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The impact of a high tibial valgus osteotomy and unicondylar medial arthroplasty on the treatment for knee osteoarthritis: a meta-analysis

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Abstract

Purpose Both high tibial valgus osteotomy (HTO) and unicompartmental medial knee arthroplasty (UKA) are established methods for the treatment for moderate stages of OA. This is the first global meta-analysis to compare the long-term effects of both methods regarding survival, outcomes and complications of total arthroplasty.

Methods Literature research was performed using established medical databases: MEDLINE (via PubMed), EMBASE (via OVID) and the Cochrane register. Criteria for inclusion were as follows: English or German papers, a clinical trial with a clear description of survival, an outcome evaluation using a well-described knee score and a follow-up >5 years. Statistical analysis was performed using the special meta-analysis software called "Comprehensive Meta Analysis" (version 2.0; Biostat, Englewood, NJ, USA).

Results Final meta-analysis after the full-text review included 46 studies about valgus HTO and 43 studies about medial UKA. There were no significant differences between valgus HTO and medial UKA in terms of the number of total required replacements. After a 5- to 8-year follow-up, 91.0% of the valgus HTO patients and 91.5% of medial UKA patients did not need a total replacement. This value was 84.4% for valgus HTOs and 86.9% for medial UKAs after a 9- to 12-year follow-up. Mean survival time to TKA was 9.7 years after valgus HTO and 9.2 years after medial UKA. Clinical outcome was significantly better after medial UKA in a 5- to 12-year follow-up. After more than 12 years, results were comparable in both groups. No significant differences were seen in the complication rates.

Conclusions This meta-analysis aimed to find the advantages and disadvantages of two established methods for the treatment for medial compartment knee osteoarthritis. Valgus HTO is more appropriate for younger patients who accept a slight decrease in their physical activity. Medial UKA is appropriate for older patients obtaining sufficient pain relief but with reduced physical activity.

Level of evidence II.

Keywords Knee · Osteoarthritis · Unicondylar arthroplasty · Osteotomy · Meta-analysis

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Introduction

Knee osteoarthritis (OA) is a frequent orthopedic disease [14]. Treatment includes both conservative and operative options that depend on the patient's individual characteristics and disease stage. The disease is generally staged by a radiological classification, as detailed in Kellgren and Lawrence [51]. Today, total knee arthroplasty (TKA) is the method of choice for the treatment for symptomatic late-stage OA. Moderate-grade stages of the disease require an individualized approach. Both high tibial valgus osteotomy (HTO) and unicompartmental medial knee arthroplasty (UKA) are established methods for the treatment for medial moderate OA.

Valgus HTO was first described in 1960s [18, 22, 61, 86]. This method is used for medial unicompartmental knee OA. It aims for a mild valgus correction and a shift of the mean bearing axis into the non-affected lateral compartment.

Nearly in the same period, unicompartmental arthroplasty was established [39]. This method aims to replace only the damaged compartment and thus protects the unaffected joint compartments.

Valgus HTO is more appropriate for younger patients who accept a slight decrease in their physical activity. Medial UKA is appropriate for older patients obtaining sufficient pain relief but with reduced physical activity.

Consent on the best indication was unknown until now. Many studies and partially controversial results have been published. This is the first meta-analysis to compare the impacts of both methods on the treatment for unicompartmental medial knee OA.

Materials and methods

Retrieval of published studies and inclusion and exclusion criteria

Literature search was performed using the following established medical databases: MEDLINE (via PubMed), EMBASE (via OVID) and the Cochrane register. Retrieval in PubMed was conducted using the following combination: Knee [Mesh] AND Osteotomy [Mesh], Knee [Mesh] and Unicondylar [Mesh] OR Unicompartmental [Mesh] AND Knee.

Criteria for inclusion were as follows: English or German papers, a clinical trial with a clear description of survival, an outcome evaluation using a well-described knee score and a long-term follow-up (minimum 5 years).

In the first step, two investigators (the first and senior authors) independently reviewed the titles and abstracts of all of the retrieved studies. Second, both investigators hold a conference and found a consensus about which studies were to be evaluated with a full-text review. Then, a full-text review was performed independently by the two lead investigators. After determining the results of the second review, the studies were indentified for their final inclusion into the meta-analysis. Data extraction was performed by

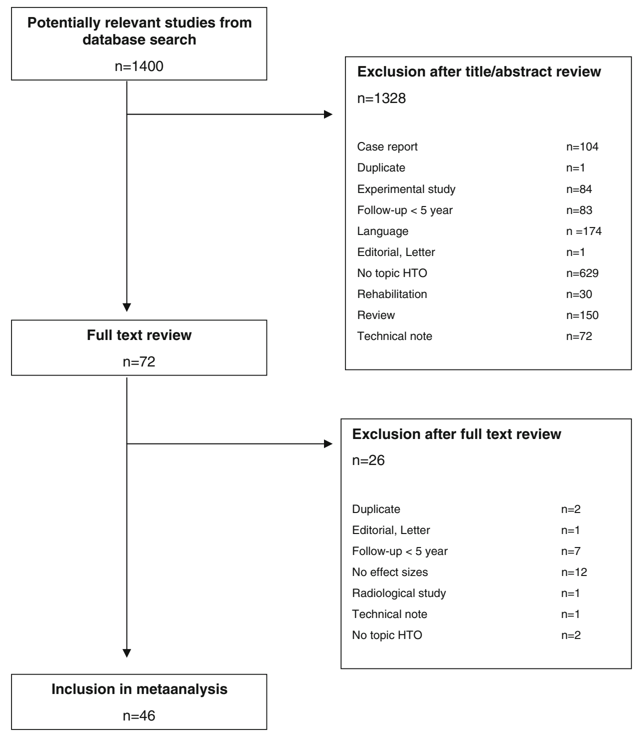

Fig. 1 Flowchart for the identification of valgus HTO studies

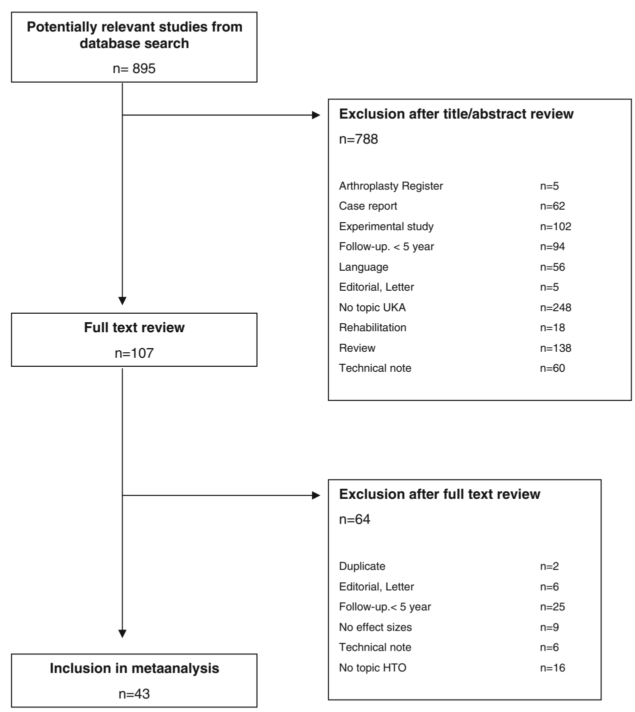

Fig. 2 Flowchart for the identification of medial UKA studies

Group by Comparison	Study name	Comparison	Event rate	Lower limit	Upper limit	Relative weight	Relative weight
HTO	Ha'eri GB et al. (1979)	HTO	0,857	0,639	0,953	2,93	
HTO	Vainionpää S et al. (1981)-normal	HTO	0,909	0,561	0,987	1,56	
HTO	Vainionpää S et al. (1981)-varus	HTO	0,837	0,747	0,899	4,73	
HTO	Sasaki T et al. (1986)	HTO	0,986	0,907	0,998	1,65	
HTO	Ivarsson I et al. (1990)	HTO	0,939	0,872	0,973	3,96	
HTO	Yasuda K et al. (1992)	HTO	0,946	0,847	0,983	3,07	
HTO	Coventry MB et al. (1993)	HTO	0,885	0,799	0,937	4,43	
HTO	Wada M et al. (1998)	HTO	0,988	0,829	0,999	0,97	
HTO	Naudie D et al. (1999)	HTO	0,726	0,634	0,803	5,05	
HTO	Billings A et al. (2000)	HTO	0,870	0,768	0,931	4,32	
HTO	Hernigou P and Ma W (2001)	HTO	0,943	0,869	0,976	3,74	
HTO	Stukenborg-C C et al. (2001)-hto	HTO	0,688	0,510	0,823	4,18	
HTO	Aglietti P et al. (2003)	HTO	0,882	0,804	0,932	4,59	
HTO	Devgan A et al. (2003)	HTO	0,990	0,862	0,999	0,97	
HTO	Flamme CH et al. (2003)	HTO	0,931	0,862	0,967	4,12	
HTO	Sen C et al. (2003)-fix	HTO	0,926	0,748	0,981	2,47	
HTO	Sen C et al. (2003)-int	HTO	0,846	0,655	0,941	3,31	
HTO	Sprenger TR et al. (2003)	HTO	0,855	0,757	0,918	4,49	
HTO	Trieb H et al. (2003)	HTO	0,926	0,852	0,964	4,12	
HTO	Koshino T et al (2004)	HTO	0,973	0,900	0,993	2,54	
HTO	Christodoulou NA et al. (2005)-LR	HTO	0,985	0,799	0,999	0,97	
HTO	Christodoulou NA et al. (2005)	HTO	0,985	0,799	0,999	0,97	
HTO	Huang TL et al (2005)	HTO	0,946	0,877	0,977	3,75	
HTO	Tang WC et al. (2005)	HTO	0,896	0,797	0,949	4,08	
HTO	Flecher X et al. (2006)	HTO	0,949	0,921	0,967	4,97	
HTO	Polyzois D et al. (2006)	HTO	0,912	0,851	0,949	4,62	
HTO	Matsunaga D et al. (2007)	HTO	0,996	0,934	1,000	0,98	
HTO	Nago ON et al. (2007)	HTO	0,769	0,572	0,892	3,72	
HTO	Gstöttner M et al. (2008)	HTO	0,948	0,894	0,975	4,14	
HTO	Sterett WI et al. (2010)	HTO	0,887	0,811	0,935	4,60	
HTO			0,910	0,882	0,932		
UKA	Johnell O et al. (1985)	UKA	0,875	0,711	0,952	3,65	
UKA	Larsson SE et al. (1986)	UKA	0,882	0,804	0,932	4,59	
UKA	Stewart HD and Newton G (1989)	UKA	0,725	0,568	0,841	4,41	
UKA	Scott RD et al. (1990)	UKA	0,970	0,911	0,990	3,44	
UKA	Stockelman RE and Pohl K (1990)	UKA	0,794	0,676	0,876	4,58	
UKA	Tateishi H et al. (1991)	UKA	0,800	0,530	0,934	3,20	
UKA	Heck DA et al. (1993)	UKA	0,973	0,947	0,986	4,39	
UKA	Hasegawa Y et al. (1998)	UKA	0,883	0,790	0,938	4,41	
UKA	Murray DW et al. (1998)	UKA	0,986	0,946	0,996	2,95	
UKA	Squire M et al. (1999)	UKA	0,971	0,926	0,989	3,77	
UKA	Stukenborg-C C et al. (2001)-uka	UKA	0,800	0,621	0,907	3,98	
UKA	Svärd UCG and Price AJ (2001)	UKA	0,839	0,763	0,894	4,82	
UKA	Ridgeway SR et al. (2002)	UKA	0,878	0,832	0,913	4,98	
UKA	Romanowski MR and Repicci JA (2002)	UKA	0,926	0,869	0,960	4,51	
UKA	Skyrme AD et al. (2002)	UKA	0,577	0,385	0,748	4,23	
UKA	Hendel D et al. (2003)	UKA	0,818	0,604	0,930	3,58	
UKA	Keys GW et al. (2004)	UKA	0,975	0,843	0,996	2,04	
UKA	Naudie D et al. (2004)	UKA	0,938	0,876	0,970	4,26	
UKA	Endres S et al. (2005)	UKA	0,956	0,889	0,983	3,75	
UKA	Price AJ et al. (2005)	UKA	0,973	0,956	0,984	4,76	
UKA	Amin AK et al. (2006)	UKA	0,889	0,774	0,949	4,08	
UKA	Berger RA et al. (2006)	UKA	0,984	0,894	0,998	2,05	
UKA	Eickmann TH et al. (2006)	UKA	0,929	0,900	0,951	4,98	
UKA	Emerson RH el Higgins LL (2008)	UKA	0,944	0,841	0,982	3,41	
UKA	Gulati A et al. (2009)	UKA	0,997	0,953	1,000	1,28	
UKA	Mercier N et al. (2009)	UKA	0,884	0,749	0,951	3,90	
UKA			0,915	0,882	0,939		
Overall			0,912	0,892	0,929		

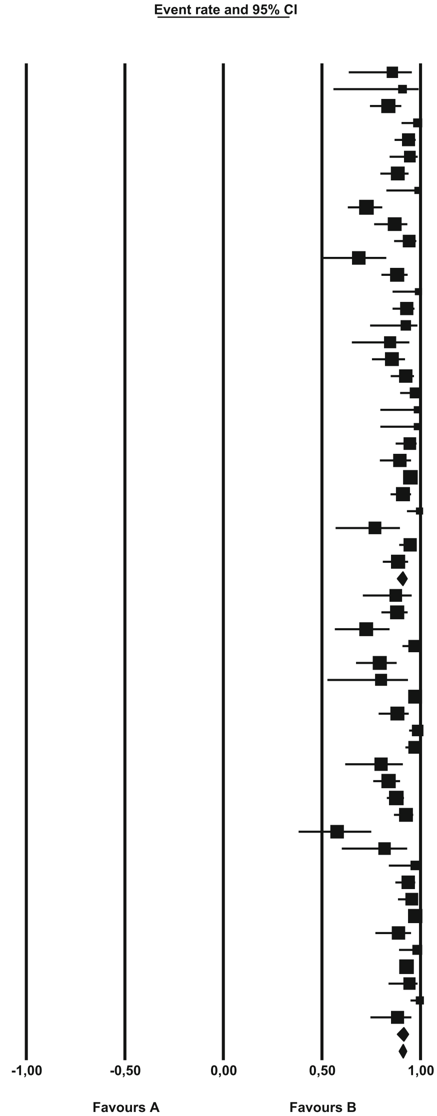

Fig. 3 Survival to endpoint total knee arthroplasty after 5–8 years of follow-up. The forest plots present the effect size (*ER* event rate). Each *square* represents the individual study's ER with a 95% CI indicated by the *horizontal lines*. Number of included studies: valgus HTO, $n = 30$; medial UKA, $n = 26$. Survival: valgus HTO, 0.910; medial UKA, 0.915. Heterogeneity (I^2): HTO = 71.1, UKA = 82.3. Significance: $P = 0.801$

both investigators. Results were entered into an Excel table. The established and well-described scores were normalized to a 0-to-100 scale. Before the statistical evaluation, both investigators fine-tuned the results once again.

Statistical analysis

Statistical analysis was performed using the special meta-analysis software called "Comprehensive Meta Analysis" (version 2.0; Biostat, Englewood, NJ, USA).

All of the effect sizes were calculated using a random-effects model. Dichotomous effect sizes (rate of survival, rate of complications and a semi-quantitative estimate of the results) were expressed as ERs (event rates). Continuous values (estimates determined from the knee scores) were calculated by comparing their means (*t* test). Scores (baseline to follow-up) were compared by calculating the standard difference of the means (SDM). All of the results were presented as forest plots. Results of the scores were normalized to a 0-to-100 scale. In other words, results were calculated as [x = (points) × 100/(maximum possible score points)].

A 95% confidence interval was given for each effect size.

Heterogeneity was calculated according to the method of Higgins et al. [44]. Heterogeneity is expressed as I^2. This value ranges from 0% (complete consistency) to 100% (complete inconsistency).

Group by Comparison	Study name	Comparison	Event rate	Lower limit	Upper limit
HTO	Broughton NS et al. (1986)-hto	HTO	0,711	0,564	0,824
HTO	Holden D et al. (1988)	HTO	0,941	0,833	0,981
HTO	Ivarsson I et al. (1990)	HTO	0,889	0,810	0,937
HTO	Yasuda K et al. (1992)	HTO	0,946	0,847	0,983
HTO	Coventry MB et al. (1993)	HTO	0,747	0,646	0,827
HTO	Hassenpflug J et al. (1998)	HTO	0,944	0,898	0,969
HTO	Naudie D et al. (1999)	HTO	0,509	0,415	0,603
HTO	Billings A et al. (2000)	HTO	0,522	0,405	0,636
HTO	Majima T et al (2000)	HTO	0,938	0,823	0,980
HTO	Hernigou P and Ma W (2001)	HTO	0,851	0,759	0,911
HTO	Aglietti P et al. (2003)	HTO	0,784	0,694	0,854
HTO	Flamme CH et al. (2003)	HTO	0,812	0,724	0,877
HTO	Sprenger TR et al. (2003)	HTO	0,737	0,627	0,823
HTO	Trieb H et al. (2003)	HTO	0,851	0,764	0,910
HTO	Koshino T et al (2004)	HTO	0,947	0,866	0,980
HTO	Gall N et al. (2005)	HTO	0,795	0,727	0,850
HTO	Huang TL et al (2005)	HTO	0,860	0,774	0,917
HTO	Tang WC et al. (2005)	HTO	0,746	0,629	0,836
HTO	Aoki Y et al. (2006)-c.w	HTO	0,977	0,912	0,994
HTO	Aoki Y et al. (2006)-dome	HTO	0,948	0,870	0,980
HTO	Flecher X et al. (2006)	HTO	0,927	0,896	0,950
HTO	Papachristou G et al. (2006)	HTO	0,795	0,651	0,890
HTO	Akizuki S et al. (2007)	HTO	0,975	0,924	0,992
HTO	Frey P et al. (2008)	HTO	0,740	0,690	0,785
HTO	Gstöttner M et al. (2008)	HTO	0,806	0,730	0,864
HTO	Omori G et al. (2008)	HTO	0,956	0,872	0,986
HTO	van Raaij TM et al. (2008)	HTO	0,760	0,668	0,832
HTO	Sterett WI et al. (2010)	HTO	0,547	0,452	0,639
HTO			0,844	0,797	0,882
UKA	Broughton NS et al. (1986)-uka	UKA	0,913	0,790	0,967
UKA	Marmor L (1988)	UKA	0,650	0,522	0,759
UKA	Barck AL (1989)	UKA	0,854	0,724	0,929
UKA	Stewart HD and Newton G (1989)	UKA	0,725	0,568	0,841
UKA	Scott RD et al. (1990)	UKA	0,100	0,055	0,176
UKA	Heck DA et al. (1993)	UKA	0,912	0,873	0,939
UKA	Murray DW et al. (1998)	UKA	0,972	0,928	0,989
UKA	Tabor OB (1998)	UKA	0,852	0,740	0,921
UKA	Bert JM (1998)	UKA	0,874	0,791	0,927
UKA	Squire M et al. (1999)	UKA	0,914	0,855	0,951
UKA	Weale AE et al. (1999)	UKA	0,964	0,868	0,991
UKA	Svärd UCG and Price AJ (2001)	UKA	0,782	0,701	0,846
UKA	Pennington DW et al. (2003)	UKA	0,933	0,813	0,978
UKA	Hernigou P and Deschamps G (2004)	UKA	0,896	0,847	0,931
UKA	Keblish PA et al. (2004)	UKA	0,884	0,822	0,927
UKA	Naudie D et al. (2004)	UKA	0,894	0,822	0,939
UKA	Price AJ et al. (2005)	UKA	0,957	0,937	0,971
UKA	Vorlat P et al. (2006)	UKA	0,754	0,667	0,825
UKA	Berger RA et al. (2006)	UKA	0,935	0,840	0,976
UKA	Eickmann TH et al. (2006)	UKA	0,798	0,756	0,834
UKA	Steele RG et al. (2006)	UKA	0,970	0,936	0,987
UKA	Cartier P et al. (2007)	UKA	0,939	0,891	0,967
UKA	Emerson RH el Higgins LL (2008)	UKA	0,889	0,774	0,949
UKA	Mercier N et al. (2009)	UKA	0,767	0,619	0,870
UKA	Parratte S et al. (2009)	UKA	0,800	0,636	0,902
UKA			0,869	0,814	0,909
Overall			0,854	0,820	0,883

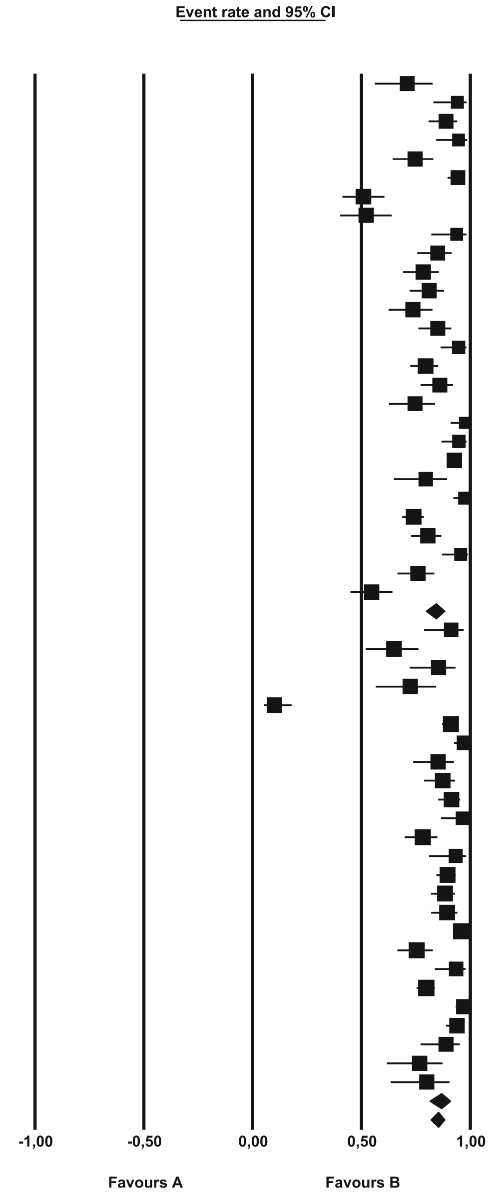

Fig. 4 Survival to endpoint total knee arthroplasty after 9–12 years of follow-up. The forest plots present the effect size (*ER* event rate). Each *square* represents the individual study's ER with a 95% CI indicated by the *horizontal lines*. Number of included studies: valgus HTO, $n = 28$; medial UKA, $n = 25$. Survival: valgus HTO, 0.844; medial UKA, 0.869. Heterogeneity (I^2): HTO = 89.5, UKA = 92.0. Significance: $P = 0.458$

Results

Included studies

The deadline for evaluation in the databases was July 31, 2010. Primary search resulted in 1,400 studies about valgus HTO and 895 studies about medial UKA.

Final meta-analysis after the full-text review included 46 studies about valgus HTO and 43 studies about medial UKA. Flowcharts describing the study selection are in Figs. 1, 2. Mean age of patients at operation who had undergone valgus HTO was 56.1 years (95% CI, 53.2–58.7 years). Medial UKA patients were significantly ($P < 0.001$) older. Mean age at operation was 70.1 years (95% CI, 67.3–72.7 years).

Comparative studies

Only one randomized prospective study was identified. Borjesson et al. [12] reported the 5-year results of 18 valgus HTO patients (closed-wedge technique) versus 22 medial UKAs. During the follow-up, no significant difference in the subjective outcome (BOA Score) was found.

Group by Comparison	Study name	Comparison	Event rate	Lower limit	Upper limit	Relative weight	Relative weight
HTO	Naudie D et al. (1999)	HTO	0,302	0,222	0,396	6,78	
HTO	Hernigou P and Ma W (2001)	HTO	0,690	0,585	0,778	6,69	
HTO	Aglietti P et al. (2003)	HTO	0,706	0,611	0,786	6,76	
HTO	Sprenger TR et al. (2003)	HTO	0,461	0,352	0,573	6,70	
HTO	Trieb H et al. (2003)	HTO	0,723	0,625	0,804	6,70	
HTO	Koshino T et al (2004)	HTO	0,880	0,785	0,936	6,07	
HTO	Tang WC et al. (2005)	HTO	0,672	0,551	0,773	6,56	
HTO	Flecher X et al. (2006)	HTO	0,849	0,809	0,882	7,02	
HTO	Papachristou G et al. (2006)	HTO	0,659	0,509	0,783	6,27	
HTO	Akizuki S et al. (2007)	HTO	0,898	0,829	0,941	6,34	
HTO	Frey P et al. (2008)	HTO	0,520	0,466	0,573	7,12	
HTO	Gstöttner M et al. (2008)	HTO	0,604	0,519	0,684	6,92	
HTO	Omori G et al. (2008)	HTO	0,706	0,588	0,802	6,53	
HTO	Benzakour T et al. (2010)	HTO	0,880	0,826	0,919	6,74	
HTO	Sterett WI et al. (2010)	HTO	0,670	0,575	0,753	6,80	
HTO			0,701	0,605	0,782		
UKA	Stewart HD and Newton G (1989)	UKA	0,700	0,543	0,821	10,98	
UKA	Heck DA et al. (1993)	UKA	0,813	0,764	0,853	11,56	
UKA	Squire M et al. (1999)	UKA	0,900	0,838	0,940	11,21	
UKA	Svärd UCG and Price AJ (2001)	UKA	0,121	0,074	0,191	11,24	
UKA	O'Rourke MRO et al. (2005)	UKA	0,890	0,825	0,932	11,24	
UKA	Berger RA et al. (2006)	UKA	0,903	0,801	0,956	10,62	
UKA	Steele RG et al. (2006)	UKA	0,936	0,893	0,962	11,20	
UKA	Mercier N et al. (2009)	UKA	0,698	0,546	0,816	11,03	
UKA	Parratte S et al. (2009)	UKA	0,686	0,517	0,817	10,91	
UKA			0,775	0,583	0,895		
Overall			0,716	0,631	0,787		

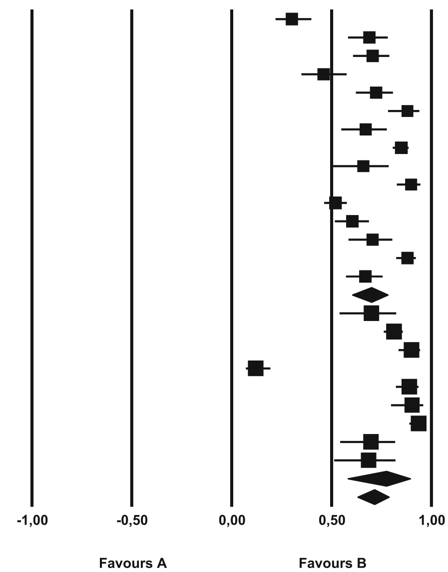

Fig. 5 Survival to endpoint total knee arthroplasty after more than 12 years of follow-up. The forest plots present the effect size (*ER* event rate). Each *square* represents the individual study's ER with a 95% CI indicated by the *horizontal lines*. Number of included studies: valgus HTO, $n = 15$; medial UKA, $n = 9$. Survival: valgus HTO, 0.701; medial UKA, 0.775. Heterogeneity (I^2): valgus HTO = 93.7, medial UKA = 95.9, Significance: $P = 0.451$

Group by Comparison	Study name	Comparison	Mean	Lower limit	Upper limit	Relative weight	Relative weight
HTO	Hassenpflug J et al. (1998)	HTO	12,0	10,7	13,3	8,74	
HTO	Naudie D et al. (1999)	HTO	11,0	9,4	12,6	8,42	
HTO	Billings A et al. (2000)	HTO	5,4	4,5	6,3	8,95	
HTO	Aglietti P et al. (2003)	HTO	10,7	9,1	12,3	8,39	
HTO	Gall N et al. (2005)	HTO	9,2	8,8	9,6	9,18	
HTO	Tang WC et al. (2005)	HTO	9,5	6,7	12,3	7,20	
HTO	Akizuki S et al. (2007)	HTO	13,4	10,9	15,9	7,46	
HTO	Nago ON et al. (2007)	HTO	6,4	4,2	8,6	7,79	
HTO	Frey P et al. (2008)	HTO	11,5	10,6	12,4	8,97	
HTO	Gstöttner M et al. (2008)	HTO	17,0	14,1	19,9	7,05	
HTO	van Raaij TM et al. (2008)	HTO	6,0	5,4	6,6	9,14	
HTO	Sterett WI et al. (2010)	HTO	5,9	4,6	7,2	8,72	
HTO			9,7	8,1	11,2		
UKA	Larsson SE et al. (1986)	UKA	5,0	4,0	6,0	21,46	
UKA	Bert JM (1998)	UKA	10,1	7,9	12,3	19,43	
UKA	Squire M et al. (1999)	UKA	7,2	5,6	8,8	20,61	
UKA	Steele RG et al. (2006)	UKA	12,9	10,7	15,1	19,44	
UKA	Mercier N et al. (2009)	UKA	6,3	3,9	8,7	19,06	
UKA			8,2	5,5	11,0		
Overall			9,3	8,0	10,7		

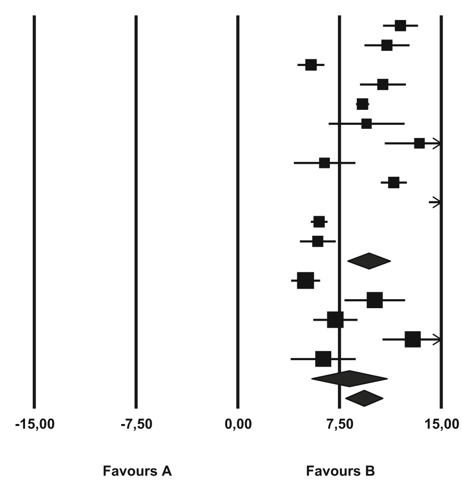

Fig. 6 Mean survival (Kaplan–Maier). The forest plots present the mean survival of each study. Each *square* represents the individual study's mean survival with a 95% CI indicated by the *horizontal lines*. Number of included studies: HTO, $n = 12$; UKA, $n = 5$. Mean survival: valgus HTO, 9.7 years; medial UKA, 8.2 years. Heterogeneity (I^2): valgus HTO = 96.0, medial UKA 92.1. Significance: $P = 0.374$

Broughton et al. [13] published the 10-year results of a retrospective comparative study. They found a significant better outcome after a medial UKA. Survival was 0.711 for valgus HTO ($n = 49$) and 0.913 for medial UKA ($n = 42$). In HSS, 76.1% of the medial UKAs had good or excellent outcomes. This rate was 42.8% in the valgus HTO group.

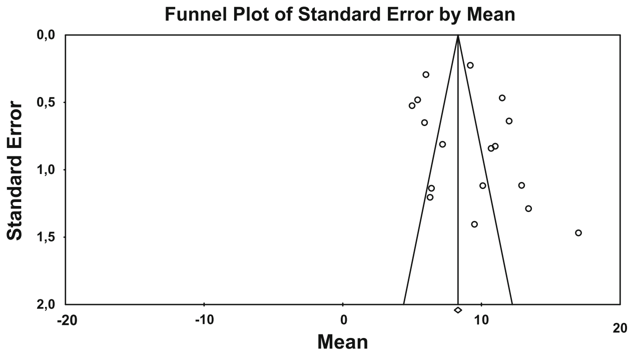

Fig. 7 Mean survival (Kaplan–Meier) funnel plot

Stukenborg-Colsman et al. [94] also retrospectively assessed the 7.5-year outcome after 32 valgus HTOs and 28 medial UKAs. The 5- to 10-year survival after a valgus HTO was 0.688 and 0.800 after a medial UKA. In KSS, 71% of the valgus HTO patients and 65% of the medial UKA patients had an excellent outcome.

Survival

Survival was defined as the time to a total arthroplasty revision. ERs for survival were grouped as follows: 5–8 [mean] years, 9–12 years and more than 12 years of follow-up.

Table 1 Studies included in the meta-analysis (valgus HTO)

Author	*n*	Method	Follow-up (years)	Score
Ha'eri et al. [36]	21	Closing wedge	6.0	
Vainionpaa et al. [101]-normal[a]	11	Closing wedge	6.7	Coventry
Vainionpaa et al. [101]-varus[a]	92	Closing wedge	7.1	Coventry
Broughton et al. [13]-hto[b]	45	Closing wedge	7.8	HSS
Sasaki et al. [82]	71	Closing wedge	6.1	JOA
Holden et al. [45]	51	Closing wedge	10.0	HSS
Ivarsson et al. [48]	99	Closing wedge	11.9	
Yasuda et al. [106]	56	Closing wedge	15.0	JOA
Coventry et al. [20]	87	Closing wedge	10.0	Coventry
Hassenpflug et al. [38]	177	Closing wedge	10.0	JOA
Rinonapoli et al. [79]	102	Closing wedge	15.0	HSS
Wada et al. [104]	39	Maquet, fixator	6.0	HSS
Naudie et al. [67]	106	Closing wedge or dome	15.0	
Billings et al. [11]	69	Closing wedge	10.0	HSS
Majima et al. [59]	48	Closing wedge	12.0	Own score
Choi et al. [16]	30	Closing wedge, plate	15.3	JOA
Hernigou and Ma [43]	87	Opening wedge, substitutes and plate	10.0	
Stukenborg-Colsman et al. [94]-hto[c]	32	Closing wedge	7.5	KSS
Aglietti et al. [2]	102	Closing wedge	15.0	HSS
Devgan et al. [23]	50	Open wedge	7.5	
Flamme et al. [29]	101	Closing wedge, plate	10.0	KSS
Sen et al. [85]-fix[d]	27	Closing wedge, fixator	6.0	HSS
Sen et al. [85]-int[d]	26	Closing wedge, plate	6.0	HSS
Sprenger and Doerzbacher [88]	76	Closing wedge, plate	20.0	HSS
Trieb et al. [100]	94	Closing wedge, plate	12.7	KSS
Koshino et al. [54]	75	Closing wedge	19.0	KSS
Borjesson et al. [12]-hto[e]	18	Closing wedge	5.0	BOA
Christodoulou et al. [17]-LR[f]	32	Closing wedge, fixator-LR	5.0	KSS
Christodoulou et al. [17][f]	32	Closing wedge, fixator	5.0	KSS
Gall et al. [32]	166	Closing wedge	9.3	
Huang et al. [46]	93	Closing wedge	10.9	
Tang and Henderson [98]	67	Closing wedge	6.5	
Aoki et al. [5]-c.w[g]	86	Closing wedge	10.0	JOA
Aoki et al. [5]-dome[g]	77	v-dome HTO	10.0	JOA
Flecher et al. [30]	372	Closing wedge, staples	18.0	Own score

Table 1 continued

Author	n	Method	Follow-up (years)	Score
Papachristou et al. [71]	44	Closing wedge, staples	15.0	HSS
Polyzois et al. [74]	136	Closing wedge, plate	8.4	HSS
Akizuki et al. [3]	118	Closing wedge, Giebel plate	16.4	HSS
Matsunaga et al. [63]	114	Closing wedge, Giebel plate	5.0	JOA
Nagi et al. [66]	26	Closing wedge	17.5	HSS
Frey et al. [31]	331	Closing wedge	13.5	KSS
Gstöttner et al. [34]	134	Closing wedge	12.4	
Omori et al. [70]	68	Closing wedge	17.1	JOA
van Raaij et al. [102]	104	Closing wedge	10.0	
Benzakour et al. [8]	192	Open wedge and closed wedge	15.0	KSS
Sterett et al. [91]	106	Open wedge, Puddu or fixator	10.0	Lysholm

Some studies addressed the effects of different kinds of first-line treatments or were comparative studies (valgus HTO vs. Medial UKA). Different groups were described as detailed. Both groups were described. However, the ESs for all of the patients were not given. Thus, the results of both groups were estimated as two different studies

[a] Vainionpaa et al. [101] used a randomized study to compare the effect of valgus HTO on patients with a pathological varus and patients with a normal leg axis

[b] Broughton et al. [13] presents a comparative study of the evaluation of valgus HTO versus medial UKA

[c] Stukenborg-Colsman et al. [94] presents a comparative study of the evaluation of valgus HTO versus medial UKA

[d] Sen et al. [85] evaluated the outcomes of valgus HTOs that were fixed either externally or internally

[e] Borjesson et al. [12] presents a randomized prospective study of the evaluation of valgus HTO versus medial UKA

[f] Christodoulou et al. [17] compared valgus HTO outcomes with or without additional arthroscopic lateral release (LR)

[g] Aoki et al. [5] compared the outcomes after a closed-wedge valgus HTO (c.w.) versus a complex v-dome valgus HTO (dome)

At 5–8 years, 91.0% of the valgus HTO patients and 91.5% of the medial UKA patients did not require a TKA revision (Fig. 3). Within 9–12 years after the operation, 84.4% of the valgus HTO patients and 86.9% of the medial UKA patients did not require revision (Fig. 4). After more than 12 years, valgus HTO tended to be revised more frequently (n.s). Survival to revision was 70.1% in the valgus HTO patients and 77.5% in the medial UKA patients (Fig. 5).

In 17 studies, the survival time to revision was calculated according to the method of Kaplan–Meier (Figs. 6, 7). Time of the required revision tended to be sooner in the medial UKA patients than in the valgus HTO patients (n.s). Medial UKA patients were revised after a mean of 8.2 years, while the valgus HTO patients had undergone a revision 1 year later at a mean of 9.7 years (Tables 1, 2).

Outcome measurement using established knee scores (continuous values)

The papers that were included in this investigation are listed in Table 3. For outcome evaluation, following different scores were used.

BOA (British Orthopaedic Association; $n = 2$) [1]; Bristol or synonymous Baily score ($n = 1$) [58]; Conventry score ($n = 3$) [19]; HSS (Hospital for Special Surgery score; $n = 30$) [77]; JOA (Japanese Orthopaedic Association; $n = 8$) [82]; KOOS (Knee Injury And Surgery Outcome score; $n = 1$) [81]; KSS (Knee Society score) or synonymous Insall score ($n = 21$) [47]; and the Lysholm score ($n = 1$) [57]. Each study used a self-created 100-point score. This score was well described and similar to the other scores.

Dates at baseline (Fig. 8) were extracted from 19 papers (for valgus HTO group, the mean score was 60.1 and medial UKA group 55.9; n.s.).

There was a significant difference between valgus HTO and medial UKA in the 5- to 8-year follow-up ($P < 0.001$). Mean score was 83.4 in the valgus HTO patients and 91.2 in the medial UKA patients (Fig. 9).

Only one study reported 10-year results after medial UKA. In this study, mean score was 90.0. Mean score in the 9 valgus HTO papers was 79.9. Results from Price et al. [75, 76] were significantly better ($P < 0.001$) than results from the valgus HTO papers (Fig. 10).

A total of 5 papers (2 valgus HTO and 3 medial UKA) reported results beyond 12 years. The outcome of medial UKA (mean 65.6) tended to be better than the outcome of valgus HTO (mean, 58.8; n.s). Results are shown in Fig. 11.

Whenever possible, the baseline score was compared to the score at the 5- to 8-year follow-up, 9- to 12-year

Table 2 Studies included in the meta-analysis (medial UKA)

Author	*n*	Method	Follow-up (years)	Score
Johnell et al. [49]	32	St. Georg, Waldemar Link GmbH	8.0	HSS
Broughton et al. [13]-uka[a]	46	No statement	5.8	HSS
Larsson et al. [56]	102	St. Georg, Waldemar Link GmbH	8.0	HSS
Marmor [62]	60	Marmor	10.0	
Barck [6]	48	No statement	10.0	
Stewart and Newton [92]	40	Manchester	12.0	
Scott et al. [84]	100	Marmor	13.0	HSS
Stockelman and Pohl [93]	63	Johnson & Johnson	7.5	
Tateishi et al. [99]	15	Marmor	7.0	HSS
Heck et al. [40]	294	No statement	6.0	HSS
Hasegawa et al. [37]	77	No statement	7.0	
Murray et al. [65]	143	Oxford I,	7.6	KSS
Tabor and Tabor [96]	61	Marmor	9.7	HSS
Bert [10]	95	Oxford, Biomet	10.1	HSS
Squire et al. [89]	140	Marmor	15.0	HSS
Weale et al. [105]	56	Oxford I, Biomet	10.0	KSS
Stukenborg-Colsman et al. [94]-uka[b]	30	Unicondylar, Aesculap	7.5	
Svard and Price [95]	124	Oxford I, Biomet	10.0	HSS
Ridgeway et al. [78]	254	No statement	5.0	KSS
Romanowski and Repicci [80]	136	Repicci	8.0	KSS
Skyrme et al. [87]	26	No statement	6.9	KSS
Hendel et al. [41]	22	No statement	5.5	HSS
Pennington et al. [73]	45	Miller-Galanate, Zimmer	11.0	
Hernigou and Deschamps [42]	212	No statement	10.0	HSS
Keblish and Briard [50]	147	LCS, Zimmer	12.0	HSS
Keys et al. [52]	40	Oxford	7.5	KSS
Naudie et al. [68]	113	Miller-Galanate, Zimmer	10.0	KOOS
Borjesson et al. [12]-uka[c]	22	Brigham	5.0	BOA
Endres et al. [27]	91	Osteonics, Stryker	5.0	
O'Rourke et al. [69]	136	Marmor	20.0	KSS
Price et al. [75]	564	Oxford, Biomet	10.0	HSS
Vorlat et al. [103]	114	Oxford, Biomet	10.0	HSS
Amin et al. [4]	54	Oxford, Biomet	5.0	KSS
Berger et al. [9]	62	Miller-Galanate, Zimmer	13.0	KSS
Eickmann et al. [24]	411	No statement	10.0	HSS
Steele et al. [90]	203	St Georg, Waldemar Link	15.0	
Cartier et al. [15]	165	No statement	9.0	Bristol
Emerson and Higgins [26]	54	Oxford II; Biomet	11.8	KSS
Daniilidis et al. [21]-c[d]	42	Endomodell Waldemar Link, cemented	7.6	
Daniilidis et al. [21]-cl[d]	64	Different models, cementless	7.6	HSS
Gulati et al. [35]	161	Oxford III, Biomet	5.0	HSS
Mercier et al. [64]	43	Oxford II, Biomet	15.0	KSS
Parratte et al. [72]	35	Miller-Galante, Zimmer	9.7	KSS

Some studies addressed the effects of different kinds of first-line treatments or were comparative studies (valgus HTO vs. medial UKA). The different groups were described as detailed. Both groups were described. However, the ESs of all of the patients were not given. Thus, the results of both groups were estimated as two different studies

[a] Broughton et al. [13] present a comparative study of the evaluation of valgus HTO versus medial UKA

[b] Stukenborg-Colsman et al. [94] present a comparative study of the evaluation of valgus HTO versus medial UKA

[c] Borjesson et al. [12] present a randomized prospective study of the evaluation of valgus HTO versus medial UKA

[d] Daniilidis et al. [21] present a comparative study of cemented (c) and cementless (cl) medial UKA

Table 3 Outcome measurements grouped by established knee score

Author	Group	Score	Time point	Mean	SD	*n*
Baseline						
Hasegawa et al. [37]	UKA	HSS	Baseline	52.0	11.0	77
Price et al. [75, 76]	UKA	HSS	Baseline	54.4	4.0	564
Gulati et al. [35]	UKA	KSS	Baseline	42.7	4.6	161
Mercier et al. [64]	UKA	KSS	Baseline	53.3	12.6	43
Wada et al. [104]	HTO	HSS	Baseline	69.2	5.8	39
Majima et al. [59]	HTO	Own	Baseline	59.1	5.5	48
Choi et al. [16]	HTO	JOA	Baseline	65.2	7.6	30
Sprenger and Doerzbacher [88]	HTO	HSS	Baseline	58.0	22.0	76
Koshino et al. [54]	HTO	KSS	Baseline	37.0	20.0	75
Christodoulou et al. [17]-LR	HTO	KSS	Baseline	58.0	3.2	32
Christodoulou et al. [17]	HTO	KSS	Baseline	60.0	5.5	32
Aoki et al. [5]-c.w	HTO	JOA	Baseline	53.2	21.2	86
Aoki et al. [5]-dome	HTO	JOA	Baseline	57.6	24.7	77
Akizuki et al. [3]	HTO	HSS	Baseline	60.7	11.2	118
Matsunaga et al. [63]	HTO	JOA	Baseline	51.6	7.1	114
Nagi et al. [66]	HTO	HSS	Baseline	74.0	8.5	26
Omori et al. [70]	HTO	JOA	Baseline	59.1	7.6	68
5- to 8-year follow-up						
Amin et al. [4]	UKA	KSS	5 year	83.5	8.1	48
Gulati et al. [35]	UKA	KSS	5 year	87.2	15.5	161
Sprenger and Doerzbacher [88]	HTO	HSS	5 year	79.6	18.4	65
Koshino et al. [54]	HTO	KSS	5 year	93.0	9.0	73
Christodoulou et al. [17]-LR	HTO	KSS	5 year	91.0	2.0	32
Christodoulou et al. [17]	HTO	KSS	5 year	80.0	3.6	32
Matsunaga et al. [63]	HTO	JOA	5 year	87.2	6.7	114
Wada et al. [104]	HTO	HSS	6 year	90.2	2.5	39
Hasegawa et al. [37]	UKA	HSS	7 year	88.0	7.0	68
Daniilidis et al. [21]-c	UKA	HSS	8 year	73.5	20.1	42
10-year follow-up						
Price et al. [75, 76]	UKA	HSS		90.0	2.5	540
Majima et al. [59]	HTO	Own	10 year	80.7	5.4	45
Sprenger and Doerzbacher [88]	HTO	HSS	10 year	70.0	24.8	56
Trieb et al. [100]	HTO	KSS	10 year	71.8	19.6	80
Koshino et al. [54]	HTO	KSS	10 year	93.0	9.0	71
Aoki et al. [5]-c.w	HTO	JOA	10 year	74.4	31.8	84
Aoki et al. [5]-dome	HTO	JOA	10 year	85.2	31.8	73
15-year follow-up						
Berger et al. [9]	UKA	HSS	15 year	67.0	9.0	56
Mercier et al. [64]	UKA	KSS	15 year	72.7	19.9	30
Sprenger and Doerzbacher [88]	HTO	HSS	15 year	52.6	30.2	43
Koshino et al. [54]	HTO	KSS	15 year	87.0	13.0	66
Akizuki et al. [3]	HTO	HSS	15 year	84.0	12.0	106
Omori et al. [70]	HTO	JOA	15 year	83.1	9.3	48

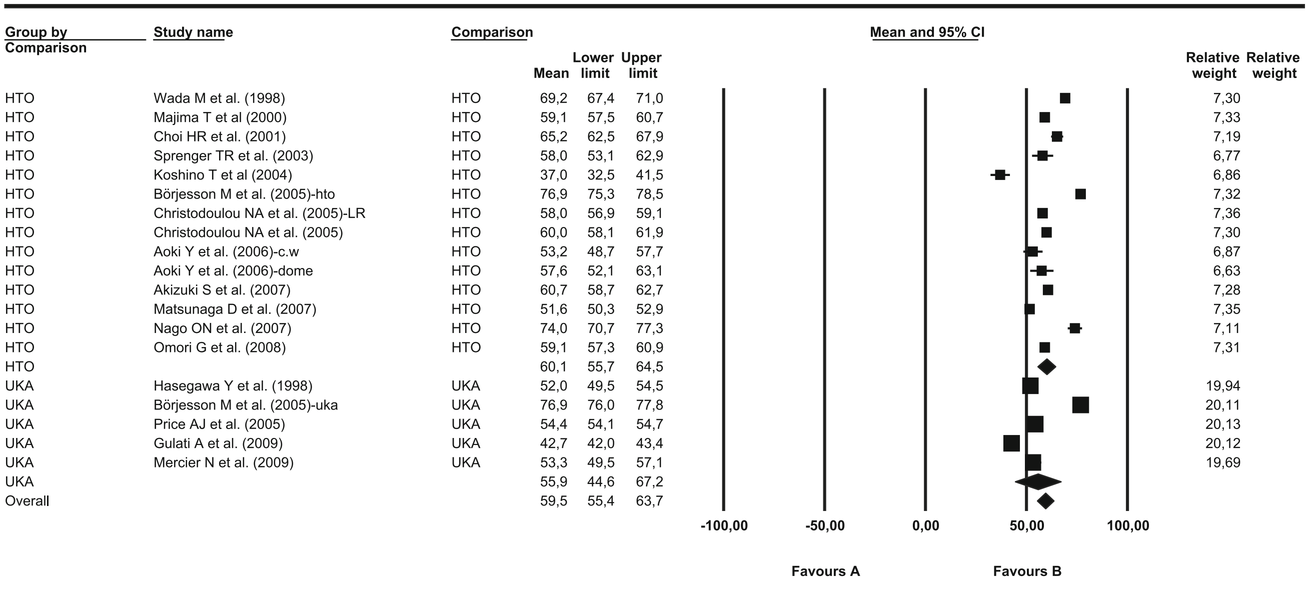

Fig. 8 Mean normalized knee scores at baseline. The forest plots present the mean score of each study. Each *square* represents the individual study's mean score with a 95% CI indicated by the *horizontal lines*. Number of included studies: valgus HTO, $n = 14$; medial UKA, $n = 5$. Mean: valgus HTO, 60.1; medial UKA, 55.9. Heterogeneity (I^2): valgus HTO = 98.5, medial UKA = 99.6, Significance: $P = 0.496$

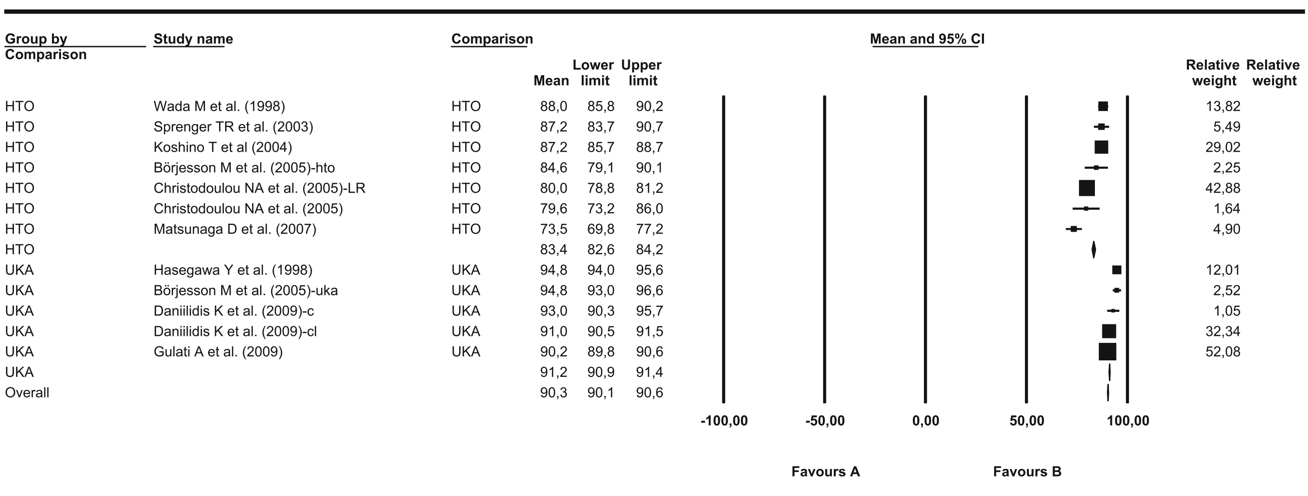

Fig. 9 Mean normalized knee score after 5–8 years of follow-up. The forest plots present the mean score of each study. Each *square* represents the individual study's mean score with a 95% CI indicated by the *horizontal lines*. Number of included studies: valgus HTO, $n = 7$; medial UKA, $n = 5$. Mean: valgus HTO, 83.4; medial UKA, 91.2. Heterogeneity (I^2): valgus HTO = 94.2, medial UKA = 96.6. Significance: $P < 0.001$

follow-up or the >12-year follow-up. SDM after valgus HTO tended to increase more in the valgus HTO studies (SDM = 5.0) compared with the medial UKA studies (4.1) after a 5- to 8-year follow-up (Fig. 12; n.s.).

Only the study by Price et al. [76] was available to compare the valgus HTO results ($n = 8$ studies) between baseline and the 9- to 12-year follow-up. In this study, the 9- to 12-year SDM was 10.7, whereas the SDM of the 8 valgus HTO studies was only 1.7 (Fig. 13). This difference was significant ($P < 0.001$).

Only 2 studies with very long-term results (>12-year follow-up) were identified. Mercier et al. [64] reported an SDM of approximately 1.2 after valgus HTO. Sprenger and Doerzbacher [88] found an SDM of −0.2 after 12 years. The difference between these studies was not significant (n.s; Fig. 14).

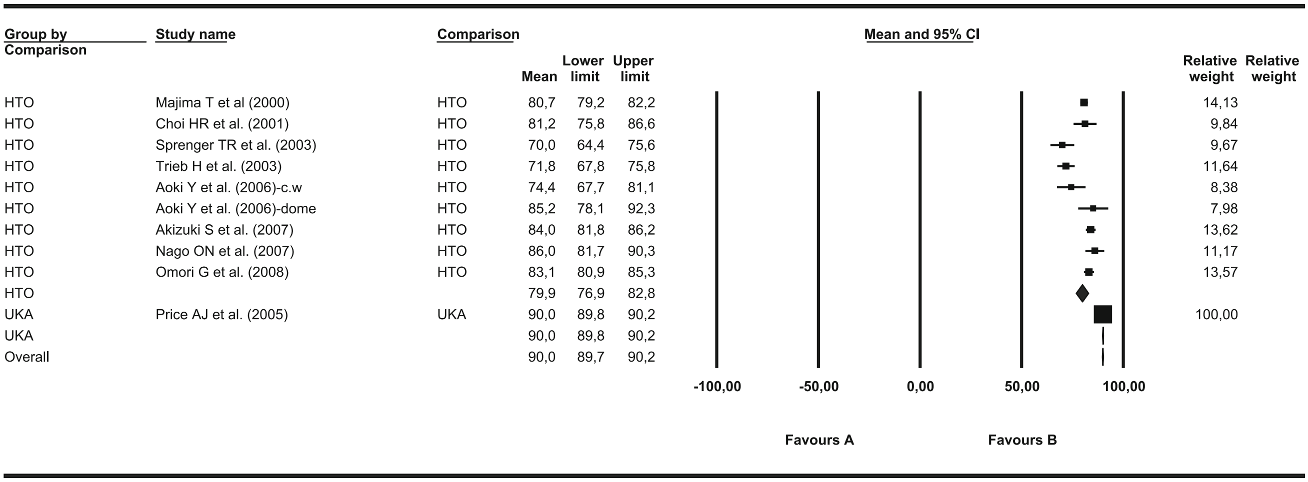

Fig. 10 Mean normalized knee score after 9–12 years of follow-up. The forest plots present the mean score of each study. Each *square* represents the individual study's mean score with a 95% CI indicated by the *horizontal lines*. Number of included studies: valgus HTO, $n = 9$; medial UKA, $n = 1$. Mean: valgus HTO, 79.9; medial UKA, 90.0. Heterogeneity (I^2): valgus HTO = 85.9; medial UKA is not adjustable. Significance: $P < 0.001$

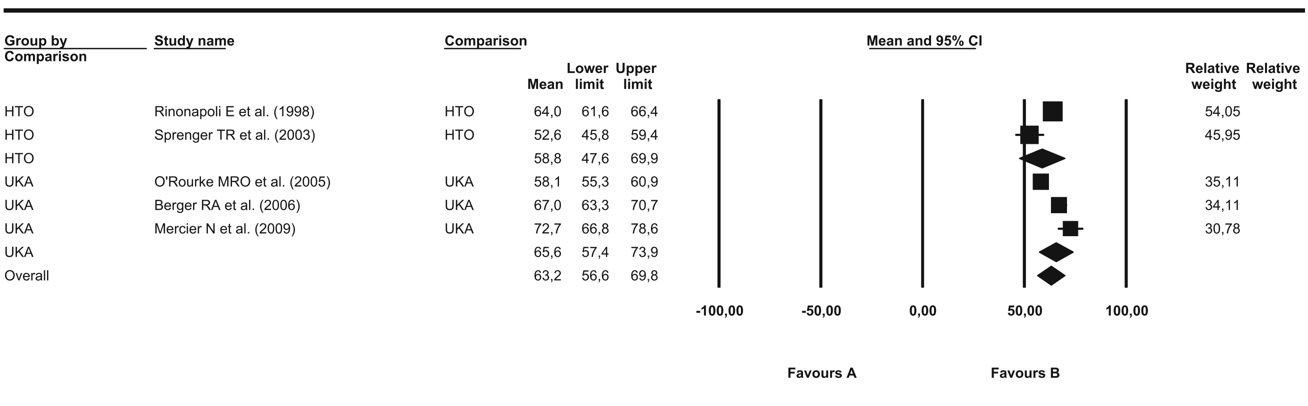

Fig. 11 Mean normalized knee score after more than 12 years of follow-up. The forest plots present the mean score of each study. Each *square* represents the individual study's mean score with a 95% CI indicated by the *horizontal lines*. Number of included studies: valgus HTO, $n = 2$; medial UKA, $n = 3$. Mean valgus HTO, 58.8; medial UKA, 65.6. Heterogeneity (I^2): valgus HTO = 89.2, medial UKA = 92.3. Significance: $P = 0.331$

Outcome measurement using established knee scores (semi-quantitative estimation)

In some papers, the result was estimated by establishing knee scores, and the results were expressed as semi-quantitative estimates. No significant differences between valgus HTO and medial UKA were observed (Table 3, Fig. 15).

Complications

In general, there were more complications after a valgus HTO (13.8%) than after a medial UKA (11.3%; n.s). Forest plots are shown in Fig. 16.

Discussion

The most important finding of this study was both valgus HTO and medial UKA are sufficient operative treatment options for symptomatic medial knee osteoarthritis.

This meta-analysis was undertaken to compare the impacts of valgus HTO and medial UKA on the treatment for symptomatic unicondylar medial knee osteoarthritis. Survival rates to total knee replacement were not different. Over time, both groups exhibited increased revision rates. Clinical outcome of medial UKA is better than that of valgus HTO. After more than 12 postoperative years, patients in both groups exhibited worsening clinical outcomes.

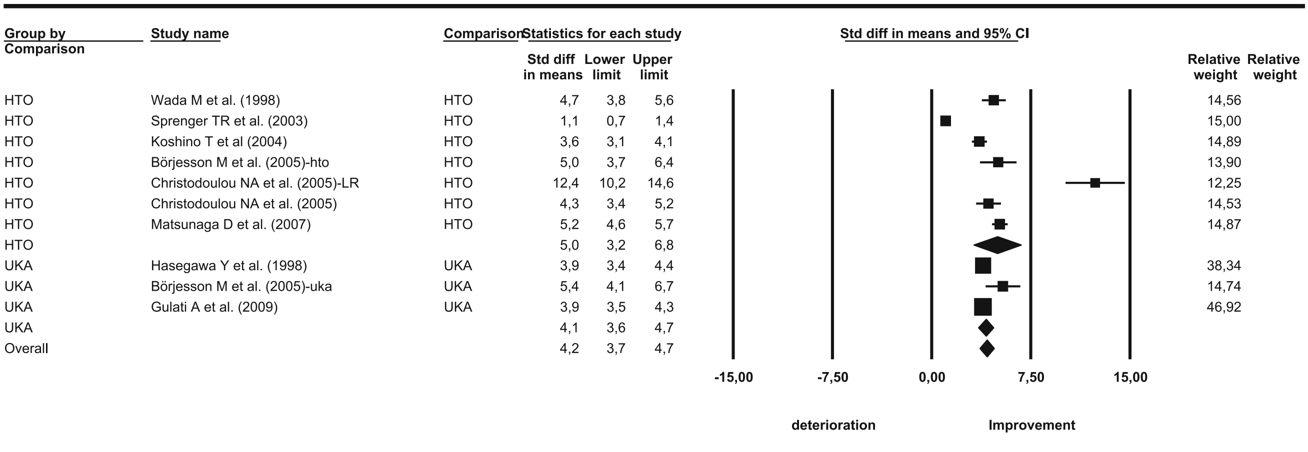

Fig. 12 Weighted (standardized) mean (SDM) of the score from baseline to 5–8 years of follow-up. The forest plots present the SDMs of each study. Each *square* represents the individual study's SDM with a 95% CI indicated by the *horizontal lines*. Number of included studies: valgus HTO, $n = 7$; medial UKA, $n = 3$. SDM: valgus HTO, 5.0; medial UKA, 4.1. Heterogeneity (I^2): valgus HTO = 97.5; medial UKA = 60.1. Significance: $P = 0.359$

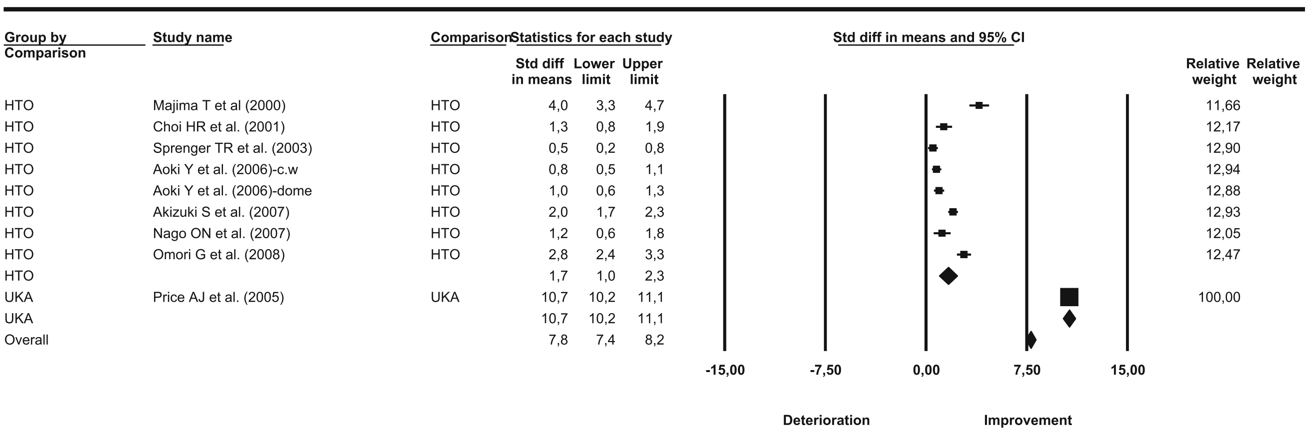

Fig. 13 Weighted (standardized) mean (SDM) of the score from baseline to 9–12 years of follow-up. The forest plots present the SDMs of each study. Each *square* represents the individual study's SDM with a 95% CI indicated by the *horizontal lines*. Number of included studies: valgus HTO: $n = 8$; medial UKA: $n = 1$. SDM: valgus HTO, 1.7; medial UKA, 10.7. Heterogeneity (I^2): valgus HTO = 95.4. Heterogeneity (I^2) was not adjustable. Significance: $P < 0.001$

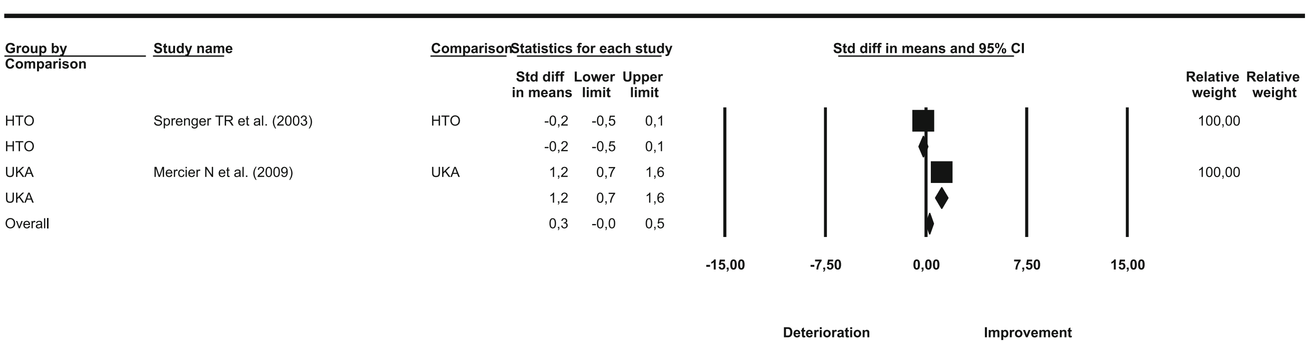

Fig. 14 Weighted (standardized) mean (SDM) of the score from baseline to more than 12 years of follow-up. The forest plots present the SDMs of each study. Each *square* represents the individual study's SDM with a 95% CI indicated by the *horizontal lines*. Number of included studies: valgus HTO, $n = 1$; medial UKA, $n = 1$. SDM: valgus HTO, −0.2; medial UKA, 1.2. Heterogeneity was not adjustable. Significance: $P = 0.603$

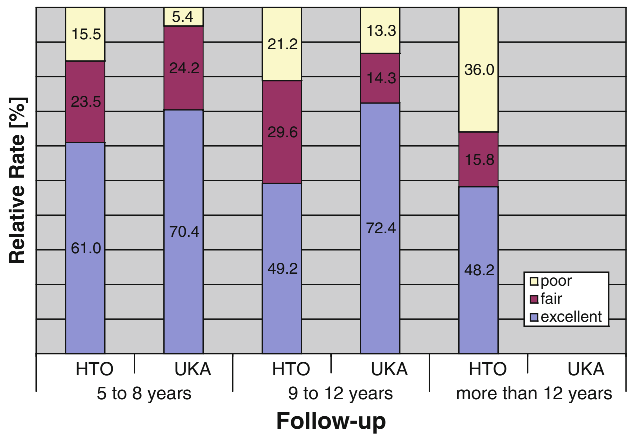

Fig. 15 Semi-quantitative estimation of the clinical outcome based on the evaluation using clinical scores. The detailed ESs are given in Table 4

Both methods are clinically very interesting. This is reflected by the large number of published studies on this topic. In this meta-analysis, we excluded studies with follow-ups >5 years and studies that did not enable the evaluation of concrete effect sizes. Furthermore, clear duplicates were excluded from this evaluation. This was also considered for the results of the central arthroplasty registers [28, 53, 55, 60]. An important limitation is the large heterogeneity of the studies (range, 70–95%). Only 3 comparative [12, 13, 94] studies were found on this topic. The survival and outcome results of these studies are contradictory.

Both valgus HTO and medial UKA are, in principle, sufficient for the treatment for medial knee osteoarthritis.

A valgus HTO corrects varus malalignment by transferring the load to the relatively unaffected lateral

Table 4 Outcome estimates grouped by established knee score

Author	Group	Score	Excellent–good	Moderate–fair	Poor	*n*
5- to 8-year follow-up						
Broughton et al. [13]-uka	UKA	HSS	24	2	2	28
Stockelman and Pohl [93]	UKA	HSS	33	10	5	48
Ridgeway et al. [78]	UKA	HSS	105	40	31	176
Berger et al. [9]	UKA	HSS	40	10	1	51
Vainionpaa et al. [101]-normal	HTO	Coventry	3	6	2	11
Vainionpaa et al. [101]-varus	HTO	Coventry	48	29	15	92
Broughton et al. [13]-hto	HTO	HSS	21	11	7	39
Sasaki et al. [82]	HTO	JOA	41	20	10	71
Yasuda et al. [106]	HTO	JOA	35	14	7	56
Rinonapoli et al. [79]	HTO	HSS	19	5	2	26
Koshino et al. [54]	HTO	KSS	72	3	0	75
Polyzois et al. [74]	HTO	HSS	58	16	21	95
10-year f.u.						
Marmor [62]	UKA	HSS	30	12	18	60
Weale et al. [105]	UKA	HSS	25	2	1	28
Holden et al. [45]	HTO	HSS	36	11	4	51
Yasuda et al. [106]	HTO	JOA	10	25	16	51
Coventry et al. [20]	HTO	Coventry	38	40	9	87
Hassenpflug et al. [38]	HTO	JOA	28	25	85	138
Majima et al. [59]	HTO	Own	5	12	11	28
Koshino et al. [54]	HTO	KSS	71	4	0	75
Papachristou et al. [71]	HTO	HSS	16	2	3	21
15-year f.u.						
Rinonapoli et al. [79]	HTO	HSS	12	3	11	26
Choi et al. [16]	HTO	JOA	18	3	9	30
Aglietti et al. [2]	HTO	HSS	43	13	35	91
Koshino et al. [54]	HTO	KSS	68	7	0	75
Flecher et al. [30]	HTO	Own	98	133	44	275
Papachristou et al. [71]	HTO	HSS	8	5	2	15

Group by Comparison	Study name	Comparison	Event rate	Lower limit	Upper limit	Relative weight	Relative weight
HTO	Ha'eri GB et al. (1979)	HTO	0,571	0,360	0,760	3,13	
HTO	Broughton NS et al. (1986)-hto	HTO	0,378	0,249	0,526	3,64	
HTO	Sasaki T et al. (1986)	HTO	0,141	0,077	0,242	3,52	
HTO	Holden D et al. (1988)	HTO	0,078	0,030	0,191	2,83	
HTO	Ivarsson I et al. (1990)	HTO	0,101	0,055	0,178	3,54	
HTO	Yasuda K et al. (1992)	HTO	0,054	0,017	0,153	2,56	
HTO	Hassenpflug J et al. (1998)	HTO	0,164	0,116	0,226	3,99	
HTO	Wada M et al. (1998)	HTO	0,013	0,001	0,171	0,88	
HTO	Naudie D et al. (1999)	HTO	0,340	0,256	0,435	3,98	
HTO	Billings A et al. (2000)	HTO	0,087	0,040	0,180	3,18	
HTO	Majima T et al (2000)	HTO	0,042	0,010	0,152	2,14	
HTO	Choi HR et al. (2001)	HTO	0,067	0,017	0,231	2,12	
HTO	Hernigou P and Ma W (2001)	HTO	0,161	0,098	0,254	3,70	
HTO	Stukenborg-C C et al. (2001)-hto	HTO	0,281	0,153	0,458	3,32	
HTO	Devgan A et al. (2003)	HTO	0,060	0,019	0,170	2,56	
HTO	Flamme CH et al. (2003)	HTO	0,099	0,054	0,174	3,55	
HTO	Sen C et al. (2003)-fix	HTO	0,519	0,336	0,696	3,35	
HTO	Sen C et al. (2003)-int	HTO	0,269	0,134	0,467	3,13	
HTO	Sprenger TR et al. (2003)	HTO	0,211	0,133	0,316	3,73	
HTO	Trieb H et al. (2003)	HTO	0,053	0,022	0,121	3,06	
HTO	Koshino T et al (2004)	HTO	0,053	0,020	0,134	2,85	
HTO	Gall N et al. (2005)	HTO	0,120	0,079	0,179	3,88	
HTO	Huang TL et al (2005)	HTO	0,075	0,036	0,150	3,32	
HTO	Tang WC et al. (2005)	HTO	0,075	0,031	0,167	3,04	
HTO	Aoki Y et al. (2006)-c.w	HTO	0,174	0,108	0,269	3,72	
HTO	Aoki Y et al. (2006)-dome	HTO	0,065	0,027	0,147	3,05	
HTO	Papachristou G et al. (2006)	HTO	0,114	0,048	0,245	3,00	
HTO	Polyzois D et al. (2006)	HTO	0,081	0,045	0,140	3,62	
HTO	Akizuki S et al. (2007)	HTO	0,127	0,078	0,200	3,75	
HTO	Gstöttner M et al. (2008)	HTO	0,284	0,214	0,366	4,02	
HTO	Benzakour T et al. (2010)	HTO	0,099	0,064	0,150	3,87	
HTO			0,138	0,107	0,177		
UKA	Broughton NS et al. (1986)-uka	UKA	0,109	0,046	0,236		7,39
UKA	Larsson SE et al. (1986)	UKA	0,049	0,021	0,112		7,58
UKA	Marmor L (1988)	UKA	0,200	0,117	0,320		9,46
UKA	Barck AL (1989)	UKA	0,188	0,101	0,323		8,79
UKA	Hasegawa Y et al. (1998)	UKA	0,143	0,081	0,240		9,42
UKA	Stukenborg-C C et al. (2001)-uka	UKA	0,067	0,017	0,231		4,71
UKA	Romanowski MR and Repicci JA (2002)	UKA	0,132	0,085	0,200		10,44
UKA	Skyrme AD et al. (2002)	UKA	0,192	0,082	0,387		7,09
UKA	Hendel D et al. (2003)	UKA	0,022	0,001	0,268		1,71
UKA	Keblish PA et al. (2004)	UKA	0,231	0,170	0,306		11,18
UKA	Keys GW et al. (2004)	UKA	0,050	0,013	0,179		4,76
UKA	Naudie D et al. (2004)	UKA	0,088	0,048	0,157		9,34
UKA	Cartier P et al. (2007)	UKA	0,036	0,016	0,079		8,15
UKA			0,113	0,079	0,160		
Overall			0,129	0,105	0,158		

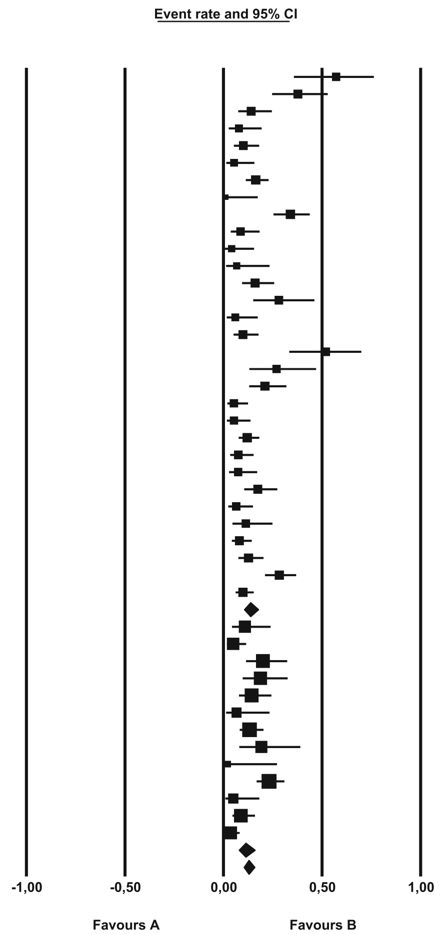

Fig. 16 Complication rates. The forest plots present the effect sizes (*ER* event rate). Each *square* represents the individual study's ER with a 95% CI indicated by the *horizontal lines*. Number of included studies: valgus HTO, $n = 31$; medial UKA, $n = 13$. Complications: valgus HTO, 0.138; medial UKA, 0.113. Heterogeneity (I^2): valgus HTO = 82.0, medial UKA = 70.2. Significance: $P = 0.369$

compartment. This can be accompanied by pain relief and improvements in gait and function. Mechanical release alone or a combination of HTO with arthroscopic measures (debridement, synovectomy or microfracture), chondral resurfacing or meniscal transplantation can also improve these results [25, 83]. The main benefit for the patient is the preservation of the natural joint. The main advantage for the patient is that potential physical loading (professional or sports-related) is almost entirely unaffected. The limits of valgus HTO are failure of medial compartment restoration, progression of medial degeneration, progression of degeneration in the patellofemoral or lateral compartment and development of pathological valgus. However, in most patients, this method is generally sufficient for avoiding a TKA for about 10 years. Moreover, a revision to a TKA generally does not cause problems [33, 97].

With the proviso that very excellent results are seldom achieved, the valgus HTO can be considered to be the method of choice for younger and physically active patients who are suffering from unicompartmental knee osteoarthritis.

Unlike medial UKA, this treatment addresses the reconstruction of the joint surface by replacing the degenerated joint part and preserving the unaffected joint. A correction of axial misalignment is seldom possible. The main limitation of medial UKA is partially similar to that of valgus HTO (progression of osteoarthritis). The method is comparable to valgus HTO but with a slightly lower complication rate and a shorter rehabilitation time. This outcome is associated with a better 12-year knee score outcome. However, this method also has important disadvantages. Medial UKA requires restricted physical activity. This may be a reason for the higher mean age of the patients who undergo medial UKA. If needed, a revision from medial UKA to total arthroplasty causes more problems and worsens the worse result [7].

Conclusions

This meta-analysis examined the advantages and disadvantages of two established methods for treatment for medial compartment knee osteoarthritis. Valgus HTO is more appropriate for younger patients who accept slight decreases in physical activity in their lifestyles. Medial UKA is a good method for older patients who need painless but reduced physical activity.

References

1. Aglietti P, Buzzi R, Vena LM, Baldini A, Mondaini A (2003) High tibial valgus osteotomy for medial gonarthrosis: a 10- to 21-year study. J Knee Surg 16:21–26
2. Akizuki S, Shibakawa A, Takizawa T, Yamazaki I, Horiuchi H (2008) The long-term outcome of high tibial osteotomy: a ten- to 20-year follow-up. J Bone Joint Surg Br 90:592–596
3. Amin AK, Patton JT, Cook RE, Gaston M, Brenkel IJ (2006) Unicompartmental or total knee arthroplasty? Results from a matched study. Clin Orthop Relat Res 451:101–106
4. Aoki Y, Yasuda K, Mikami S, Ohmoto H, Majima T, Minami A (2006) Inverted V-shaped high tibial osteotomy compared with closing-wedge high tibial osteotomy for osteoarthritis of the knee. Ten-year follow-up result. J Bone Joint Surg Br 88:1336–1340
5. Barck AL (1989) 10-year evaluation of compartmental knee arthroplasty. J Arthroplast 4(Suppl:S49–S54)
6. Becker R, John M, Neumann WH (2004) Clinical outcomes in the revision of unicondylar arthoplasties to bicondylar arthroplasties. A matched-pair study. Arch Orthop Trauma Surg 124:702–707
7. Benzakour T, Hefti A, Lemseffer M, El Ahmadi JD, Bouyarmane H, Benzakour A (2010) High tibial osteotomy for medial osteoarthritis of the knee: 15 years follow-up. Int Orthop 34:209–215
8. Berger RA, Nedeff DD, Barden RM, Sheinkop MM, Jacobs JJ, Rosenberg AG, Galante JO (1999) Unicompartmental knee arthroplasty. Clinical experience at 6- to 10-year followup. Clin Orthop Relat Res 367:50–60
9. Bert JM (1998) 10-year survivorship of metal-backed, unicompartmental arthroplasty. J Arthroplast 13:901–905
10. Billings A, Scott DF, Camargo MP, Hofmann AA (2000) High tibial osteotomy with a calibrated osteotomy guide, rigid internal fixation, and early motion. Long-term follow-up. J Bone Joint Surg Am 82:70–79
11. BOA (1978) A knee function assessment chart. From the British Orthopaedic Association Research Sub-Committee. J Bone Joint Surg Br 60-B:308–309
12. Borjesson M, Weidenhielm L, Mattsson E, Olsson E (2005) Gait and clinical measurements in patients with knee osteoarthritis after surgery: a prospective 5-year follow-up study. Knee 12:121–127
13. Broughton NS, Newman JH, Baily RA (1986) Unicompartmental replacement and high tibial osteotomy for osteoarthritis of the knee. A comparative study after 5–10 years' follow-up. J Bone Joint Surg Br 68:447–452
14. Buckwalter JA, Saltzman C, Brown T (2004) The impact of osteoarthritis: implications for research. Clin Orthop Relat Res 427:S6–S15
15. Cartier P, Khefacha A, Sanouiller JL, Frederick K (2007) Unicondylar knee arthroplasty in middle-aged patients: a minimum 5-year follow-up. Orthopedics 30:62–65
16. Choi HR, Hasegawa Y, Kondo S, Shimizu T, Ida K, Iwata H (2001) High tibial osteotomy for varus gonarthrosis: a 10- to 24-year follow-up study. J Orthop Sci 6:493–497
17. Christodoulou NA, Tsaknis RN, Sdrenias CV, Galanis KG, Mavrogenis AF (2005) Improvement of proximal tibial osteotomy results by lateral retinacular release. Clin Orthop Relat Res 441:340–345
18. Coventry MB (1965) Osteotomy of the upper portion of the tibia for degenerative arthritis of the knee. A preliminary report. J Bone Joint Surg Am 47:984–990
19. Coventry MB (1973) Osteotomy about the knee for degenerative and rheumatoid arthritis. J Bone Joint Surg Am 55:23–48
20. Coventry MB, Ilstrup DM, Wallrichs SL (1993) Proximal tibial osteotomy. A critical long-term study of eighty-seven cases. J Bone Joint Surg Am 75:196–201
21. Daniilidis K, Skwara A, Skuginna A, Fischer F, Tibesku CO (2009) Comparison of medium-term clinical and radiological outcome between cemented and cementless medial unicompartmental knee arthroplasty. Z Orthop Unfall 147:188–193
22. De MP, Maquet P, Simonet J (1963) Biomechanical consideration of arthrosis of the knee. 1. Introduction. Some remarks on radiographs. Rev Rhum Mal Osteoartic 30:775–776
23. Devgan A, Marya KM, Kundu ZS, Sangwan SS, Siwach RC (2003) Medial opening wedge high tibial osteotomy for osteoarthritis of knee: long-term results in 50 knees. Med J Malaysia 58:62–68
24. Eickmann TH, Collier MB, Sukezaki F, McAuley JP, Engh GA (2006) Survival of medial unicondylar arthroplasties placed by one surgeon 1984–1998. Clin Orthop Relat Res 452:143–149
25. Elattar M, Dhollander A, Verdonk R, Almqvist KF, Verdonk P (2011) Twenty-six years of meniscal allograft transplantation: is it still experimental? A meta-analysis of 44 trials. Knee Surg Sports Traumatol Arthrosc 19:147–157
26. Emerson RH Jr, Higgins LL (2008) Unicompartmental knee arthroplasty with the oxford prosthesis in patients with medial compartment arthritis. J Bone Joint Surg Am 90:118–122
27. Endres S, Steinheiser E, Wilke A (2005) Minimally Invasive Stryker-Osteonics unicondylar knee prosthesis with metal-backed tibia component: a 5-year follow-up. Z Orthop Ihre Grenzgeb 143:573–580
28. Espehaug B, Furnes O, Havelin LI, Engesaeter LB, Vollset SE, Kindseth O (2006) Registration completeness in the Norwegian Arthroplasty Register. Acta Orthop 77:49–56
29. Flamme CH, Ruhmann O, Schmolke S, Wichmann R (2003) Long-term outcome following high tibial osteotomy with tension bend principle. Arch Orthop Trauma Surg 123:12–16
30. Flecher X, Parratte S, Aubaniac JM, Argenson JN (2006) A 12–28-year followup study of closing wedge high tibial osteotomy. Clin Orthop Relat Res 452:91–96
31. Frey P, Muller M, Munzinger U (2008) Closing-wedge high tibial osteotomy with a modified Weber technique. Oper Orthop Traumatol 20:75–88
32. Gall N, Fickert S, Puhl W, Gunther KP, Stove J (2005) Predictors of tibial head transposition in the therapy of varus knee osteoarthritis. Z Orthop Ihre Grenzgeb 143:551–555
33. Gill T, Schemitsch EH, Brick GW, Thornhill TS (1995) Revision total knee arthroplasty after failed unicompartmental knee arthroplasty or high tibial osteotomy. Clin Orthop Relat Res 321:10–18
34. Gstottner M, Pedross F, Liebensteiner M, Bach C (2008) Long-term outcome after high tibial osteotomy. Arch Orthop Trauma Surg 128:111–115

35. Gulati A, Pandit H, Jenkins C, Chau R, Dodd CA, Murray DW (2009) The effect of leg alignment on the outcome of unicompartmental knee replacement. J Bone Joint Surg Br 91:469–474
36. Ha'eri GB, Wiley AM (1980) High tibial osteotomy combined with joint debridement: a long-term study of results. Clin Orthop Relat Res 151:153–159
37. Hasegawa Y, Ooishi Y, Shimizu T, Sugiura H, Takahashi S, Ito H, Iwata H (1998) Unicompartmental knee arthroplasty for medial gonarthrosis: 5 to 9 years follow-up evaluation of 77 knees. Arch Orthop Trauma Surg 117:183–187
38. Hassenpflug J, von Haugwitz A, Hahne HJ (1998) Long-term results of tibial head osteotomy. Z Orthop Ihre Grenzgeb 136:154–161
39. Heaton KT, Dorr LD (2003) History of knee arthroplasty. In: Callaghan JJ, Rosenberg AG, Rubash HE, Simonian PT, Wickeewicz TL (eds) The adult knee. Lipincott Williams and Wilkins, Philadelphia, pp 15–24
40. Heck DA, Marmor L, Gibson A, Rougraff BT (1993) Unicompartmental knee arthroplasty. A multicenter investigation with long-term follow-up evaluation. Clin Orthop Relat Res 286:154–159
41. Hendel D, Beloosesky Y, Garti A, Weisbort M (2003) Medial unicompartmental replacement for tricompartmental disease in the elderly. Knee 10:363–365
42. Hernigou P, Deschamps G (2004) Posterior slope of the tibial implant and the outcome of unicompartmental knee arthroplasty. J Bone Joint Surg Am 86-A:506–511
43. Hernigou P, Ma W (2001) Open wedge tibial osteotomy with acrylic bone cement as bone substitute. Knee 8:103–110
44. Higgins JP, Thompson SG, Deeks JJ, Altman DG (2003) Measuring inconsistency in meta-analyses. BMJ 327:557–560
45. Holden DL, James SL, Larson RL, Slocum DB (1988) Proximal tibial osteotomy in patients who are fifty years old or less. A long-term follow-up study. J Bone Joint Surg Am 70:977–982
46. Huang TL, Tseng KF, Chen WM, Lin RM, Wu JJ, Chen TH (2005) Preoperative tibiofemoral angle predicts survival of proximal tibia osteotomy. Clin Orthop Relat Res 432:188–195
47. Insall JN, Dorr LD, Scott RD, Scott WN (1989) Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 248:13–14
48. Ivarsson I, Myrnerts R, Gillquist J (1990) High tibial osteotomy for medial osteoarthritis of the knee. A 5 to 7 and 11 year follow-up. J Bone Joint Surg Br 72:238–244
49. Johnell O, Sernbo I, Gentz CF (1985) Unicompartmental knee replacement in osteoarthritis: an 8-year follow-up. Arch Orthop Trauma Surg 103:371–374
50. Keblish PA, Briard JL (2004) Mobile-bearing unicompartmental knee arthroplasty: a 2-center study with an 11-year (mean) follow-up. J Arthroplast 19:87–94
51. Kellgren JH, Lawrence JS (1957) Radiological assessment of osteo-arthrosis. Ann Rheum Dis 16:494–502
52. Keys GW, Ul-Abiddin Z, Toh EM (2004) Analysis of first forty Oxford medial unicompartmental knee replacement from a small district hospital in UK. Knee 11:375–377
53. Knutson K, Robertsson O (2010) The Swedish Knee Arthroplasty Register (http://www.knee.se). Acta Orthop 81:5–7
54. Koshino T, Yoshida T, Ara Y, Saito I, Saito T (2004) Fifteen to twenty-eight years' follow-up results of high tibial valgus osteotomy for osteoarthritic knee. Knee 11:439–444
55. Koskinen E, Paavolainen P, Eskelinen A, Pulkkinen P, Remes V (2007) Unicondylar knee replacement for primary osteoarthritis: a prospective follow-up study of 1,819 patients from the Finnish Arthroplasty Register. Acta Orthop 78:128–135
56. Larsson SE, Larsson S, Lundkvist S (1988) Unicompartmental knee arthroplasty. A prospective consecutive series followed for six to 11 years. Clin Orthop Relat Res 232:174–181
57. Lysholm J, Gillquist J (1982) Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. Am J Sports Med 10:150–154
58. Mackinnon J, Young S, Baily RA (1988) The St Georg sledge for unicompartmental replacement of the knee. A prospective study of 115 cases. J Bone Joint Surg Br 70:217–223
59. Majima T, Yasuda K, Katsuragi R, Kaneda K (2000) Progression of joint arthrosis 10 to 15 years after high tibial osteotomy. Clin Orthop Relat Res 381:177–184
60. Malik MH, Chougle A, Pradhan N, Gambhir AK, Porter ML (2005) Primary total knee replacement: a comparison of a nationally agreed guide to best practice and current surgical technique as determined by the North West Regional Arthroplasty Register. Ann R Coll Surg Engl 87:117–122
61. Maqut P (1963) A biomechanical treatment of femoro-patellar arthrosis: advancement of patellar tendon. Rev Rhum Mal Osteoartic 30:779–783
62. Marmor L (1988) Unicompartmental arthroplasty of the knee with a minimum ten-year follow-up period. Clin Orthop Relat Res 228:171–177
63. Matsunaga D, Akizuki S, Takizawa T, Yamazaki I, Kuraishi J (2007) Repair of articular cartilage and clinical outcome after osteotomy with microfracture or abrasion arthroplasty for medial gonarthrosis. Knee 14:465–471
64. Mercier N, Wimsey S, Saragaglia D (2010) Long-term clinical results of the Oxford medial unicompartmental knee arthroplasty. Int Orthop 34:1137–1143
65. Murray DW, Goodfellow JW, O'Connor JJ (1998) The Oxford medial unicompartmental arthroplasty: a ten-year survival study. J Bone Joint Surg Br 80:983–989
66. Nagi ON, Kumar S, Aggarwal S (2007) Combined lateral closing and medial opening-wedge high tibial osteotomy. J Bone Joint Surg Am 89:542–549
67. Naudie D, Bourne RB, Rorabeck CH, Bourne TJ (1999) The Install Award. Survivorship of the high tibial valgus osteotomy. A 10- to -22-year followup study. Clin Orthop Relat Res 367:18–27
68. Naudie D, Guerin J, Parker DA, Bourne RB, Rorabeck CH (2004) Medial unicompartmental knee arthroplasty with the Miller-Galante prosthesis. J Bone Joint Surg Am 86-A:1931–1935
69. Omori G, Koga Y, Miyao M, Takemae T, Sato T, Yamagiwa H (2008) High tibial osteotomy using two threaded pins and figure-of-eight wiring fixation for medial knee osteoarthritis: 14 to 24 years follow-up results. J Orthop Sci 13:39–45
70. O'Rourke MR, Gardner JJ, Callaghan JJ, Liu SS, Goetz DD, Vittetoe DA, Sullivan PM, Johnston RC (2005) The John Insall Award: unicompartmental knee replacement: a minimum twenty-one-year followup, end-result study. Clin Orthop Relat Res 440:27–37
71. Papachristou G, Plessas S, Sourlas J, Levidiotis C, Chronopoulos E, Papachristou C (2006) Deterioration of long-term results following high tibial osteotomy in patients under 60 years of age. Int Orthop 30:403–408
72. Parratte S, Argenson JN, Pearce O, Pauly V, Auquier P, Aubaniac JM (2009) Medial unicompartmental knee replacement in the under-50 s. J Bone Joint Surg Br 91:351–356
73. Pennington DW, Swienckowski JJ, Lutes WB, Drake GN (2003) Unicompartmental knee arthroplasty in patients sixty years of age or younger. J Bone Joint Surg Am 85-A:1968–1973
74. Polyzois D, Stavlas P, Polyzois V, Zacharakis N (2006) The oblique high tibial osteotomy technique without bone removal and with rigid blade plate fixation for the treatment of medial osteoarthritis of the varus knee: medium and long-term results. Knee Surg Sports Traumatol Arthrosc 14:940–947
75. Price AJ, Dodd CA, Svard UG, Murray DW (2005) Oxford medial unicompartmental knee arthroplasty in patients younger

and older than 60 years of age. J Bone Joint Surg Br 87:1488–1492
76. Price AJ, Waite JC, Svard U (2005) Long-term clinical results of the medial Oxford unicompartmental knee arthroplasty. Clin Orthop Relat Res 435:171–180
77. Ranawat CS, Shine JJ (1973) Duo-condylar total knee arthroplasty. Clin Orthop Relat Res 94:185–195
78. Ridgeway SR, McAuley JP, Ammeen DJ, Engh GA (2002) The effect of alignment of the knee on the outcome of unicompartmental knee replacement. J Bone Joint Surg Br 84:351–355
79. Rinonapoli E, Mancini GB, Corvaglia A, Musiello S (1998) Tibial osteotomy for varus gonarthrosis. A 10- to 21-year followup study. Clin Orthop Relat Res 353:185–193
80. Romanowski MR, Repicci JA (2002) Minimally invasive unicondylar arthroplasty: eight-year follow-up. J Knee Surg 15:17–22
81. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD (1998) Knee Injury and Osteoarthritis Outcome Score (KOOS)—development of a self-administered outcome measure. J Orthop Sports Phys Ther 28:88–96
82. Sasaki T, Yagi T, Monji J, Yasuda K, Tsuge H (1986) High tibial osteotomy combined with anterior displacement of the tibial tubercle for osteoarthritis of the knee. Int Orthop 10:31–40
83. Schultz W, Gobel D (1999) Articular cartilage regeneration of the knee joint after proximal tibial valgus osteotomy: a prospective study of different intra- and extra-articular operative techniques. Knee Surg Sports Traumatol Arthrosc 7:29–36
84. Scott RD, Cobb AG, McQueary FG, Thornhill TS (1991) Unicompartmental knee arthroplasty. Eight- to 12-year follow-up evaluation with survivorship analysis. Clin Orthop Relat Res 271:96–100
85. Sen C, Kocaoglu M, Eralp L (2003) The advantages of circular external fixation used in high tibial osteotomy (average 6 years follow-up). Knee Surg Sports Traumatol Arthrosc 11:139–144
86. Simonet J, Maquet P, De MP (1963) Biomechanical considerations on arthrosis of the knee. Study of forces. Osteotomy. Rev Rhum Mal Osteoartic 30:777–778
87. Skyrme AD, Mencia MM, Skinner PW (2002) Early failure of the porous-coated anatomic cemented unicompartmental knee arthroplasty: A 5- to 9-year follow-up study. J Arthroplast 17:201–205
88. Sprenger TR, Doerzbacher JF (2003) Tibial osteotomy for the treatment of varus gonarthrosis. Survival and failure analysis to twenty-two years. J Bone Joint Surg Am 85-A:469–474
89. Squire MW, Callaghan JJ, Goetz DD, Sullivan PM, Johnston RC (1999) Unicompartmental knee replacement. A minimum 15 year followup study. Clin Orthop Relat Res 367:61–72
90. Steele RG, Hutabarat S, Evans RL, Ackroyd CE, Newman JH (2006) Survivorship of the St Georg Sled medial unicompartmental knee replacement beyond ten years. J Bone Joint Surg Br 88:1164–1168
91. Sterett WI, Steadman JR, Huang MJ, Matheny LM, Briggs KK (2010) Chondral resurfacing and high tibial osteotomy in the varus knee: survivorship analysis. Am J Sports Med 38:1420–1424
92. Stewart HD, Newton G (1992) Long-term results of the Manchester knee. Surface arthroplasty of the tibiofemoral joint. Clin Orthop Relat Res 278:138–146
93. Stockelman RE, Pohl KP (1991) The long-term efficacy of unicompartmental arthroplasty of the knee. Clin Orthop Relat Res 271:88–95
94. Stukenborg-Colsman C, Wirth CJ, Lazovic D, Wefer A (2001) High tibial osteotomy versus unicompartmental joint replacement in unicompartmental knee joint osteoarthritis: 7–10-year follow-up prospective randomised study. Knee 8:187–194
95. Svard UC, Price AJ (2001) Oxford medial unicompartmental knee arthroplasty. A survival analysis of an independent series. J Bone Joint Surg Br 83:191–194
96. Tabor OB Jr, Tabor OB (1998) Unicompartmental arthroplasty: a long-term follow-up study. J Arthroplast 13:373–379
97. Takai S, Yoshino N, Hirasawa Y (1997) Revision total knee arthroplasty after failed high tibial osteotomy. Bull Hosp Jt Dis 56:245–250
98. Tang WC, Henderson IJ (2005) High tibial osteotomy: long term survival analysis and patients' perspective. Knee 12:410–413
99. Tateishi H, Maruoka T, Yoh K, Iwata Y, Futani H, Yamada H, Maruo S (1991) A long-term follow-up study of unicompartmental replacement with a Marmor knee prosthesis and the introduction of a new ceramic prosthesis. Bull Hosp Jt Dis Orthop Inst 51:132–139
100. Trieb K, Cetin E, Stulnig T, Wanivenhaus A (2003) Long-term results after uni- and bilateral high tibial osteotomies. Z Orthop Ihre Grenzgeb 141:33–36
101. Vainionpaa S, Laike E, Kirves P, Tiusanen P (1981) Tibial osteotomy for osteoarthritis of the knee. A five to ten-year follow-up study. J Bone Joint Surg Am 63:938–946
102. van Raaij T, Reijman M, Brouwer RW, Jakma TS, Verhaar JN (2008) Survival of closing-wedge high tibial osteotomy: good outcome in men with low-grade osteoarthritis after 10–16 years. Acta Orthop 79:230–234
103. Vorlat P, Putzeys G, Cottenie D, Van IT, Pouliart N, Handelberg F, Casteleyn PP, Gheysen F, Verdonk R (2006) The Oxford unicompartmental knee prosthesis: an independent 10-year survival analysis. Knee Surg Sports Traumatol Arthrosc 14:40–45
104. Wada M, Imura S, Nagatani K, Baba H, Shimada S, Sasaki S (1998) Relationship between gait and clinical results after high tibial osteotomy. Clin Orthop Relat Res 354:180–188
105. Weale AE, Murray DW, Crawford R, Psychoyios V, Bonomo A, Howell G, O'Connor J, Goodfellow JW (1999) Does arthritis progress in the retained compartments after 'Oxford' medial unicompartmental arthroplasty? A clinical and radiological study with a minimum ten-year follow-up. J Bone Joint Surg Br 81:783–789
106. Yasuda K, Majima T, Tsuchida T, Kaneda K (1992) A ten- to 15-year follow-up observation of high tibial osteotomy in medial compartment osteoarthrosis. Clin Orthop Relat Res 282:186–195