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CAS and PSI increase coronal alignment accuracy and reduce outliers when compared to traditional technique of medial open wedge high tibial osteotomy: a meta-analysis

S. Cerciello^{1,2} · M. Ollivier³ · K. Corona⁴  · B. Kaocoglu⁵ · R. Seil^{6,7,8}

Abstract

Purpose Medial open-wedge high tibial osteotomy (MOWHTO) is an accepted option in the treatment of medial compartment osteoarthritis of the knee in young and active patients. Functional results are closely correlated to the correction of the mechanical axis of the lower limb. Although several angular and geometrical methods and values have been proposed in the past, the ideal target is still debated. In addition, it is important to have a deep correlation between the planned correction and the achieved correction after surgery. The aim of the present systematic review was to identify the ideal coronal correction after MOWHTO and the most accurate method to achieve it.

Methods A systematic review of the literature was completed on July 3rd 2020 in the Pubmed, Medline, Cochrane Reviews, and Google Scholar databases using the Medical Subject Headings (MeSH) terms: “high tibial osteotomy” AND “accuracy” OR “planning”.

Results 28 studies were included; 18 were focused on computer-assisted surgery (CAS) and 10 on patient-specific instrumentation (PSI). There were 598 patients in the CAS group and 501 in the control group; the rate of outliers was 16% and 38.2% respectively ($P = 0.04$), while there was no significant difference between the two groups (SMD = -0.10 ; 95% CI 1.31 to 1.12; $P = n.s.$) in terms of coronal accuracy. Likewise, there were 318 patients in the PSI group and 40 in the control group; the rate of outliers was 15% and 40% respectively ($P = 0.98$), while there was no significant difference between the two groups (SMD = 0.01 ; 95% CI 0.58 to 0.59; $P = 0.98$).

Conclusions A statistically significant reduced outlier rate and a non-significant increased accuracy emerged with the use of CAS when compared to the traditional surgical technique, whereas the results of PSI were still inconclusive. In addition, it emerged clearly that no consensus still exists on the ideal correction target to be achieved after surgery.

Level of evidence III.

Keywords High tibial osteotomy · Medial open wedge · Accuracy · Coronal alignment · Computer assisted surgery · Patient specific instrumentation

Introduction

Medial open-wedge high tibial osteotomy (MOWHTO) is a well-recognized option in the treatment of medial compartment osteoarthritis of the knee, medial compartment overload or spontaneous osteonecrosis of the medial femoral condyle [1, 2]. It was also been proposed in association with ligament reconstruction or meniscal transplantation in varus knees with encouraging outcomes [24]. The MOWHTO aims to correct an extra-articular deformity, shifting the weight bearing line from the medial compartment to a more lateral position, thus unloading cartilage and subchondral bone.

The clinical outcomes are often satisfactory, even at long-term follow-up, with 10 and 15-year survival rates of 92% and 71%, respectively [37]. However, the results depend on the accurate correction of the lower limb alignment according to the preoperative plan [16]. Historically, it was suggested to achieve 8°–10° of postoperative valgus in the anatomical axis (AA) or 3°–5° of valgus in the mechanical axis (MA) [20]. Persistent varus axis can lead to recurrence of deformity whereas overcorrection can accelerate lateral compartment OA [20]. An angular correction of 3°–5° usually corresponds to a mechanical axis that crosses the tibial plateau at around 65–70% of its width (with 0% being the medial and 100% the lateral border). This area has been initially described by Fujisawa et al. [9]. More recently authors advocated for a postoperative mechanical axis (MA) of the lower limb of approximately of 2°–7° valgus which is the range usually associated with favorable clinical outcomes for cartilage repair [17, 18]. Although the theoretical principles seem clear and easy, some fundamental aspects of high tibial medial wedge osteotomy, like the ideal postoperative target, the precision of planning and intraoperative accuracy have not yet clearly addressed.

The present systematic review and meta-analysis has therefore several aims. First of all, to compare the accuracy of new technologies such as computer assisted surgery (CAS) and patient specific instrumentation (PSI) in achieving the postoperative correction target when compared to the traditional MOWHTO. Second, to compare the rate of postoperative outliers among the different surgical options. Finally to identify the ideal anatomic and angular target after MOWHTO. It was hypothesized that CAS and PSI were more accurate and yield less outliers than the traditional technique.

Methods

This systematic review was carried out in accordance with the recommendations proposed by the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement [29].

Search strategy

Multiple database, including MEDLINE, EMBASE and the Cochrane Library were searched on the 3rd of July 2020 for studies reporting the accuracy of different methods of planning (conventional, navigation and patient specific guides) in high tibial osteotomy. Medical Subject Headings (MeSH) terms used for the search included “medial open wedge high tibial osteotomy” AND/OR “accuracy” AND/OR “planning”. After the initial electronic search which yielded 110 results, relevant articles and their bibliographies were searched manually. Articles identified were assessed individually for inclusion (Fig. 1).

Study selection

The following exclusion criteria were applied to the articles: (1) non-English literature; (2) biomechanical studies; (3) articles in which standard-procedure HTO, with the indication osteoarthritis and/or genu varum, was not the main objective; (4) case reports (less than 5 knees in the study), replies to other publications; (5) studies in which data on the accuracy of HTO, or the rate of outliers was unavailable. The remaining articles were included in this systematic review.

Data extraction

Each study was evaluated for the following variables: type of study, population size, gender and age, correction target in terms of Fujisawa area or angular correction, duration of the surgical procedure, follow-up (FU), accuracy of the achieved correction (in terms of Fujisawa area or angular correction), complications and outliers. All these information was searched and reported for three groups: patients treated with MOWHTO and traditional radiographic planning, patients treated with computer assisted MOWHTO and patients operated with the assistance of 3D CT analysis and patient specific instrumentation (PSI). All the articles were evaluated, and data extracted by two authors independently. Any differences in the sensible data between the two authors lead to a new analysis and a double check of the article. If any data was missing in one of the two authors evaluation, this lead to a new analysis and a double check of the article.

Methodological quality assessment

As no randomized controlled trials were found, the Methodological Index for Nonrandomized Studies (MINORS) checklist [39], a tool specifically created to evaluate the

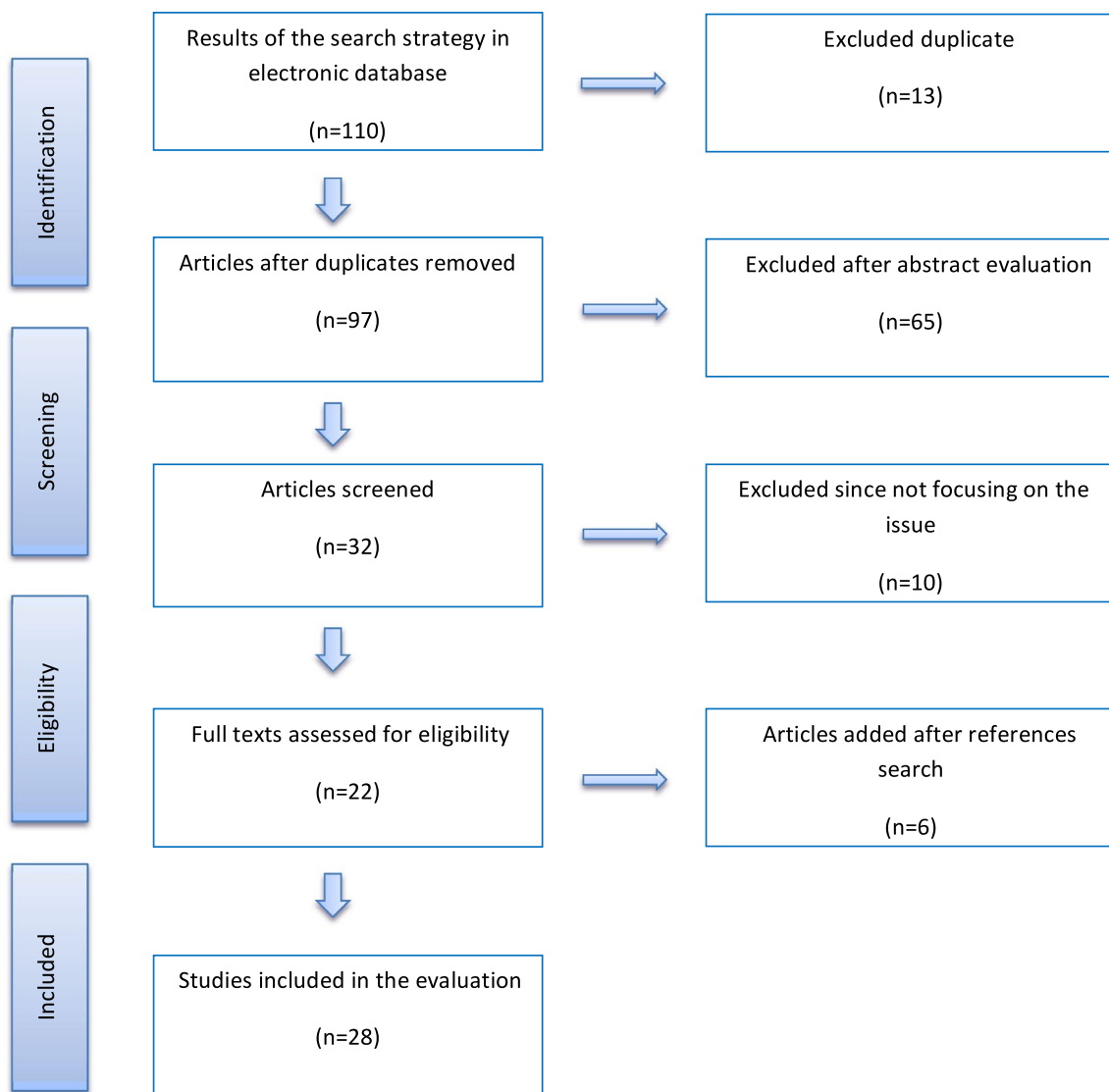


Fig. 1 PRISMA flow chart of the papers selection process

quality of nonrandomized surgical studies, was used to evaluate the quality of the included studies. The checklist includes 12 items, with the last 4 specific to comparative studies. Scoring was as follows: 0, not reported; 1, reported but poorly done and/or inadequate; and 2, reported, well done and adequate. The highest overall score was 16 for non-comparative studies and 24 for comparative studies. Each study was scored by two authors (KC and SC) who reached consensus if disagreement occurred with the intervention of the third author (MO).

Outcomes assessment

The target of coronal alignment after MOWHTO was reported in terms of angular correction referred to the hip-knee angle (HKA), femoro-tibial angle (FTA) or mechanical

medial proximal tibial angle (mMPTA) or in terms of the rate of the lateral tibial plateau intersected by the lower limb mechanical axis. The difference between the preoperative target and the achieved correction (accuracy) was reported. In comparative studies the difference between navigated osteotomies and traditional technique and between 3D CT scan-based PSI and traditional technique was measured. The rate of outliers in terms of postoperative correction (if available), the duration of the surgical procedure (if available), the rate of complications (if available) were reported for the different groups.

Statistical analysis

Statistical analysis was performed with Review Manager (Version 5.3, The Cochrane Collaboration). Risk ratio (RR)

and odds ratio (OR) were used as summary statistics to perform statistical analysis of dichotomous variables, and the mean difference (MD) was used to analyse continuous variables. They were reported with 95% confidence intervals (95% CI), and *P* value of 0.05 was used as the level of statistical significance. Statistical heterogeneity between trials was evaluated by the Chi square and *I*-square (*I*²) test, with significance set at *P* < 0.10. An *I*² above 40% was considered to be significant. The random effect model was used in the presence of significant heterogeneity, while in the absence of significant heterogeneity, the fixed effect was preferred. A sensitivity analysis was conducted by excluding one study in each round and evaluating the influence of any single study on the primary meta-analysis estimate.

Results

Search results

The electronic search yielded 110 studies. After 13 duplications were removed, 97 studies remained; of these, 65 were excluded after review of the abstracts and full-text articles leaving 32 eligible studies. An additional 10 articles were then excluded mainly based on the different ways to analyze the outcomes (uniquely on standard X-rays, or using the cable method alone or with a theoretical computer-method, or with picture archiving method). When manually checking the reference list of the included articles, 6 additional studies were found. Finally, 28 articles met the inclusion criteria: 18 were focusing on CAS compared to traditional technique and 10 on PSI compared to traditional technique. Figure 2 shows the flow chart of the study selection process.

Methodological quality assessment

The studies in the CAS/traditional technique subgroup had a mean MINORS score of 15.9 (range 10–18) while in the PSI/traditional subgroup the mean MINORS score was 12.6 (range 10–18), which confirmed the good methodological quality of the available literature (Tables 1, 2).

Patients and study characteristics

Tables 3 and 4 show the characteristics of the studies and the demographic characteristics of the cohorts. When focusing on CAS/traditional technique 18 studies were available. There were 598 patients in the study (CAS) group and 501 in the control group. The groups were comparable in terms of age and male/female ratio. The targeted correction was extremely variable in the different studies (Table 1). When focusing on PSI/traditional technique 10 studies were available. There were 318 patients in the study (PSI) group and 40 in the control group. The groups were comparable in terms of age, the rate of female patients was higher in the control group (75%). The targeted correction was extremely variable in the different studies (Table 2).

Outcomes assessment: coronal correction and outliers

In the CAS/traditional technique the pooled results of aggregate analysis for comparison of navigated and conventional HTO regarding accuracy of alignment, including subgroup analysis by the method of post-operative alignment: angular correction (mean ± SD) and area (%) described by Fujisawa,

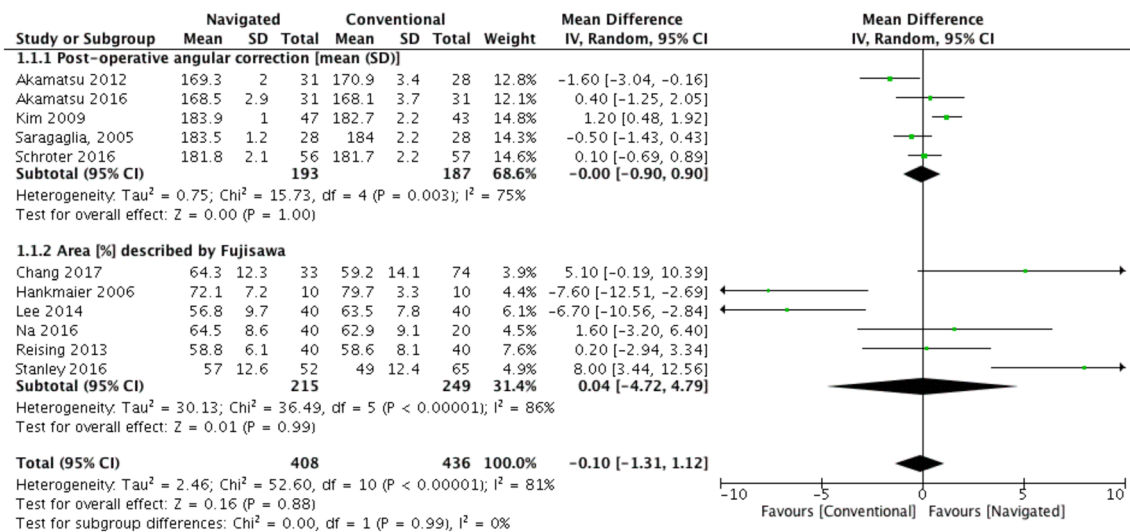


Fig. 2 Comparison of coronal correction in the computer assisted surgery (CAS)/traditional technique studies

Table 1 Coronal correction of the computer-assisted surgery (CAS)/traditional technique studies

Authors	SG	1st target	2nd target	FU months	Conclusions	Minors
Saragaglia 2005 [36]	28	182–186		3	Better navigation	14
Maurer 2006 [27]	44	182–185			Better navigation	16
Hankemeier 2006 [12]	10	80%		0	Better navigation	18
Kim 2009 [19]	47	183–185	62	12	Better navigation	16
Lutzner 2010 [25]	10	80%		0	Better navigation	18
Iorio 2011 [14]	14	182–186		12.6	No control	12
Gebhard 2011 [10]	51	182–183		1.5	No control	10
Lee 2012 [23]	39	182–188	62%	6.5	No control	12
Akamatsu 2012 [2]	31	190	167–173	12	Better navigation	16
Reising 2013 [34]	40	62%			No difference less outliers	16
Iorio 2013 [13]	14	182–186		39	Better navigation	18
Lee 2014 [22]	40	62%		2	Worse navigation	18
Ribeiro 2014 [35]	18	62%	62%	12	No difference	16
Akamatsu 2016 [1]	31	(FTA) 165–175	62%	24	Better navigation	18
Na 2016 [31]	40	62%		3	Better navigation	16
Schröter 2016 [38]	56	182–183		1.5	No difference	18
Stanley 2016 [40]	52	58%			No difference	16
Chang 2017 [3]	33	62.5%		12	Better navigation	18

SG Study group, FTA femoro-tibial angle, FU follow-up

Table 2 Coronal correction of the Patient Specific Instrumentation (PSI)/traditional technique studies

Authors	SG	1st target	2nd target	FU months	Conclusions	Minors
Pérez-Mañanes 2016 [33]	8	62%	183–185		Less errors	18
Munier 2017 [30]	10	182.4°		12	No control	12
Kim 2018 [17]	20	57.2–67.5%	183°–186°		Higher accuracy	16
Yang 2018 [41]	10	62.5%			No control	10
Chernchujit 2019 [5]	19	185°–187°			No control	12
Donnez 2018 [6]		ΔmMPTA	88	20	No control	18
Chaouche 2019 [4]	100	ΔHKA		24	No control	12
Jacquet 2019 [15]	71	ΔHKA	57.2–67.5%	12	No control	12
Kuriyama 2019 [21]	47	62.5%			No control	12
Fucentese 2020 [8]	23	62.5%	Planned HKA 9.7°		No control	10

SG Study group, FU Follow-Up, HKA Hip-Knee Angle, mMPTA mechanical medial proximal tibial angle

the analysis showed that there was no significant difference between the two groups (SMD = -0.10; 95% CI -1.31 to 1.12; $P = n.s.$) (Fig. 2). The rate of outliers was 15.9% in the CAS group and 38.2% in the traditional group. The pooled results showed that the number of outliers was lower in navigated HTO than that in conventional HTO (OR = 0.40; 95% CI 0.17 to 0.96; $P = 0.04$) (Fig. 3).

In the PSI/traditional technique studies the rate of outliers was 15% in the PSI group and 40% in the traditional group (Table 2). The pooled results showed that there was no significant difference between the two groups (SMD = 0.01; 95% CI -0.58 to 0.59; $P = 0.98$) (Fig. 4).

Outcomes assessment: duration of surgery and complications

In the CAS/traditional subgroup the average duration of surgery was much longer in the CAS subgroup (97.4 min), while the rate of complications was lower (7.7%) (Table 5). The pooled results showed that the risk of complications was lower in navigated HTO than that in conventional HTO (OR = 0.38; 95% CI 0.10 to 1.45; $P = 0.16$) (Fig. 5).

In the PSI/traditional subgroup the average duration of surgery was shorter in the PSI subgroup (60.8 min), while the rate of complications was higher (7.7%) (Table 6)

Table 3 Demographic characteristics of the computer assisted surgery (CAS)/traditional technique studies

Authors	Type of study	Study group					Control group					Target
		Pts (N)	Age (mean)	Gender (M) %	OT min	OT (min)	Pts (N)	Age (mean)	Gender (M) %	OT (min)		
Saraglia 2005 [36]	RCS	28	44				28	55				182°–186°
Maurer 2006 [27]	RCS	44	60	25			23	60				182°–185°
Hankemeier 2006 [12]	Cadaver	10	53	70	82		10	53	70	59		80%
Kim 2009 [19]	RCS	47	54	91.5	74.8		43	53.5	88.4	73.8		183°–185°
Lutzner 2010 [25]	Cadaver	10					9					80%
Iorio 2011 [14]	PRMS	14	56.5	53.9	78.9							182°–186°
Gebhard 2011 [10]	PRCOS	51	51	78	105							182°–183°
Lee 2012 [23]	PRCOS	39	53	30.8								182°–188°
Akamatsu 2012 [2]	RCS	31	62	19.2			28	57	50			190°
Reising 2013 [34]	RCS	40	43.6	32	141		40	43.6	32	141		62%
Iorio 2013 [13]	PRCS	14	56.5	538			13	54.8	63.6			182°–186°
Lee 2014 [22]	PRCS	40	51.9	22.5			40	54.4	21.1			62%
Ribeiro 2014 [35]	RCS	18	46.6	94.4			20	48.4	60			62%
Akamatsu 2016 [1]	PRCS	31	63.6	25.8			31	66.3	25.8			165°–175° (FTA)
Na 2016 [31]	RCS	40	55.4	21.2	41.3		20	50	45	39.2		62%
Schröter 2016 [38]	PRCS	56	45	83.9	84		57	47	63.2	66		182°–183°
Stanley 2016 [40]	RCS	52	49.2	78			65	47.6	86.9			58%
Chang 2017 [3]	RCS	33	43.5	45.5	172		74	43.3	75.7	115		62.5%

RCS retrospective comparative study, PRCS prospective comparative study, PRCOS prospective cohort study, PRMS prospective multicenter study, Pts patients, N number, M males, OT, operative time, FTA femoro-tibial angle

Table 4 Demographic characteristics of the PSI/traditional technique studies

Authors	Type of study	Study group				Control group				Target
		Pts (N)	Age (mean)	Gender M (%)	OT (min)	Pts (N)	Age (mean)	Gender M (%)	OT (min)	
Pérez-Mañanes 2016 [33]	PRCS	8	44		61	20	45		92	62%
Munier 2017 [30]	PRCOS	10	46							182.4°
Kim 2018 [17]	RCS	20	55.7	4		20	55.1	3		57.2–67.5%
Yang 2018 [41]	PRCOS	10	67.2	4						62.5%
Chernchujit 2019 [5]	PRCOS	19	46.9	11	95					185°–187°
Donnez 2018 [6]	Cadaver	88	88	20				No		ΔmMPTA
Chaouche 2019 [4]	PROCS	100	44.2	59						ΔHKA
Jacquet 2019 [15]	PROCS	71	44.3	38	26.3					ΔHKA
Kuriyama 2019 [21]	PROCS	47	61.7	16						62.5%
Fucentese 2020 [8]	PRCOS	23	45.2	16						62.5%

RCS retrospective comparative study, PRCS prospective comparative study, PRCOS prospective cohort study, Pts patients, N number, M males, OT operative time, min minutes, HKA hip-knee angle, mMPTA mechanical medial proximal tibial angle

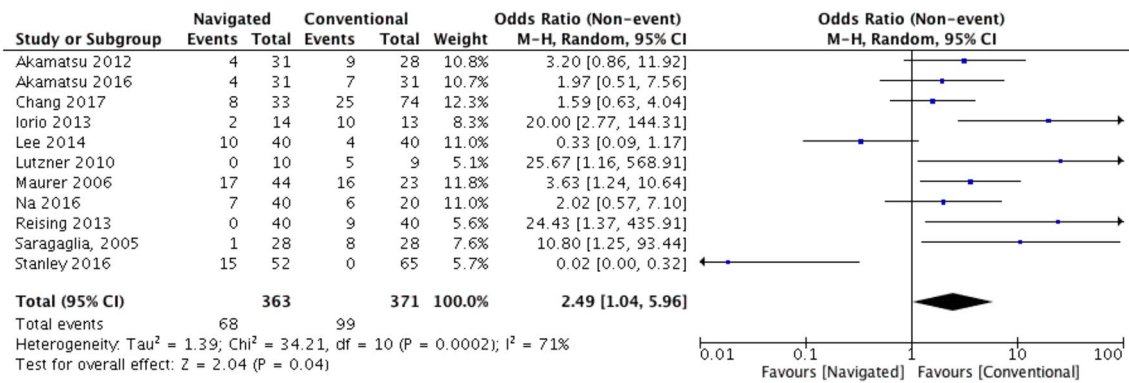


Fig. 3 Comparison of outliers in the computer assisted surgery (CAS)/traditional technique studies

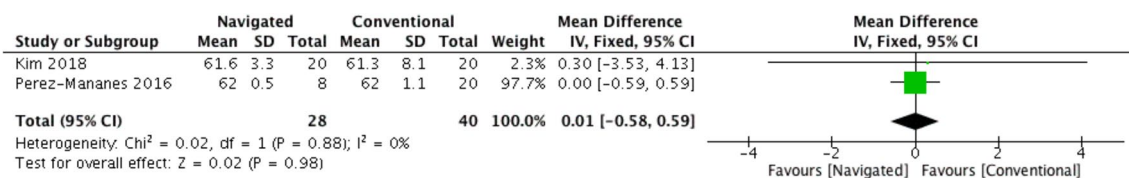


Fig. 4 Comparison of coronal correction in the patient specific instrumentation (PSI)/traditional technique studies

Discussion

The present study has some notable findings. First of all, the use of CAS and PSI leads to statistically significant reduction of postoperative outliers when compared to traditional technique. Second, they do not lead to a statistically superior accuracy in achieving the target postoperative alignment, although a small trend toward superior results was observed.

Finally there is no consensus on which is the ideal correction target after MOWHTO.

Several studies aimed at angular correction (HKA) with wide angular variability while others aimed at a specific target in the Fujisawa area (Tables 3, 4). Mikulicz-Radecki first proposed in 1880 a straight line (Mikulicz line) connecting the center of the femoral head and the center of the talus. The line gives the overall mechanical alignment of the lower limb. The HKA gives the overall alignment of the lower limb and is the result of three components: the bony alignment

Table 5 Computer-assisted surgery (CAS)/traditional technique

Authors	1st target	1st SG	1st CG	2nd target	2nd SG	2nd CG	COMPL SG %	COMPL CG %	OUTL SG %	OUTL CG %
Saraglia 2005 [36]	182–186	183.4	184						4	29
Maurer 2006 [27]	182–185								38	70
Hankemeier 2006 [12]	80%	72.1%	79.7%				0	0		
Kim 2009 [19]	183–185	183.9	182.7	62%	62.3%	58.7%	3	2	0	55.5
Lutzner 2010 [25]	80%	80%	79.4%				0			
Iorio 2011 [14]	182–186	183.3					0			
Gebhard 2011 [10]	182–183						18		15	
Lee 2012 [23]	182–188	182.9		62%	59.9%				15.4	
Akamatsu 2012 [2]	190	190.1	189.7	167–173	169.3	170.9	19.2	27.2	13	32
Reising 2013 [34]	62%	58.6%	58.6%				0	0	0	22.5
Iorio 2013 [13]	182–186	180.7	180.8				0	18.2	14	77
Lee 2014 [22]	62%	56.8%	63.5%						25	10
Ribeiro 2014 [35]	183–186	183.06	183.35							
Akamatsu 2016 [1]	(FTA) 165–175	168.5	168.1	62%	68.6%	73.5%	29	19.4	12.9	22.6
Na 2016 [31]	62%	64.5%	62.9%						18	30
Schröter 2016 [38]	182–183	181.8	181.7				7.1	5.3		
Stanley 2016 [40]	58%	57%	49%				0.43	36.9	28.8	33.8
Chang 2017 [3]	62.5%	64.3%	57.3%				7.7%	34	24.4	33.8
Total								15.9%	16%	38.2%

SG study group, CG control group, COMPL complications, OUTL outliers, FTA femoro-tibial angle

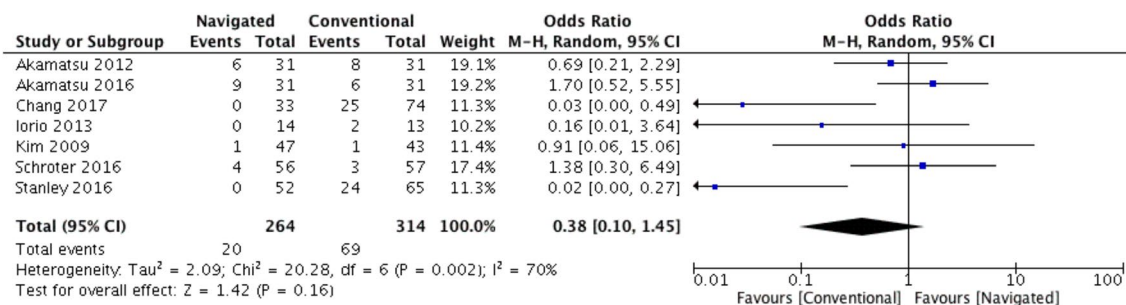


Fig. 5 Comparison of complication rate in the computer assisted surgery (CAS)/traditional technique studies

of the femur and the tibia, the wear of the articular cartilage and the slackness of the capsule/ligaments complex around the knee. However it does not give any information on where the deformity is located (bone, cartilage or ligaments).

The first step of a traditional MOWHTO is to establish the desired postoperative alignment and therefore to plan the desired correction. The planning should be performed on full leg standing weight bearing X-ray [22]. During planning, it is easier to consider the Mikulicz line in relation to the % of the tibial plateau rather than the HKA. The physiological Mikulicz line crosses the tibial plateau in the geometrical middle, but with a mechanical axis deviation (MAD) of some 4–8 mm to the medial side [32]. As a result, an intersection at 45% TPW has to be considered normal while its medial shift is associated with a varus deformity. The most common way to plan the desired correction is to follow the Miniaci and Jakob method [28]. It is based on the necessity to shift the Mikulicz line in a more lateral position to correct the varus deformity. Fujisawa et al. were the first to advocate a postoperative Mikulicz line passing at around 65–70% of the tibial width [9]. This principle roughly corresponds to a postoperative HKA of 183°–185°. Although Dugdale and Noyes hypothesized that different intersection points could provide equivalent outcomes [7], the principles of the correction proposed by Jakob and Miniaci remain accepted. In any case, a shift of 65% is set as the upper boundary, but for some surgeons, when osteoarthritis is severe, this upper boundary might be extended up to 75% [26]. On the contrary the general trend is to reduce the shift toward 55–60% adapting the correction to the individual deformity. This wide variability reflects the different target values found in the present review.

A second aspect emerges from the present review and meta-analysis: the addition of technology do not clearly increase the accuracy of MOWHTO, although a trend toward superior accuracy was observed. The accuracy of bony correction is important; traditional technique has several drawbacks when compared to CAS and PSI. First of all, errors with the traditional technique can result from inappropriate planning. When transferring angular correction

into millimeters (of opening or closing wedges) there can be mismatches. This may result from poorly performed X-ray (not real dimensions, malrotations of the limb, poor projections, wrong assessment of the deformity, absence of correction of intraarticular deformity) or poor planning itself (wrong drawings, lines, HKA correction). PSI involves patient specific cutting blocks which are manufactured on patient-specific 3D-CT scan films and therefore this kind of errors are significantly reduced. In addition there can be intraoperative errors associated with direct visual inspection methods such as the cable method or grid boards [31]. They can also be the consequence of high intra-observer variations and the low reproducibility of intra-operative assessment tools, including fluoroscopy-based methods [23, 26]. Both the CAS and PSI are advantageous in reducing the rate and amount of these errors since they guarantee objective intra-operative references and data. Several previous studies have shown that navigation assisted HTO is superior in terms of reducing outliers from the predicted postoperative limb alignment [10, 11, 23, 34]. In a similar way the use of patient specific instrumentation (PSI) can be a reliable option to improve the accuracy of HTOs [15]. In the present review several studies compared the accuracy of coronal alignment between the traditional technique and the CAS. Although a trend toward increased accuracy was observed in the CAS group, the pooled results including subgroup of angular correction (mean \pm SD) and area (%) described by Fujisawa showed that there was no statistically significant difference between the two groups. On the contrary a significant reduction of outliers was observed when CAS was used, although some authors still reported no differences in their series [22, 34, 35, 38, 40]. Less studies analyzed the accuracy of PSI and only 2 compared this technique to traditional surgery [17, 33]. The pooled results including subgroup of angular correction (mean \pm SD) and area (%) described by Fujisawa showed that there was no statistically significant difference between the two groups.

The present study has some notable limitations. Firstly, although several databases have been accessed with different combination of appropriate keywords, it is possible that

Table 6 Patient specific instrumentation (PSI)/traditional technique

Author	1st target	1st SG	1st CG	2nd target	2nd SG	2nd CG	COMPL SG %	COMPL CG %	OUTL SG %	OUTL CG %
Pérez-Mañanes 2016 [33]	62%	± 0.5°	± 1.1°	183–185	187	187			0	
Munier 2017 [30]	182.4°	182.3°							20	40
Kim 2018 [17]	57.2–67.5%	61.6%	61.3%	183°–186°	Δ±2.3°	Δ±6.2	0	0	20	
Yang 2018 [41]	62.5%	60.2%							4.9	
Chernhujit 2019 [5]	185°–187°	Δ±5.1								
Donnez 2018 [6]	ΔmMPTA	ΔmMPTA±0.2°								
Chaouche 2019 [4]	ΔHKA	ΔHKA±1°					10			
Jacquet 2019 [15]	ΔHKA	ΔHKA±1°		57.2–67.5%						
Kuriyama 2019 [21]	62.5%	61.5%							24	
Fucentese 2020 [8]	62.5%			Planned HKA	9.7°	8.9°	13		26.1	

SG study group, CG control group, COMPL complications, OUTL outliers, FTA femoro-tibial angle, HKA hip-knee angle, mMPTA mechanical medial proximal tibial angle

some articles may not have been included in our search. Second, the level of evidence of the included studies was not high because the majority were observational comparative studies rather than randomized controlled. Third, almost all of the available articles in the PSI subgroup are case series with no control group; this could reduce the scientific relevance of the reported data. Fourthly, the analysis of postoperative alignment should be performed at the same time in the different studies.

Although the reported limitations the present study yields some relevant informations for daily practice First of all, CAS and PSI ensure a statistically significant reduction in the rate of postoperative outliers. Second, they do not lead to a statistically superior accuracy in achieving the target postoperative alignment, although a small trend toward superior results was observed. Finally, a lack of consensus on which is the ideal postoperative alignment target clearly emerges from the present review.

Conclusions

New technologies such as CAS and PSI yield reduced rate of outliers after MOWHTO when compared to the traditional surgical technique. Conversely they do not lead to statistically significant improvement in the accuracy of postoperative alignment, At the same time, it is clear that no consensus exists on the ideal correction target to achieve after surgery, in terms of angular corrections (HKA) or target zone on the tibial plateau (Fujisawa area and Mikulicz line).

Compliance with ethical standards

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

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Ethical approval Ethical approval was not required for this study.

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