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Review

Median age of patients undergoing total ankle replacement has not significantly changed between 1999 and 2023: A systematic review of prospective studies

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ABSTRACT

Introduction: Total ankle replacement (TAR) is an effective treatment for end-stage osteoarthritis. The aim of this systematic review was to assess the age of patients undergoing TAR in prospective comparative studies. Our hypothesis is that the age reported in most recent papers might be lower than those reported in older papers.
Methods: This systematic review was performed using Pubmed, Scopus, EMBASE and Cochrane databases. Only Level I and II studies dealing with TAR were included. Data regarding demographics, study design, number of cohorts in each study, year of publication and year/years in which surgery was performed were extracted. A two-fold analysis was conducted building groups of patients based on the year of publication and creating 1) two groups (before and after the median year) and 2) three groups (using tertiles) in order to compare age of patients operated in different period of times. A comparison was also performed considering the median year of surgery for patients undergoing TAR.
Results: Overall 59 cohorts (42 studies, published between 1999 and 2023; median year of publication: 2017) were included (6397 ankles, 6317 patients, median age 63 years). The difference between the median age for 27 cohorts published until 2016 (weighted median 63 years; IQR, 62.5–64) and the median age for 32 cohorts published after 2017 (weighted median 63.2 years; IQR, 63–67.8) was not statistically significant ($p = 0.09$). The division in tertiles did not reveal any significant change in the weighted median age at surgery (T1 (1999–2014; 63.2 years; IQR, 62.8–64.1), T2 (2015–2018; 63 years; IQR,63–63.5) and T3 (2019–2023; 63.2 years; IQR, 62.6–67.8)) over time ($p = 0.65$). The median age of patients operated between 1999 and 2008 vs 2009 and 2023 (data from 48 cohorts) was not different either ($p = 0.12$).
Conclusion: According to this review of prospective studies published between 1999 and 2023, the median age for patients undergoing TAR over the last two decades has been 63 years, remaining steady with no significant changes over time.
Level of evidence: Level II - systematic review including Level I and Level II studies

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Contents

1. Introduction

Symptomatic end-stage ankle osteoarthritis is usually treated through ankle arthrodesis or total ankle replacement (TAR) [1,2]. While the first has been considered the gold standard for decades, there has been a rise in the number of studies reporting positive outcomes after TAR with a satisfactory clinical outcome also at 10 years [3,4], which is probably at the basis of a progressive increase of its use worldwide [5–8]. Data extracted from registries have demonstrated an 86 % (ranging from 80 % to 91 %) at 5 years and a 77 % survivorship rate (ranging from 66 % and 84 %) at 10 years [9] In a large French study on 4748 TARs followed using a discharge records database, at 10 years the survivorship free of metal component revision stood at 78 % [10]. In another study from United Kingdom, out of 5562 TARs, 199 were followed up at 10 years with a similar survival (86.2 %) [11].

In this context, although a significant clinical improvement after TAR has been shown both in younger and older patients, there is still some debate about the minimum age of patients for which the benefits of performing a replacement still outweigh the risks related to the loosening of the implant and the need of revision procedures. While there is a large number of patients presenting with painful post-traumatic osteoarthritis requesting treatments to get rid of symptoms without sacrificing the mobility of the ankle, the high risk of one or multiple revisions in a lifetime, the greater level of activity of young patients (which increases the chances of early loosening of the prosthesis) and their high expectations would often orientate the surgeon to propose arthrodesis as a safer option. On the other hand, the knock-on effect on other joints with a risk of developing or worsening osteoarthritis along with gait alteration inherently related to an ankle fusion are the main reasons why arthrodeses cannot be considered an ‘ideal’ treatment.

In practical terms, the role of age in the decision-making process to perform a TAR is debated, with a split literature on the topic. According to some authors, age would not affect the revision and the complication rate nor the clinical outcome after TAR [12–14]. In a noncomparative retrospective study on 41 patients younger than 50 years (average 39.7) undergone TAR, Ebaugh et al. documented a satisfactory recovery of ordinary activities after replacement and found that 87 % would have the surgery again at nearly 5-year follow-up [15]. Conversely, according to other reports younger age would represent a risk factor for early failure and poor outcome [16–20]. Additionally, it’s unclear whether more recent prosthetic designs have led surgeons to consider ankle replacements in younger patients as compared to the past.

With this background, we set out to perform a systematic review of prospective studies dealing with TARs published over the last three decades in order to verify if the mean age of patients undergoing this procedure has been significantly changing in this timeframe. We hypothesized that in studies published more recently the mean age of patients would be lower as compared to previous reports.

2. Methods

2.1. Study design

This systematic review was designed according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The project was prospectively registered on the PROSPERO database (Number CRD42024498326).

2.2. Data sources and search

A comprehensive electronic search of the current literature was performed by two authors (AI and AS) using Pubmed, Scopus, EMBASE and Cochrane databases, from the earliest records through the 15th of December 2023. The following keywords and Boolean operators were entered to identify potential papers: ((ankle) AND (replacement)) OR ((ankle) AND (arthroplast*)) OR ((ankle) AND (prosthes*)) AND (prospect*). Additional studies were identified by checking the bibliographies of the articles selected. If full texts were not available, authors were contacted.

2.3. Study selection

All results were managed through Microsoft Excel. Duplicates were deleted, then studies without abstract were excluded. All titles and abstracts were screened by two reviewers (AS and AI) at different places and times, according to a previously defined protocol. After applying exclusion criteria, eligible studies for systematic review were selected. Disagreements were solved through discussion and consensus. If disagreement remained, a senior reviewer was consulted (AB) and solved it through discussion and consensus with other two reviewers.

2.4. Inclusion/exclusion criteria

To be included in our systematic review, a study had to meet the following criteria: prospective and comparative Level I or Level II studies (RCT, CCT, quasi-randomized studies) reporting data on patients undergoing primary TAR for end-stage ankle osteoarthritis; published from 1993 on; English language; reporting the mean age of patients treated. Retrospective cohort studies, case series, reviews, case reports, technical notes, cadaveric studies, animal studies, letters to the editor, and expert opinions were excluded. Also, studies reporting results after revision TAR were left out. If two studies reported data on the same cohort, the one with more details (e.g., subgroup analysis) on the age of patients was included.

2.5. Data extraction

The following data were extracted from primary studies: first author, year of publication, level of evidence, study design, number of ankles and patients included, mean age of the cohort, year (or years) in which surgery was performed. When results were indicated in percent, rounding down (< 0.5) or up (> 0.5) was applied.

2.6. Statistical analysis

Continuous variables were reported as the mean and 95 % confidence interval (95 %CI) or standard deviations (SD) and range for normally distributed variables, and as the median and interquartile range (IQR) for non-normally distributed variables. Specifically, age was reported as a weighted value taking into account the sample size of studies included. Data were tested for normality using a Shapiro-Wilk test and were then compared using the Student-T test (two groups) or ANOVA (multiple groups) for normally distributed variables and Wilcoxon rank sum test (two groups) or Kruskal-Wallis rank sum test (multiple groups) (or non-normally distributed variables. Chi-squared test was used to compare categorical variables. In order to compare age of patients operated in different periods, a two-fold analysis was conducted building groups of patients based on the year of publication of studies and creating 1) two groups (studies published before and after the median year of publication of studies) and 2) three groups (dividing the years of publication using tertiles). A further analysis was performed considering the mean year of surgery reported in studies and comparing cohorts of patients treated before and after the median year of surgery in the review. The significance level for the overall estimates of effect was set at $p < 0.05$. All analyses were performed using STATA statistical software package (Version 14.0, StataCorp, 2015).

3. Results

Overall, 59 cohorts from 42 studies (13 studies reported data on 2 or more cohorts) published between 1999 and 2023 were included (6397 ankles from 6317 patients, median age 63 years) [14,21–61] The median sample size for each dataset was 75 ankles (IQR, 28 −138). The median year of publication was 2017.

3.1. Age and year of publication

The difference between the median age for 27 cohorts published until 2016 (weighted median 63 years; IQR, 62.5 to 64) and the median age for 32 cohorts published after 2017 (weighted median 63.2 years; IQR, 63 to 67.8) was not statistically significant (p = 0.09) (Table 1) (Fig. 1 and Fig. 2). Comparing studies pooled in three groups (using tertiles) we did not find any significant change of the weighted median age at surgery (T1 (1999–2014; 63.2 years; IQR, 62.8 to 64.1), T2 (2015–2018; 63 years; IQR, 63 to 63.5) and T3 (2019–2023; 63.2 years; IQR, 62.6 to 67.8)) over time either (p = 0.65) (Table 2) (Fig. 3).

Table 1
Baseline characteristics for studies included in this review divided according to the median year of publication. Age values have been weighted by sample size.

	Studies published from 1999 to 2016	Studies published from 2017 to 2023	*P-value*
Studies *(N)*	19	23	-
Cohorts *(N)*	27	32	-
Ankles *(N)*	2821	3576	-
Mean sample size *(N)*	103.2	111.7	0.94 *
LoE *(N)*	I: 4 II: 23	I: 2 II: 30	0.27 * *
Weighted median age *(y)*	63 (IQR, 62.5 – 64)	63.2 (IQR, 63 – 67.8)	0.09 *

Abbreviations: N, number; y, years; IQR, interquartile range
* Wilxocon rank sum test
* * Chi-squared

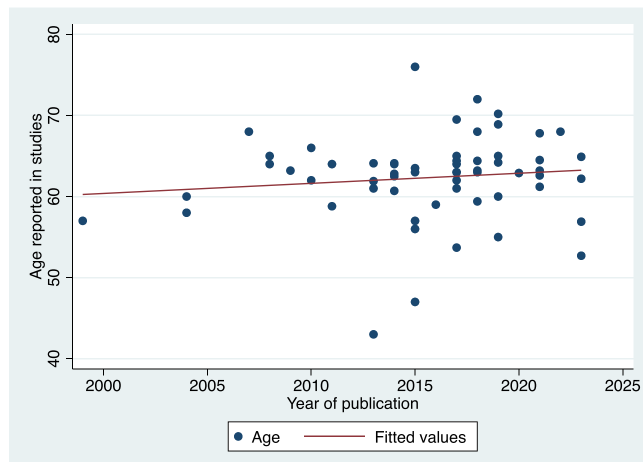

Fig. 1. Scatter plot illustrating the correlation between the mean age of patients reported in studies included in this review and the year of publication of studies.

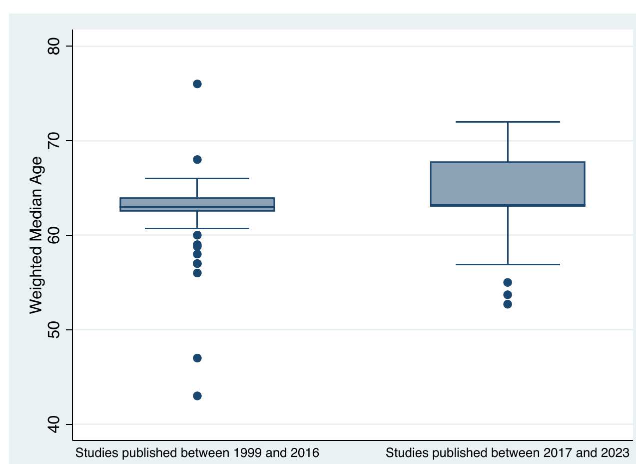

Fig. 2. Box-and-whisker plots comparing the median age (weighted by sample size) in studies published between 1999 and 2016 vs those published between 2017 and 2023. The interquartile range is shown as a box, and the median is shown as a line within the box. Whiskers represent adjacent values (i.e., all data points within 1.5 interquartile range of the nearer quartile). Outliers are shown as individual points.

Table 2
Baseline characteristics for studies included in this review after pooling them in three groups using tertiles of the year of publication. Age values have been weighted by sample size.

	Studies published from 1999 to 2014	Studies published from 2015 to 2018	Studies published from 2019 to 2023	*P-value*
Studies *(N)*	14	14	14	-
Cohorts *(N)*	20	22	17	-
Ankles *(N)*	1701	2569	2127	-
Mean sample size *(N)*	83.4	116.7	125.1	0.56 *
LoE *(N)*	I: 4 II: 16	I: 0 II: 22	I: 2 II: 15	0.09 * *
Weighted median age *(y)*	63.2 (IQR, 62.8 – 64.1	63 (IQR, 63 – 63.5)	63.2 (IQR, 62.6 – 67.8)	0.65 *

Abbreviations: N, number; y, years, IQR, interquartile range
* Kruskal Wallis test
* * Chi-squared

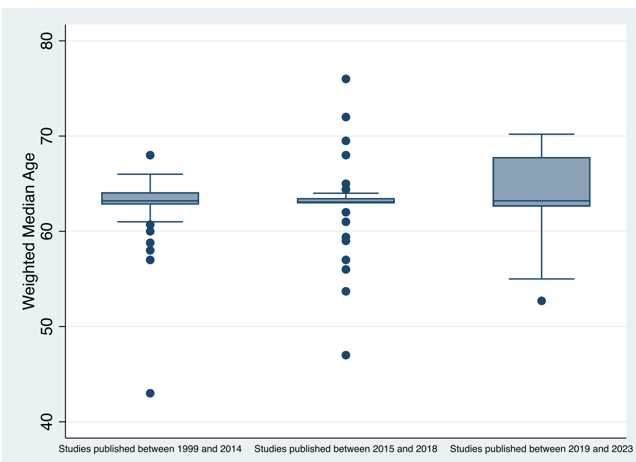

Fig. 3. Box-and-whisker plots comparing the median age (weighted by sample size) in studies published between 1999 and 2014 vs studies published between 2015 and 2018 vs studies published between 2019 and 2023. The interquartile range is shown as a box, and the median is shown as a line within the box. Whiskers represent adjacent values (i.e., all data points within 1.5 interquartile range of the nearer quartile). Outliers are shown as individual points.

3.2. Age and year of surgery

Details regarding the timeframe in which patients had been recruited and had undergone surgery were reported in 48 (81 %) cohorts. Mean year of surgery was 2008.5 (IQR, 2004.5 to 2012.5; range, 1987.5 to 2019). The difference between the median age of 26 cohorts in which the mean year of surgery was before 2008 (weighted median 63 years; IQR, 62 to 64.1) and the median age of 22 cohorts for which the mean year of surgery was after 2009 (weighted median 63.2 years; IQR, 62.8 to 67.8) was not statistically significant (p = 0.12) (Table 3) (Fig. 4).

4. Discussion

The main finding of this systematic review, in which only Level I and Level II studies were included, was that the median age at surgery for patients undergoing total ankle replacement during the last two decades has been 63 years, with no significant changes in the timeframe between 1999 and 2023. The hypothesis of a progressive lowering of the mean age of patients in more recent studies as compared to previous reports was thus disproved. To the best of our knowledge, this is the first review of prospective studies to investigate age at surgery for ankle replacements and to analyze potential trends in literature.

Looking at revision rates, it's well known that the risk of a second procedure at the ankle is approximately three to four times higher than at suprasegmentary joints. If for the hip and for the knee the risk of revision at 10 years is around 5 % [62] the expected revision rate after an ankle replacement ranges from 14 %[11] to 22 % [10,63]. This generates concern in surgeons about younger patients undergoing TAR which are highly likely to require one or more revisions. In this scenario, the discussion around the optimal age for patients undergoing TAR has been ongoing for some time, with a number of papers documenting its role as a potential risk factor for early failure of the implant. More in detail, it's still controversial whether there should be a minimum age to consider ankle replacement for patients presenting with end-stage osteoarthritis or not. The obvious rationale behind this point is that, the lower the age of arthroplasty, the higher the level of activity of the patient and the greater the shear forces which may apply to the implant with subsequential increased risk of loosening and failure. This entails a potential higher number of revisions needed over time, with any following procedure being technically more demanding and at higher risk of failure than the previous one (or ones) due to the reduced bone stock, scars on soft tissues, and impaired blood supply [16]. However, it should also be considered that younger patients might paradoxically be those who benefit more from an ankle replacement due to their active lifestyle. This seems confirmed by a study where, out of 103 TARs, a significantly greater improvement in the AOFAS score was observed in patients younger than 50 years as compared to the improvement observed in older patients [64].

As for the hip and the knee [62], a significant increase in the lifetime risk of revision for younger patients undergoing TAR has been reported in some studies [11,17–20]. Among these, in a data linkage study (i.e., using both a national joint registry and national health service digital data) including 5562 primary TARs, the 5-year survivorship of the implant was significantly lower for patients aged < 65 years (85.6 %) as compared with those aged between 65 and 74 years (90.7 %) and those aged ≥ 75 years (95.5 %) [11]. In that study, a regression analysis showed a significantly lower risk of failure in TARs performed in patients aged 65–74 years (Hazard Ratio (HR) 0.61) and those aged ≥ 75 years (HR 0.25) compared to those aged < 65 years [11]. This confirmed the results of a Korean nationwide longitudinal cohort study on 2914 TARs, where at 3.8-year follow-up an increased risk of implant failure was observed in patients treated before 65 years versus those operated after 75 years of age (adjusted HR (aHR) 2.273 in the 60–64 age group; aHR 2.697 in the 55–59 age group; aHR 2.281 in the 50–54 age group and aHR 2.851 in the < 50 age group) [18]. Similarly, in a recent scoping review including 101552 TARs, Arshad et al. found that younger age, along with comorbidities such as rheumatoid arthritis, diabetes, and increased body mass index, was a risk factor for poor outcome [17]. In another retrospective study by Stadler et al., the authors followed 224 mobile-bearing TARs at a mean of 7.1 years, comparing those operated before and after 50 years of age [19]. The authors found a higher reoperation rate (22.2 % vs 5.3 %; odds ratio: 6.5) and revision rate (36.1 % vs 13.8 %; odds ratio: 3.1) in patients younger than 50 years [19].

Interestingly, in some other studies age was not considered as a risk factor for failure after TAR [12,13,65,66]. In one of the first studies published in this area, Kofoed et al. compared 30 TARs in patients younger than 50 years (median age 46; range, 22–49 years) and 70 TARs in patients older than 70 years (median age 63 years; range, 51–83 years) and found that the clinical outcome and risk or revision was not different [65]. In a more recent prospective study (2015) published by Demetracopoulos et al., 395 consecutive TARs were divided in three groups based on the age at surgery (< 55, 55–70 and > 70) and followed-up at a mean 3.5-year follow-up [14].

Table 3
Baseline characteristics for studies included in this review divided according to the median year of surgery (data reported in 48 cohorts out of 59).

	Studies reporting on patients treated between 1999 and 2008 (mean year of surgery)	**Studies reporting on patients treated between 2009 and 2023 (mean year of surgery)**	***P-value***
Studies *(N)*	18	15	-
Cohorts *(N)*	26	22	-
Ankles *(N)*	2937	2880	-
Mean sample size *(N)*	186.8	294.8	0.41 *
LoE *(N)*	I: 4 II: 22	I: 2 II: 20	0.51 **
Weighted median age *(y)*	63 (IQR, 62 – 64.1)	63.2 (IQR, 62.8 - 67.8)	0.12 *

Abbreviations: N, number; y, years; IQR, interquartile range
* Wilxocon rank sum test
** Chi-squared

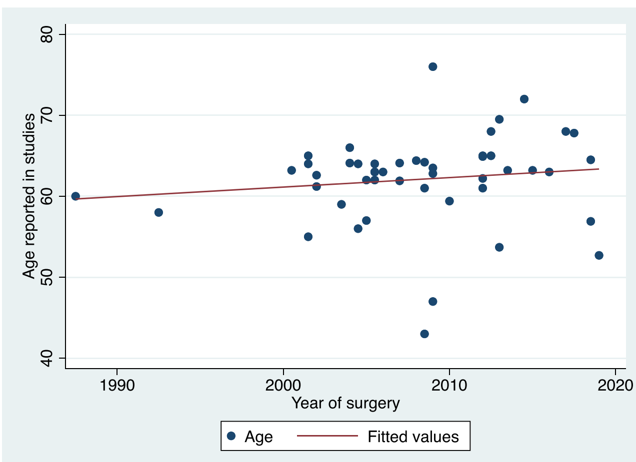

Fig. 4. Scatter plot illustrating the correlation between the mean age of patients reported in studies included in this review and the year of surgery (as a mean value between the first and last year of recruitment of patients).

While a greater functional improvement was recorded in patients younger than 55 years, the authors documented no difference in terms of pain, complication rate, reoperation rate and revision rate between groups [66] In a consecutive series of 811 ankles, Guagler et al. reported a 28.7 % risk for a minor or major revision at a mean follow-up of 5.4 years and 11.0 % at a mean follow-up of 6.9 years, respectively [13]. A subanalysis on that cohort revealed that age did not influence the hazard of major or minor revision of the implant, bringing the authors to conclude that TAR was a viable option for younger and older patients [13].

The main strength of this study is represented by the analysis of the age of surgery over the last two decades. It could be argued that the analysis of national joint registries would provide more accurate data about the mean age of patients undergoing TAR. As a matter of fact, while some joint registries reporting data on TAR have been started in the last years (Australia 2006, United Kingdom 2010) [67], others have been introduced before 2000 (i.e. Sweden 1993, Norway 1994, Finland 1999) which would allow to analyze patient demographics over the last 20 years. However, it should be emphasized that the analysis of joint registries would allow to assess demographics of a single country, with influences coming from local laws or habits and, potentially, a limited generalizability of results. Interestingly, the mean age reported in registries from inception up to 2019 (66.8 years in Australia, 57.5 years in Finland, 65.5 in New Zealand, 60.6 in Norway, 59.6 in Sweden and 67.8 in the United Kingdom) appears quite similar to the median value found in this study [67], which corroborates our results. While we are aware that median and mean are two different descriptive statistics and a formal comparison cannot be performed, we still think that all these numbers might be useful for clinicians to realize what are the epidemiological trends for patients undergoing TAR.

The authors acknowledge some limitations for the current study. First, even if we included only Level I or II studies in order to increase the quality of our findings, the analyses selected were conducted with multiple aims which generates some heterogeneity in the cohorts. However, including selectively prospective designs (in which a more reliable collection of baseline features, such as age, should theoretically be found as compared to retrospective studies) should reduce the risk of recall bias and increase the strength of our findings. Second, no subgroup analysis including other demographics was performed, which in turn was due to the lack of raw data in a number of studies. Third, although we excluded series with clear redundancies of patients from the same authors (such as long-term analyses or previous short-term studies), we are aware of potential duplicates in the studies by Townshend et al. (503 ankles [60]) and Goldberg et al. (183 ankles [61]), which were conducted in a similar period. However, considering the worst-case scenario of a 100 % doubling for the 183 TAR patients reported in the TARVA study by Goldberg, this would only represent 2 % of the patients included in this review with a theoretical low risk of heavily affecting the final median values. Last, the generation of implant used was not assessed in our study, which could potentially have weighed in the decision of clinicians to perform surgery on younger or older patients. This was due to the inclusion of a number of studies in which different implants (within the same study) had been used, making the extraction of such data often unreliable.

5. Conclusion

According to this review of prospective studies published between 1999 and 2023, the median age for patients undergoing total ankle replacement over the last two decades has been 63 years, remaining steady with no significant changes over time. Further studies will be needed to clarify whether last-generation implants and techniques may lead to a reduced risk of revision and encourage surgeons to discuss ankle replacement with younger patients.

Ethics approval

Ethics approval was not necessary for this systematic review and meta-analysis of already published studies.

Funding

No funding has been provided for the current work.

CRediT authorship contribution statement

Alessio Bernasconi: study conception, writing, statistical analysis, interpretation of data, revision. Antonio Izzo: study conception, data collection, interpretation of data, revision. Arianna Sgadari: study conception, data collection, interpretation of data, revision. Martina D'Agostino: study conception, data collection, interpretation of data, revision. Massimo Mariconda: study conception, writing, interpretation of data, revision. Andrew J. Goldberg: study conception, writing, interpretation of data, revision.

Declaration of Competing Interest

AB and AJG declare conflicts of interest as reported in the attached ICJME forms.

- AB has received support for attending meetings and declares stock options for CURVEBEAM AI. He is in the Board of the International Weightbearing CT Society and Chair of the Youth Committee of the European Foot and Ankle Society.

- AJG has received a grant from NIHR HTA for TARVA, consulting fees from Styker Inc and Paragon28, payment or honoraria for lectures from Stryker Inc, Paragon28 and Newclip. He is part of one or more boards in the American Orthopaedic Foot and Ankle Society, British Orthopaedic Foot and Ankle Society and National Joint Registry for England. He declares stock options with the Standing CT Company, Elstree Waterfront Outpatients and SOTA Orthopaedics.

AI, AS, MDS and MM declare no conflict of interest directly or indirectly related to this work.

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Nothing to declare.

Code availability (software application or custom code)

STATA software was used for statistical analysis. No other software was used for this study.

Consent for publication

Consent for publication was not necessary for this systematic review and meta-analysis of already published studies.

Informed consent

Informed consent was not necessary for this systematic review and meta-analysis of already published studies.

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