2006	5	17	0.29	[0.10; 0.56]	4.2%
Verdonk et al 2005	5	13	0.38	[0.14; 0.68]	3.8%
Random effects model		348	0.09	[0.03; 0.18]	43.6%
Heterogeneity: $I^2 = 79\%$, $p < 0.01$					
Bereiter deepening trochleoplasty					
Nelitz et al 2018	1	18	0.06	[0.00; 0.27]	4.3%
Wind et al 2019	3	22	0.14	[0.03; 0.35]	4.5%
Camathias et al 2016	4	50	0.08	[0.02; 0.19]	5.3%
Bering et al 2016	0	42	0.00	[0.00; 0.08]	5.2%
Banke et al 2014	2	18	0.11	[0.01; 0.35]	4.3%
Nelitz et al 2013	1	26	0.04	[0.00; 0.20]	4.7%
Blønd et al 2014	0	29	0.00	[0.00; 0.12]	4.8%
von Knoch et al 2006	0	45	0.00	[0.00; 0.08]	5.3%
Random effects model		250	0.03	[0.00; 0.08]	38.4%
Heterogeneity: $I^2 = 54\%$, $p = 0.03$					
Lateral elevation trochleoplasty					
Tigchelaar et al 2018	0	15	0.00	[0.00; 0.22]	4.0%
Pesenti et al 2017	0	27	0.00	[0.00; 0.13]	4.8%
Badhe et al 2003	4	4	1.00	[0.40; 1.00]	2.1%
Weiker et al 1997	3	6	0.50	[0.12; 0.88]	2.7%
Random effects model		52	0.24	[0.00; 0.76]	13.6%
Heterogeneity: $I^2 = 91\%$, $p < 0.01$					
Recession wedge trochleoplasty					
Thaunat et al 2011	1	19	0.05	[0.00; 0.26]	4.3%
Random effects model		**669**	**0.07**	**[0.03; 0.12]**	**100.0%**
Heterogeneity: $I^2 = 78\%$, $p < 0.01$					
Residual heterogeneity: $I^2 = 79\%$, $p < 0.01$					

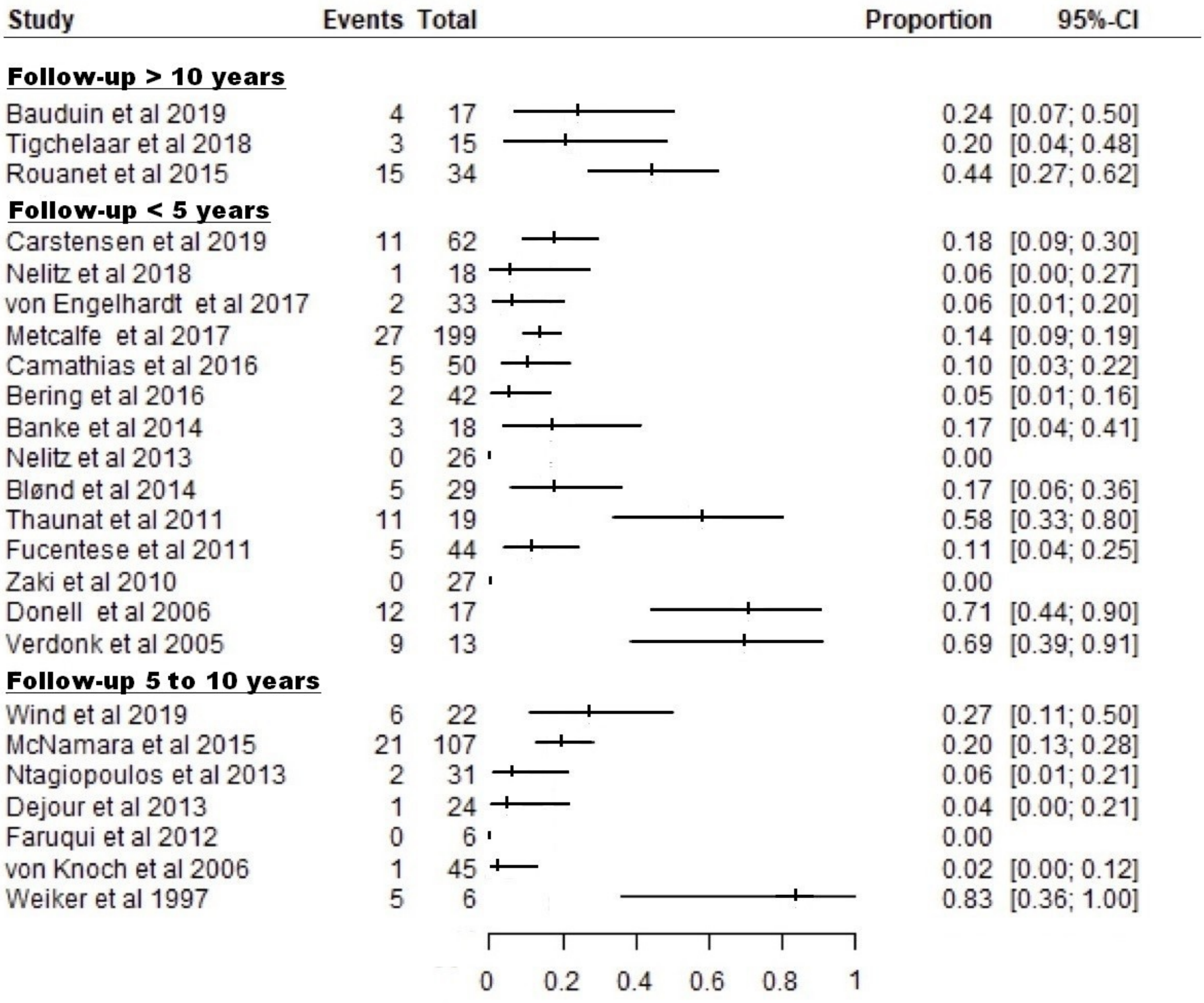


Study	Events	Total	Proportion	95%-CI
Bauduin et al 2019	4	17	0.24	[0.07; 0.50]
Carstensen et al 2019	11	62	0.18	[0.09; 0.30]
Nelitz et al 2018	1	18	0.06	[0.00; 0.27]
Wind et al 2019	6	22	0.27	[0.11; 0.50]
von Engelhardt et al 2017	2	33	0.06	[0.01; 0.20]
Tigchelaar et al 2018	3	15	0.20	[0.04; 0.48]
Metcalfe et al 2017	27	199	0.14	[0.09; 0.19]
Camathias et al 2016	5	50	0.10	[0.03; 0.22]
Bering et al 2016	2	42	0.05	[0.01; 0.16]
McNamara et al 2015	21	107	0.20	[0.13; 0.28]
Rouanet et al 2015	15	34	0.44	[0.27; 0.62]
Banke et al 2014	3	18	0.17	[0.04; 0.41]
Ntagiopoulos et al 2013	2	31	0.06	[0.01; 0.21]
Nelitz et al 2013	0	26	0.00	
Blønd et al 2014	5	29	0.17	[0.06; 0.36]
Dejour et al 2013	1	24	0.04	[0.00; 0.21]
Faruqui et al 2012	0	6	0.00	[0.00; 0.46]
Thaunat et al 2011	11	19	0.58	[0.33; 0.80]
Fucentese et al 2011	5	44	0.11	[0.04; 0.25]
Zaki et al 2010	0	27	0.00	
von Knoch et al 2006	1	45	0.02	[0.00; 0.12]
Donell et al 2006	12	17	0.71	[0.44; 0.90]
Verdonk et al 2005	9	13	0.69	[0.39; 0.91]
Weiker et al 1997	5	6	0.83	[0.36; 1.00]

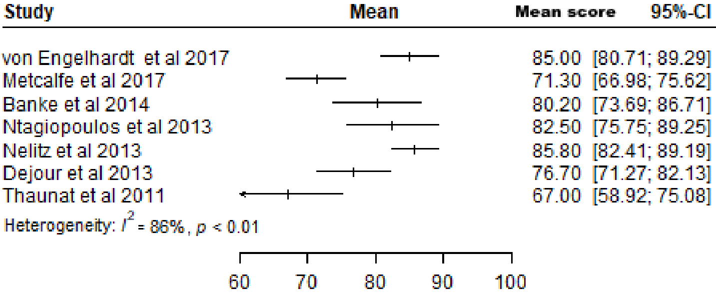


Heterogeneity: $I^2 = 83\%$, $p < 0.01$

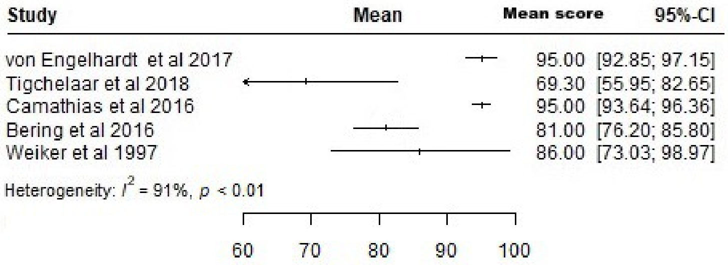

Study
Events Total
Proportion 95%-CI
Lateral elevation trochleoplasty
Bauduin et al 2019 4 17 0.24 [0.07; 0.50]
Tigchelaar et al 2018 3 15 0.20 [0.04; 0.48]
Weiker et al 1997 5 6 0.83 [0.36; 1.00]
Dejour deepening trochleoplasty
Carstensen et al 2019 11 62 0.18 [0.09; 0.30]
von Engelhardt et al 2017 2 33 0.06 [0.01; 0.20]
McNamara et al 2015 21 107 0.20 [0.13; 0.28]
Rouanet et al 2015 15 34 0.44 [0.27; 0.62]
Ntagiopoulos et al 2013 2 31 0.06 [0.01; 0.21]
Dejour et al 2013 1 24 0.04 [0.00; 0.21]
Faruqui et al 2012 0 6 0.00
Zaki et al 2010 0 27 0.00
Donell et al 2006 12 17 0.71 [0.44; 0.90]
Verdonk et al 2005 9 13 0.69 [0.39; 0.91]
Bereiter deepening trochleoplasty
Nelitz et al 2018 1 18 0.06 [0.00; 0.27]
Wind et al 2019 6 22 0.27 [0.11; 0.50]
Metcalfe et al 2017 27 199 0.14 [0.09; 0.19]
Camathias et al 2016 5 50 0.10 [0.03; 0.22]
Bering et al 2016 2 42 0.05 [0.01; 0.16]
Banke et al 2014 3 18 0.17 [0.04; 0.41]
Nelitz et al 2013 0 26 0.00
Blønd et al 2014 5 29 0.17 [0.06; 0.36]
Fucentese et al 2011 5 44 0.11 [0.04; 0.25]
von Knoch et al 2006 1 45 0.02 [0.00; 0.12]
Recession wedge trochleoplasty
Thaunat et al 2011 11 19 0.58 [0.33; 0.80]
0 0.2 0.4 0.6 0.8 1

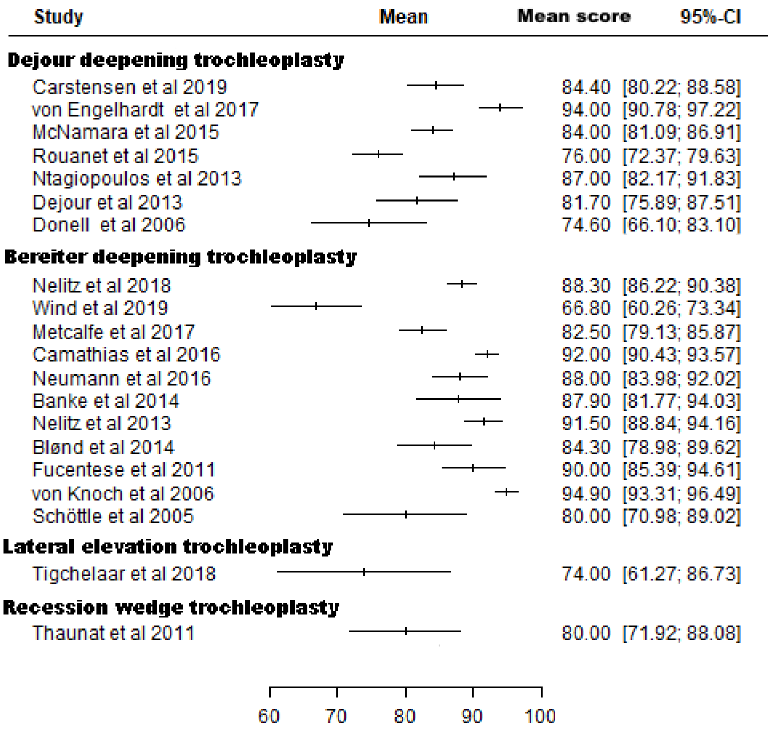


Study Events Total Proportion 95%-CI
Follow-up > 10 years
Bauduin et al 2019 4 17 0.24 [0.07; 0.50]
Tigchelaar et al 2018 3 15 0.20 [0.04; 0.48]
Rouanet et al 2015 15 34 0.44 [0.27; 0.62]
Follow-up < 5 years
Carstensen et al 2019 11 62 0.18 [0.09; 0.30]
Nelitz et al 2018 1 18 0.06 [0.00; 0.27]
von Engelhardt et al 2017 2 33 0.06 [0.01; 0.20]
Metcalfe et al 2017 27 199 0.14 [0.09; 0.19]
Camathias et al 2016 5 50 0.10 [0.03; 0.22]
Bering et al 2016 2 42 0.05 [0.01; 0.16]
Banke et al 2014 3 18 0.17 [0.04; 0.41]
Nelitz et al 2013 0 26 0.00
Blønd et al 2014 5 29 0.17 [0.06; 0.36]
Thaunat et al 2011 11 19 0.58 [0.33; 0.80]
Fucentese et al 2011 5 44 0.11 [0.04; 0.25]
Zaki et al 2010 0 27 0.00
Donell et al 2006 12 17 0.71 [0.44; 0.90]
Verdonk et al 2005 9 13 0.69 [0.39; 0.91]
Follow-up 5 to 10 years
Wind et al 2019 6 22 0.27 [0.11; 0.50]
McNamara et al 2015 21 107 0.20 [0.13; 0.28]
Ntagiopoulos et al 2013 2 31 0.06 [0.01; 0.21]
Dejour et al 2013 1 24 0.04 [0.00; 0.21]
Faruqui et al 2012 0 6 0.00
von Knoch et al 2006 1 45 0.02 [0.00; 0.12]
Weiker et al 1997 5 6 0.83 [0.36; 1.00]
0 0.2 0.4 0.6 0.8 1



Study
Mean
Mean score
95%-CI
von Engelhardt et al 2017
85.00 [80.71; 89.29]
Metcalfe et al 2017
71.30 [66.98; 75.62]
Banke et al 2014
80.20 [73.69; 86.71]
Ntagiopoulos et al 2013
82.50 [75.75; 89.25]
Nelitz et al 2013
85.80 [82.41; 89.19]
Dejour et al 2013
76.70 [71.27; 82.13]
Thaunat et al 2011
67.00 [58.92; 75.08]
Heterogeneity: I^2 = 86%, p < 0.01
60
70
80
90
100


Study
Mean
Mean score
95%-CI
von Engelhardt et al 2017
95.00 [92.85; 97.15]
Tigchelaar et al 2018
69.30 [55.95; 82.65]
Camathias et al 2016
95.00 [93.64; 96.36]
Bering et al 2016
81.00 [76.20; 85.80]
Weiker et al 1997
86.00 [73.03; 98.97]
Heterogeneity: I^2 = 91%, p < 0.01
60
70
80
90
100


Study
Mean
Mean score
95%-CI
Dejour deepening trochleoplasty
Carstensen et al 2019 84.40 [80.22; 88.58]
von Engelhardt et al 2017 94.00 [90.78; 97.22]
McNamara et al 2015 84.00 [81.09; 86.91]
Rouanet et al 2015 76.00 [72.37; 79.63]
Ntagiopoulos et al 2013 87.00 [82.17; 91.83]
Dejour et al 2013 81.70 [75.89; 87.51]
Donell et al 2006 74.60 [66.10; 83.10]
Bereiter deepening trochleoplasty
Nelitz et al 2018 88.30 [86.22; 90.38]
Wind et al 2019 66.80 [60.26; 73.34]
Metcalfe et al 2017 82.50 [79.13; 85.87]
Camathias et al 2016 92.00 [90.43; 93.57]
Neumann et al 2016 88.00 [83.98; 92.02]
Banke et al 2014 87.90 [81.77; 94.03]
Nelitz et al 2013 91.50 [88.84; 94.16]
Blønd et al 2014 84.30 [78.98; 89.62]
Fucentese et al 2011 90.00 [85.39; 94.61]
von Knoch et al 2006 94.90 [93.31; 96.49]
Schöttle et al 2005 80.00 [70.98; 89.02]
Lateral elevation trochleoplasty
Tigchelaar et al 2018 74.00 [61.27; 86.73]
Recession wedge trochleoplasty
Thaunat et al 2011 80.00 [71.92; 88.08]
60
70
80
90
100