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Original Research

Lewinnek Safe Zone References are Frequently Misquoted

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ABSTRACT

Background: Optimal acetabular component orientation in total hip arthroplasty (THA) is a necessity in achieving a stable implant. Although there has been considerable debate in the literature concerning the safe zone, to date, there has not been any review to determine if these references are consistent with the definition applied by Lewinnek et al. in 1978. Therefore, this article aims to examine the available literature in the PubMed database to determine how often a correct reference to the safe zone as defined by Lewinnek was applied to discussions regarding THA.

Methods: A search for literature in the PubMed database was performed for articles from 1978 to 2019. Search criteria included terms 'Lewinnek,' 'safe zone,' and 'total hip arthroplasty.' Exclusions included abstract-only articles, non-English articles, articles unrelated to THA, and those lacking full content.

Results: A review of literature yielded 147 articles for inclusion. Overall, only 11% (17) cited the Lewinnek article correctly. Forty-five percent (66) of articles referenced measurements in the supine position, 18% (26) referenced other positions, and 37% (55) did not specify. Nineteen percent (28) reported measurements of the acetabular cup orthogonal to the anterior pelvic plane, while 73% (108) did not, and 7% (11) did not specify. Twenty-three percent (34) measured from computed tomography scans instead of other methods.

Conclusions: In the discussion of the safe zone regarding THA, only 11% of articles listed are consistent with the definition established by Lewinnek. This warrants further investigation into a consistent application of the term and its implications for THA implant stability and dislocation rates.

Introduction

Optimal acetabular component orientation is a key component of a successful total hip replacement [1]. Hip surgeons strive to achieve a biomechanically stable reconstruction, while minimizing the incidence of postoperative complications. With projections of 572,000 total hip arthroplasties (THAs) by 2030 [2], it is imperative to diminish surgical factors that may lead to complications such as dislocation.

Despite advances in surgical techniques and implants, dislocation after THA remains a common complication leading to early revision surgery [3,4]. Malposition of the acetabular components has been associated with acceleration of bearing wear, impingement, and limb-length discrepancy [5,6]. Abdel et al [3], Lewinnek and Lewis [7], and Beamer et al [8] proposed an acceptable range for the acetabular component position, known as a 'safe zone' (acetabular inclination 40° ± 10° and anteversion 15° ± 10°), in aims of reducing these complications, and found that cups outside of this zone experience a greater dislocation rate (projection of 1.5% within the safe zone vs 6.1% outside the safe zone).

Recent works have called into question the validity of the Lewinnek safe zone, citing anteversion and inclination measurements that do not accurately predict THA instability [3,9]. Before an article makes comparisons to the Lewinnek safe zone however, it is important to ensure that the same measurement parameters are

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used as that of the original Lewinnek safe zone description. In this landmark article, anteversion and inclination of the acetabular component were measured from a supine radiograph taken perpendicular to the anterior pelvic plane (APP) to define a safe zone. Moreover, although anteversion and inclination were originally measured from radiographs, recent evidence of higher accuracy in measuring cup orientation with computed tomography (CT) than with radiographs has made CT scans the 'golden standard' in cup orientation measurement [10,11].

Although Lewinnek's study has long been the benchmark in the discussion of acetabular cup positioning, a thorough assessment is necessary to determine how accurate subsequent works are when referencing the 'safe zone' and whether it was performed similar to that cited by the original Lewinnek article. The aim of this article is to investigate the frequency of Lewinnek's 'safe zone' being referenced in studies in the PubMed database and to determine the differences, if any, in how these studies conduct measurements of the component position when compared with the original work.

Material and methods

A review of the literature was performed in PubMed to identify articles that referenced Lewinnek's 'safe zone' between 1978 and 2019. Inclusion criteria consisted of studies that were identified in this search that included 'Lewinnek safe zone,' 'safe zone total hip arthroplasty,' and 'safe zone Lewinnek.' The search strategy is displayed in Table 1.

The results of this query were then screened for relevant article content. The researchers were not blind to the author, article source, or any other element of this search. Articles were then subject to the following exclusion criteria: abstract-only articles, review articles, editorials, technical notes, case reports, articles based in languages other than English, articles that did not measure cup orientation, articles that did not pertain to THA, and repeat articles that were included only once.

Each article was evaluated based on 4 criteria demonstrated in Table 2. Although radiographs were used to measure cup orientation in Lewinnek's original study, the use of CT was also included in the criteria. Articles that met all the evaluating criteria were considered as correctly referencing Lewinnek's safe zone. Articles that incorrectly referenced or did not reference at least one of the evaluating criteria were considered as incorrectly referencing the Lewinnek safe.

Results

A review of the published literature found 223 articles that met the search criteria. From these studies, 1 article appeared under multiple search terms in the query phase and was only included once, 15 articles were in non-English languages, 38 articles did not pertain to the acetabular cup safe zone or did not measure cup orientation, and 22 articles were reviews, editorials, technical notes, or case studies, producing 147 articles that were included in this study. The dates of publication ranged from 1995 to 2019.

Of these 147, articles were evaluated based on 4 criteria listed in Table 2. Forty-five percent (66) correctly measured cup orientation in the supine position, 19% (28) correctly referenced the safe zone orthogonal to the APP, 88% (129) correctly used radiographs to measure cup orientation, and 23% (34) correctly used CT scans to measure cup orientation (Table 3).

Overall, 11% (17) of articles correctly referenced the Lewinnek safe zone and 89% (130) incorrectly referenced the safe zone (Fig. 1). A complete list of referenced articles consistent with Lewinnek's criteria is referenced in Appendix A, and those that are inconsistent with Lewinnek's criteria are referenced in Appendix B.

Table 1
PubMed search strategy.

1. 'Lewinnek'
2. 'Safe Zone'
3. 'Total Hip Arthroplasty'
4. (1 AND 2) OR (2 AND 3) OR (1 AND 3)

Table 2
Criteria used for analyzing articles.

1. Supine position	Acetabular cup orientation measured when the patient is in the supine position; includes all articles that use CT scans unless otherwise mentioned
2. Anterior pelvic plane (APP) reference	Radiographic image taken orthogonal to the APP; excludes all articles that use standard anteroposterior radiographs to make measurements unless adjustments were made to account for the pelvic tilt such as the use of jigs similar to Lewinnek's original method [7]
3. Radiographic usage	Acetabular cup orientation measured using radiographs
4. CT scan usage	Acetabular cup orientation measured using CT scans

Discussion

The safe zone originally described by Lewinnek has been widely cited in the literature and has important clinical implications in optimizing THA stability. This article aimed to analyze differences in the way articles conduct measurements of component orientation compared with Lewinnek's original work in the PubMed database. We found that although Lewinnek's safe zone remains highly cited, the method of measurement of Lewinnek's original safe zone article is only correctly used in approximately 11% of the subsequent available literature that references this safe zone.

Failure to use the same parameters invalidates comparisons with the original range of anteversion and inclination Lewinnek recommended and can ultimately lead to incorrect conclusions drawn. In particular, recent articles have questioned the accuracy of the Lewinnek safe zone in predicting dislocations [3,9]. With measurement procedures deviating from that of Lewinnek, it is difficult to assess the validity of claims for or against the safe zone. Although it is beyond the scope of this study, it is important to acknowledge that the Lewinnek's study itself had numerous limitations. For example, adjusting for the pelvic tilt on radiographs or using CT scans to ensure measurements in the APP may be impractical in clinical settings. Furthermore, the safe zone criteria were based on 9 dislocations only, bringing into question the validity of the data.

Consistency with Lewinnek's method of cup orientation is critical in ensuring accurate results and comparisons with the safe zone. Differences in positioning have an effect on acetabular orientation: compared with measurements in the supine position, inclination and anteversion in the standing position have been

Table 3
Safe zone citation.

Article references			
	Correct reference	Incorrect reference	No reference
Article referenced in the supine position	45% (66)	18% (26)	37% (55)
Acetabular cup referenced orthogonal to the APP	19% (28)	73% (108)	7% (11)
Measurements using radiographs	88% (129)	11% (16)	1% (2)
Measurements using CT scans	23% (34)	-	77% (113)

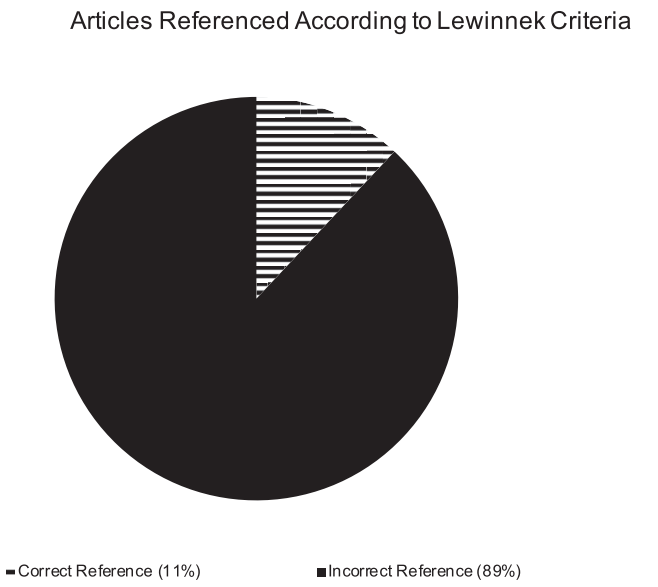

Figure 1. Articles that correctly and articles that incorrectly referenced the Lewinnek safe zone are shown. A Lewinnek safe zone reference was considered correct if an article correctly referenced all the following criteria: article referenced in the supine position, acetabular cup referenced orthogonal to the APP, measurements using radiographs, and measurements using CT scans. Articles were considered incorrect overall if at least one of these criteria was incorrect or not mentioned.

found to significantly increase and more likely to reside outside of the safe zone [12,13]. Reporting measuring cup orientation in the APP is also important. Given the technical challenges of using Lewinnek's jig to position the pelvis parallel to the radiographic film, studies often used standard anteroposterior radiographs without pelvic tilt adjustment, making the plane of reference to be the coronal plane instead of the APP. Previous works have reported that anteroposterior radiographs do not account for spinal deformity or pelvic positioning, yielding inaccuracies when compared with using imaging techniques orthogonal to the APP [14-18]. In fact, each degree of the pelvic tilt has been associated with a 0.7° change in cup anteversion [14]. In addition, different modalities of measuring cup orientation may lead to discrepancies in measurement. Previous works have indicated that CT measurements are more accurate than plain radiographs, partly because CT scans are able to account for the three-dimensional orientation of the acetabular cup that two-dimensional radiographs lack [11,18-20].

There are several limitations in this article. First, unaccounted parameters outside the criteria used to evaluate articles may affect the accuracy of measuring and reporting cup orientation. For example, Murray asserted that calculating angles of anteversion and inclination can be achieved through anatomical, radiographic, and intraoperative definitions of measurements [21]. Although the original safe zone is consistent with Murray's definition of radiographic anteversion and inclination [7], several works in the literature have attempted to compare safe zone parameters with intraoperative or anatomical measurements, which can yield misleading results [22,23]. Examining articles based on different Murray definitions of cup orientation represents a potential topic for further investigation. Moreover, the binary nature of the evaluation may oversimplify certain aspects of the results. For example, adjusting for the pelvic tilt with a jig on anteroposterior radiographs compared with adjusting for the pelvic tilt from CT scans using a software program may yield differences in accuracies. However, both methods were considered as correct for referencing the cup orthogonal to the APP. The use of computer software in several articles to measure acetabular component orientation also introduces variations in methods of measurement, which limits a comparison of similar cup measurements.

Conclusions

In conclusion, this investigation of Lewinnek's safe zone demonstrates a stark contrast between Lewinnek's method of measurement and the majority of studies that reference the original 'safe zone' with only 11% referencing correctly. Our study suggests exploring a standardized method of measuring acetabular component positioning that allows future studies to better interpret angles of inclination and anteversion in THA. Drawing broad conclusions between Lewinnek's original article and a large number of those that referenced it in this study may be of limited use considering the variety of measurement techniques used. Future studies that investigate the use of a safe zone may be served by acknowledging the differences in measurement and steps to reduce this variability.

Conflict of interests

A.J. Buckland is a paid consultant for NuVasive, Stryker, EOS Imaging, and Medtronic; S.A. Jerabek receives royalties from Stryker, is a paid consultant for Stryker, and receives research support from Stryker; J. Pierrepont is a paid employee for Corin Group and holds stock ownership in Corin Group; J.M. Vigdorchik is a paid consultant for Corin, Intellijoint Surgical, and Zimmer, holds stock ownership in Intellijoint Surgical, and receives research support from Corin; all other authors declare no potential conflicts of interest.

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Appendix

Appendix A
Article references consistent with Lewinnek criteria.

Author	Year	Journal
Dandachli W. et al. [24]	2006	*Computer Aided Surgery*
Gurgel H.M. et al. [25]	2014	*Journal of Arthroplasty*
Haimerl M. et al. [26]	2012	*Computer Aided Surgery*
Hart A.J. et al. [27]	2009	*The Journal of Bone and Joint Surgery*
Hohmann E. et al. [28]	2011	*Journal of Arthroplasty*
Jenny J.Y. et al. [29]	2009	*International Orthopaedics*
Merle C. et al. [30]	2013	*The Journal of Bone and Joint Surgery*
Murtha P.E. et al. [31]	2008	*The Journal of Bone and Joint Surgery*
Ohmori T. et al. [32]	2017	*Hip International*
Parratte S. et al. [33]	2007	*The Journal of Bone and Joint Surgery*
Reina N. et al. [34]	2017	*Orthopaedics & Traumatology: Surgery & Research*
Sariali E. et al. [35]	2016	*The Journal of Bone and Joint Surgery*
Saxler G. et al. [36]	2004	*International Orthopaedics*
Tohtz S.W. et al. [37]	2010	*Technology and Health Care*
Verdier N. et al. [38]	2016	*Orthopaedics & Traumatology: Surgery & Research*
Wassilew G.I. et al. [39]	2010	*Orthopedics*
Weber M. et al. [40]	2015	*Journal of Arthroplasty*

Appendix B
Article references inconsistent with Lewinnek criteria.

Author	Year	Journal	Incorrect criteria[a]
Abdel M.P. et al. [3]	2016	*Clinical Orthopaedics and Related Research*	1, 2, 4
Adelani M.A. et al. [41]	2014	*The Journal of Bone and Joint Surgery*	1, 2, 4
Akgün D. et al. [42]	2019	*Hip International*	2
Alzohiry M.A. et al. [43]	2018	*International Orthopaedics*	2, 4
Au J. et al. [13]	2014	*Hip International*	1, 2, 4
Bargar W.L. et al. [44]	2010	*Clinical Orthopaedics and Related Research*	2
Beamer B.S. et al. [8]	2014	*Clinical Orthopaedics and Related Research*	2, 4
Bobman J.T. et al. [45]	2016	*Journal of Arthroplasty*	1, 2, 4
Boettner F. et al. [46]	2017	*Journal of Arthroplasty*	2, 4
Bosker B.H. et al. [47]	2007	*Archives of Orthopaedic and Trauma Surgery*	1, 2, 4
Chang J.D. et al. [48]	2017	*Journal of Arthroplasty*	2
Chen A.F. et al. [49]	2016	*HSS Journal*	1, 2, 4
Choi H.R. et al. [50]	2013	*International Orthopaedics*	1, 2, 4
Danoff J.R. et al. [51]	2016	*Journal of Arthroplasty*	1, 2, 4
Dardenne G. et al. [52]	2009	*Clinical Orthopaedics and Related Research*	1, 2, 4
Darrith B. et al. [53]	2018	*The Bone and Joint Journal*	1, 2, 4
Davda K. et al. [19]	2015	*Acta Orthopaedica*	2, 4
Davis E.T. et al. [54]	2015	*Journal of Arthroplasty*	1, 2, 3, 4
Debi R. et al. [55]	2018	*BMC Musculoskeletal Disorders*	2, 4
DelSole E.M. et al. [56]	2017	*Journal of Arthroplasty*	1, 2, 4
Domb B.G. et al. [57]	2014	*Clinical Orthopaedics and Related Research*	2, 4
Domb B.G. et al. [58]	2015	*Journal of Arthroplasty*	1, 2, 4
Dorr L.D. et al. [59]	2009	*Clinical Orthopaedics and Related Research*	3, 4
Drobniewski M. et al. [60]	2017	*Ortopedia Traumatologia Rehabilitacja*	1, 2, 4
Ecker T.M. et al. [61]	2007	*Clinical Orthopaedics and Related Research*	1, 2, 4
Elmallah R.K. et al. [62]	2015	*Surgical Technology International*	1, 2, 4
Elson L. et al. [63]	2015	*Hip International*	2, 4
Esposito C.I. et al. [64]	2015	*Journal of Arthroplasty*	1, 2, 4
Ezquerra-Herrando L. et al. [65]	2015	*Revista Española de Cirugía Ortopédica y Traumatología*	1, 2, 4
Fessy M.H. et al. [66]	2017	*Orthopaedics & Traumatology: Surgery & Research*	1, 2, 4
Fujita K. et al. [67]	2014	*The Bone and Joint Journal*	2
Fukui T. et al. [68]	2013	*Orthopedic Reviews*	1, 3, 4
Fukunishi S. et al. [69]	2008	*Orthopedics*	3, 4
García-Rey E. et al. [70]	2017	*The Bone and Joint Journal*	1, 2, 4
Goodman G.P. et al. [71]	2017	*Hip International*	2, 4
Gosthe R.G. et al. [72]	2017	*Journal of Arthroplasty*	1, 2, 4
Goudie S.T. et al. [73]	2015	*Bone & Joint Research*	1, 3, 4
Harold R.E. et al. [74]	2019	*Hip International*	1, 2, 4
Hart A.J. et al. [75]	2011	*The Journal of Bone and Joint Surgery*	2
Hassan D.M. et al. [76]	1995	*Journal of Arthroplasty*	1, 2, 3, 4
Heck D.A. et al. [77]	2009	*Clinical Orthopaedics and Related Research*	1, 2, 3, 4

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Appendix B (*continued*)

Author	Year	Journal	Incorrect criteria[a]
Horsthemke M.D. et al. [78]	2019	*Archives of Orthopaedic and Trauma Surgery*	1, 2, 4
Illgen R.L. Nd et al. [79]	2017	*Surgical Technology International*	1, 2, 4
Imai H. et al. [80]	2016	*European Journal of Orthopaedic Surgery & Traumatology*	2
Inoue M. et al. [81]	2013	*Journal of Orthopaedic Surgery*	1
Ishidou Y. et al. [82]	2016	*Journal of Orthopaedic Surgery*	2, 4
Iwata H. et al. [83]	2018	*Journal of Orthopaedics*	1, 2, 4
Jacobs C.A. et al. [84]	2019	*The Bone and Joint Journal*	1, 2, 4
Jauregui J.J. et al. [85]	2016	*Orthopedics*	1, 2, 4
Jennings J.D. et al. [86]	2015	*Orthopedics*	1, 2, 4
Kajino Y. et al. [87]	2013	*Journal of Orthopaedic Science*	2
Kalteis T. et al. [88]	2006	*The Journal of Bone and Joint Surgery*	2
Kalteis T. et al. [89]	2005	*International Orthopaedics*	2
Kalteis T.A. et al. [90]	2009	*Journal of Arthroplasty*	3, 4
Kamara E. et al. [91]	2017	*Journal of Arthroplasty*	1, 2, 4
Karakoyun Ö. et al. [92]	2016	*Journal of Clinical Orthopaedics and Trauma*	1, 2, 4
Kawarai Y. et al. [93]	2017	*International Orthopaedics*	1, 2, 4
Kayani B et al. [94]	2019	*The Bone and Joint Journal*	1, 2, 4
Khan R.J. et al. [95]	2012	*The Journal of Bone and Joint Surgery*	2, 4
Kiefer H. et al. [96]	2005	*Orthopedics*	1, 2, 4
Kim Y.L. et al. [97]	2007	*Journal of Arthroplasty*	1, 2, 4
Kubota Y. et al. [98]	2019	*Clinical Orthopaedics and Related Research*	1, 2, 4
Kurosaka K et al. [99]	2016	*Orthopedics*	1, 2, 3, 4
Langlotz U. et al. [100]	2007	*Proceedings of the Institution of Mechanical Engineers*	4
Lazennec J.Y. et al. [12]	2017	*Journal of Arthroplasty*	1, 4
Lee S.H. et al. [101]	2017	*Hip & Pelvis*	1, 2, 3, 4
Li Y.J. et al. [102]	2010	*Chinese Journal of Traumatology*	1, 2, 3, 4
Liaw C.K. et al. [103]	2006	*Clinical Orthopaedics and Related Research*	1, 2, 4
Liu F. et al. [104]	2013	*Journal of Arthroplasty*	2, 4
Lu M. et al. [105]	2013	*Clinical Orthopaedics and Related Research*	2, 4
Manjunath K.S. et al. [106]	2015	*European Journal of Orthopaedic Surgery & Traumatology*	4
Masaoka T. et al. [107]	2006	*International Orthopaedics*	1, 2, 4
McLawhorn A.S. et al. [108]	2015	*American Journal of Orthopaedics*	2, 4
Meermans G. et al. [109]	2015	*The Bone and Joint Journal*	1, 2, 3, 4
Meermans G. et al. [110]	2014	*The Bone and Joint Journal*	2, 4
Meftah M. et al. [111]	2013	*Journal of Arthroplasty*	1, 2, 4
Morvan A. et al. [112]	2016	*The Bone and Joint Journal*	1, 2, 4
Murphy W.S. et al. [6]	2018	*Clinical Orthopaedics and Related Research*	2
Nakamura J. et al. [113]	2017	*BMC Musculoskeletal Disorders*	2, 4
Nakata K. et al. [114]	2009	*Journal of Arthroplasty*	1, 2, 4
Nho J.H. et al. [115]	2012	*The Journal of Bone and Joint Surgery*	2, 4
Nomura T. et al. [116]	2014	*The Bone and Joint Journal*	2, 4
Noticewala M. et al. [117]	2018	*Journal of Clinical Orthopaedics and Trauma*	1, 2, 4
Oh K.J. et al. [118]	2018	*Journal of Orthopaedic Surgery*	2
Okanoue Y. et al. [119]	2017	*Hip International*	1, 2, 4
Opperer M. et al. [120]	2016	*International Orthopaedics*	1, 2, 4
Osawa Y. et al. [121]	2017	*Journal of Arthroplasty*	1, 2, 4
Osawa Y. et al. [122]	2016	*Journal of Arthroplasty*	1, 2, 4
Park Y.S. et al. [123]	2018	*Journal of Orthopaedic Surgery and Research*	2, 4
Pearce C.J. et al. [124]	2008	*Hip International*	1, 2, 4
Peters F.M. et al. [125]	2012	*Journal of Arthroplasty*	1, 2, 3, 4
Pongkunakorn A. et al. [126]	2019	*Journal of Orthopaedic Surgery*	2, 4
Reize P. et al. [127]	2008	*American Journal of Orthopedics*	1, 2, 4
Rittmeister M. et al. [128]	2006	*Clinical Orthopaedics and Related Research*	1, 2, 4
Rivière C. et al. [129]	2019	*Orthopaedics & Traumatology: Surgery & Research*	2, 4
Rojas J. et al. [130]	2018	*International Orthopaedics*	2, 4
Sadhu A. et al. [131]	2017	*Journal of Arthroplasty*	1, 2, 4
Salal M.H. et al. [132]	2017	*Journal of the College of Physicians and Surgeons Pakistan*	1, 2, 4
Sariali E. et al. [133]	2009	*Journal of Arthroplasty*	2
Schwarz T. et al. [134]	2017	*International Journal of Computer Assisted Radiology and Surgery*	1, 2, 4
Schweppe M.L. et al. [135]	2013	*Surgical Technology International*	1, 2, 4
Seagrave K.G. et al. [136]	2017	*Journal of Arthroplasty*	1, 2, 4
Snijders T.E. et al. [137]	2019	*Orthopaedic Surgery*	2, 4
Snyder G.M. et al. [138]	2012	*Journal of Arthroplasty*	1, 2, 3, 4
Soderquist M.C. et al. [5]	2017	*Journal of Arthroplasty*	2, 4
Somers J.F. et al. [139]	2015	*Acta Orthopaedica Belgica*	1, 2, 4
Song X. et al. [140]	2018	*Journal of Orthopaedic Surgery and Research*	2, 4
Sugano N. et al. [141]	2007	*The Journal of Bone and Joint Surgery*	1, 2, 4
Suksathien Y. et al. [142]	2014	*Journal of the Medical Association of Thailand*	2
Suksathien Y. et al. [143]	2014	*Journal of the Medical Association of Thailand*	2
Surace M.F. et al.[144]	2016	*Surgical Technology International*	1, 2, 4
Tai S.M. et al. [145]	2015	*Journal of Arthroplasty*	1, 2, 4
Tamaki T. et al. [146]	2015	*Hip International*	1, 2, 4
Tannast M. et al. [147]	2005	*Computer Aided Surgery*	4
Tauriainen T.J.T. et al. [148]	2017	*Journal of Arthroplasty*	1, 2, 4
Teeter M.G. et al. [149]	2018	*The Bone and Joint Journal*	2, 4

Appendix B (*continued*)

Author	Year	Journal	Incorrect criteria[a]
Tezuka T. et al. [150]	2019	*Journal of Arthroplasty*	1, 2, 3, 4
Tiberi J.V. 3rd et al. [151]	2015	*Journal of Arthroplasty*	1, 2, 4
Timperley A.J. et al. [152]	2016	*Hip International*	1, 2, 4
Trieu J. et al. [153]	2018	*ANZ Journal of Surgery*	1, 2, 4
Tripuraneni K.R. et al. [154]	2016	*Journal of Arthroplasty*	2, 4
Tsiridis E. et al. [155]	2019	*Hip International*	2, 4
Viste A. et al. [156]	2011	*Orthopaedics & Traumatology: Surgery & Research*	1, 3, 4
Wang W. et al. [157]	2014	*BMC Musculoskeletal Disorders*	1, 2, 4
Yoon B.H. et al. [158]	2016	*Journal of Orthopaedic Science*	2
Yoshimine F. [159]	2005	*Journal of Biomechanics*	1, 2, 3, 4
Yoshitani J. et al. [160]	2018	*Journal of Orthopaedic Surgery*	1, 2, 4
Yun A. et al. [161]	2016	*Clinical Orthopaedics and Related Research*	1, 2, 4
Yun H.H. et al. [162]	2014	*Hip & Pelvis*	1, 2, 3, 4
Zhu B. et al. [163]	2017	*Hip International*	2

[a] Incorrect criteria refer to criteria that were inconsistent with the Lewinnek safe zone criteria or were not mentioned. The criteria are numbered according to [Table 2]: 1—supine position; 2—APP reference; 3—radiographic usage; 4—CT scan usage.