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REVIEW ARTICLE

Hip geometry and femoral neck fractures: A meta-analysis

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Abstract *Background:* Several studies have reported hip geometry to predict the femoral neck fractures. However, they showed inconsistency.
Objectives: To determine the association between hip geometry and femoral neck fractures.
Methods: Published literature from PubMed and Embase databases (until May 25th, 2017) was searched for eligible publications. The information related to (1) name of first author; (2) year of publication; (3) country of origin; (4) sample size of cases and controls and (5) mean and standard deviation of cases and controls were extracted. The pooled odds ratios (ORs) and 95% confidence intervals (95% CIs) for the association between hip geometry and femoral neck fractures were assessed using random or fixed effect model. A Comprehensive Meta-analysis software, version 2.0, was used to analyse the data.
Results: A total of 11 studies were included in this study. Our results showed that increase in hip axis length (OR 95% CI = 1.53 [1.06—2.21], $p = 0.025$), femoral neck angle (OR 95% CI = 1.47 [1.01—2.15], $p = 0.044$) and neck width (OR 95% CI = 2.68 [1.84—3.91], $p < 0.001$) was associated with the risk of femoral neck fractures, whereas we could not find the correlation between femoral neck axis length and the risk of femoral neck fractures.
Conclusion: There is strong evidence that elevated hip axis length, femoral neck angle and neck width are the risk factor for femoral neck fractures.

The Translational Potential of this Article: Determining the hip axis length, femoral neck angle and neck width that are most highly associated with femoral neck fracture may allow clinicians to more accurately predict which individuals are likely to experience femoral neck fractures in the future.

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Introduction

Femoral neck fracture, one of the most common traumatic injuries in elderly patients, is a serious problem in the elderly and continues to be unsolved fractures, and the guidelines for management are still evolving [1]. The incidence of femoral neck fractures, constituting 53% of all fractures of the proximal femur [2], varies, ranging from 87 per 100,000 women per year in China to 920 per 100,000 women per year in Norway [2,3]. A study estimated that there would be an increase in femoral neck fractures incidence from about 1.7 million cases in 1990 to 6 million cases in 2050 [4]. In the elderly, femoral neck fractures have triggered a significant health-care problem and have great impact on health insurance costs. In the United Kingdom, annual direct care expenditure for fractures is about one trillion dollars [5].

In younger patients, femoral neck fractures are often caused by high velocity trauma. However, in elderly and or osteoporotic individuals, femoral neck fractures may occur even without major trauma [1]. Osteoporosis is a skeletal disease characterised by the loss of bone mass and density, which results in an increased risk of fractures [6]. Osteoporosis is a silent disease, which means that osteoporosis does not have a dramatic clinical presentation except when fractures occur [7]. The three bones often affected in osteoporotic patients are femoral neck, spine and distal radius [8]. The risk of femoral neck fractures in osteoporotic patient is difficult to predict because most patients show no symptoms [6].

Hip geometry, the examination of bone strength based on the measurement of proximal femur, is often associated with femoral neck fractures [9]. Several studies have reported hip geometry to predict the femoral neck fractures [9—19]. However, they showed inconsistency. Therefore, meta-analysis is the solution to determine the real association. This study aimed to investigate the real association between hip geometry and femoral neck fractures using a meta-analysis approach. Therefore, the actual correlation between hip geometry and the femoral neck fractures can be established.

Methods

Study designs

A meta-analysis was performed to assess the association between hip geometry and femoral neck fractures. To reach this goal, several studies regarding the association between hip geometry and femoral neck fractures were collected for calculating combined odds ratios and 95% confidence intervals (ORs 95% CI) and assessed using fixed or random effect model. The design was adapted from our previous studies [20—24]. Articles were searched in PubMed and Embase. The study was conducted in January 2017—June 2017. The inclusion criteria were (1) case—control studies; (2) cohort studies; (3) cross-sectional studies; (4) randomised-controlled trials (RCTs); (5) controlled before-and-after studies; (6) cross-over studies; (7) evaluating the associations between hip geometry and femoral neck fractures and (8) providing sufficient data for

the calculation of OR 95% CI. Articles with family-based study, review and/or comment were excluded. Some of the required data were extracted from each study for calculating OR 95% CI. For each study, information related to (1) name of the first author; (2) year of publication; (3) country of origin; (4) sample size of cases and controls and (5) mean and standard deviation of cases and controls were extracted.

Search strategy and literature

Briefly, articles related to the association between hip geometry and femoral neck fractures were searched in PubMed and Embase with no language restrictions, using specified search terms to identify studies published until May 25th, 2017. The search strategy involved the use of combination of the following key words: (hip geometry OR hip axis length OR femoral neck axis length OR femoral neck angle OR neck width) AND (femoral neck fractures OR collum femur fractures OR fracture neck of femur). The publication languages were restricted to English.

Study variables

The response variable in this study was the incidence of femoral neck fractures. The explanatory variables in this study were hip axis length (HAL) (mm), femoral neck axis length (FNAL) (mm), femoral neck angle (FNA) (°) and neck width (NW) (mm). The response variable was assessed using ordinal scale, and all explanatory variables were assessed using ratio scale. Measurements of HAL, FNAL, FNA and NW are described in Fig. 1 [9].

Statistical analysis

The correlation between hip geometry and femoral neck fractures was estimated by calculating the pooled ORs and 95% CI. The significance of pooled ORs was determined by Z tests ($p < 0.05$ was considered statistically significant). A Q
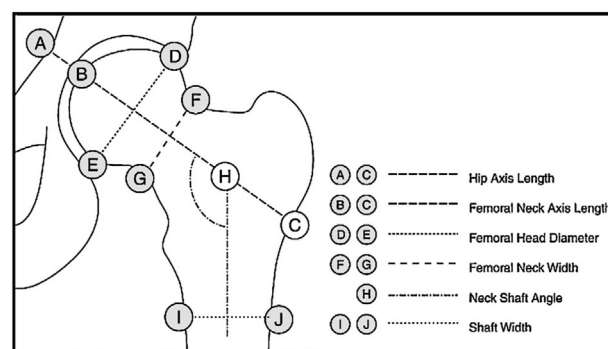
Figure 1 The scheme of hip geometry measurement. HAL, distance from the pelvic rim to the outer margin of greater trochanter along the neck axis (A—C). FNAL, distance from the user-defined centre of the femoral head to the intersection of the neck and shaft axes (B—C). FNA, angle between derived axes of the neck and shaft (H). NW, the width of the femoral neck (F—G) [9]. FNA = femoral neck angle; FNAL = femoral neck axis length; HAL = hip axis length; NW = neck width.

test was performed to evaluate whether the heterogeneity existed. Random effect model was used to calculate OR 95% CI if heterogeneity existed ($p < 0.10$), otherwise a fixed effect model was used. Publication bias was assessed using Egger's test ($p < 0.05$ was considered statistically significant). All analyses were conducted using a Comprehensive Meta-analysis software, version 2.0.

Results

Characteristics of the studies

Based on the search strategy, a total of 18,161 articles were identified. Of these, 18,141 articles were excluded because of obvious irrelevance by reading their titles and abstracts. After the full texts were read, four articles were excluded because they did not provide sufficient data for the calculation of OR with 95% CI. In addition, four reviews and one comment were excluded. A total of 11 studies were included in the meta-analysis. For HAL, a total of 10 articles consisting of five retrospective studies, four cross-sectional studies and one RCT study were included in the study. For FNAL, there were six articles consisting of two retrospective studies, two cross-sectional studies, one prospective study and one RCT study. For FNA, a total of seven studies consisting of three retrospective studies, two cross-sectional studies, one prospective study and one RCT study were included in the study. For NW, there were eight articles consisting of four retrospective studies, three cross-sectional studies and one RCT study.

Quantitative data synthesis

For HAL, a total of 773 cases and 3871 controls were identified. The result found that HAL was associated with the risk of femoral neck fractures [OR 95% CI = 1.53 (1.06−2.21), $p = 0.025$]. For FNAL, a total of 850 femoral neck fractures and 7613 controls were included in the study. We found that there was no significant association between FNAL and the risk of femoral neck fractures [OR 95% CI = 0.36 (0.10−1.29), $p = 0.117$]. For FNA, a total of 974 cases and 7915 controls were analysed. Our result showed that there was significant association between FNA and the risk of femoral neck fractures [OR 95% CI = 1.47 (1.01−2.15), $p = 0.044$]. For NW, a total of 443 cases and 1724 controls were identified. We found that elevated NW was associated with the risk of femoral neck fractures [OR 95% CI = 2.68 (1.84−3.91), $p < 0.001$]. See Table 1.

Table 1 Summary of OR and 95% CI regarding hip geometry and femoral neck fracture.

Hip geometry	OR	95% CI	p	pH	pE
HAL	1.53	1.06−2.21	0.025	<0.001	0.510
FNAL	0.36	0.10−1.29	0.117	<0.001	1.446
FNA	1.47	1.01−2.15	0.044	<0.001	0.411
NW	2.68	1.84−3.91	<0.001	0.004	0.428

CI = confidence interval; FNA = femoral neck angle; FNAL = femoral neck axis length; HAL = hip axis length; NW = neck width; OR = odds ratio; pE = p Egger; pH = p heterogeneity.

Source of heterogeneity and potential publication bias

Evidence for heterogeneity ($p < 0.10$) between studies was found in all groups (HAL, $p < 0.001$; FNAL, $p < 0.001$; FNA, $p < 0.001$; NW, $p = 0.004$). Therefore, the data in this study were assessed using random effects model. Using Egger's test, no publication bias could be detected (HAL, $p = 0.510$; FNAL, $p = 1.446$; FNA, $p = 0.411$; NW, $p = 0.428$). See Table 1.

Discussions

The most femoral neck fractures in elderly are due to the inability of the bones to withstand minor trauma [10]. Risk stratification is an ideal way to prevent femoral neck fractures; one of them is hip geometry consisting of HAL, FNAL, FNA and NW [9]. Several studies regarding the association between hip geometry and femoral neck fractures showed inconsistency. Our study reported the associations between hip geometry and femoral neck fractures with a meta-analysis approach. Overall, we compared the mean and standard deviation of hip geometry between femoral neck fracture patients and controls.
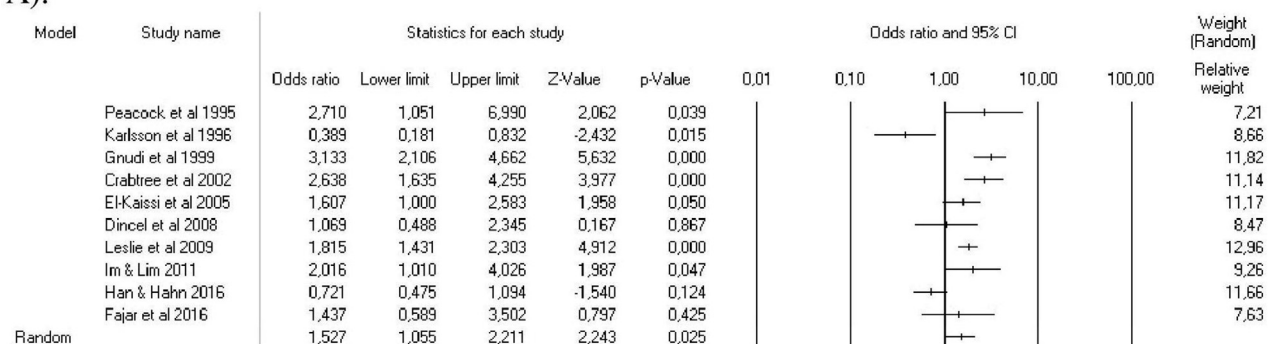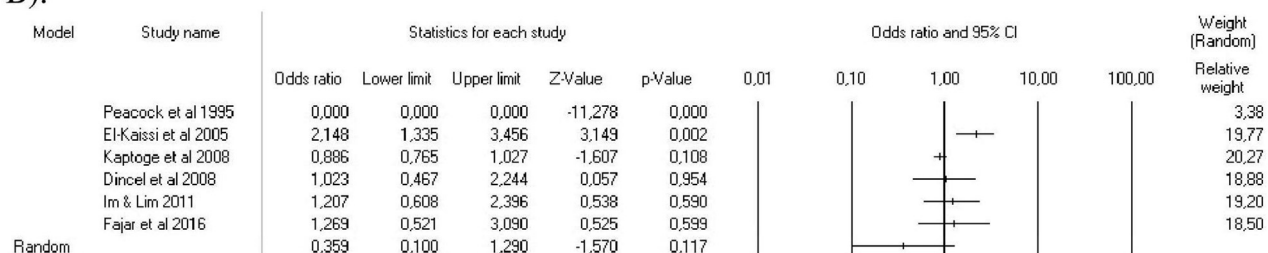
In hip geometry, HAL is defined as the distance from the pelvic rim to the outer margin of greater trochanter along the neck axis [9]. We searched articles in PubMed and Embase, and we found 10 articles evaluating the correlation between HAL and femoral neck fractures. Of these, four retrospective studies [11,14,17,18], two cross-sectional studies [12,13] and one RCT study [10] showed that HAL was associated with femoral neck fractures. However, two cross-sectional studies [9,15] and one retrospective study [19] found that no significant association between hip geometry and femoral neck fractures existed. We combined the pooled ORs and 95% CIs of these studies, and we found that HAL was associated with femoral neck fractures [OR 95% CI = 1.53 (1.06−2.21), $p = 0.025$]. See Table 1 and Fig. 2A. In this analysis, we did not consider several factors likely to affect HAL measurements such as age, ethnicity and gender [25−27]. This result implied a tendency that ethnic factors have a role to play in this outcome. A total of seven studies comprising eight Caucasians and one Asian indicated that the HAL had an association with the femoral neck fractures, whereas three studies consisting of two Asians and one Eurasian showed no significant associations between HAL and femoral neck fractures. Based on this, there was a tendency that the Caucasian seemed more likely to have association with the femoral neck fractures and the Asian was less likely to have association.

FNAL is defined as the distance from the user-defined centre of the femoral head to the intersection of the neck and shaft axes [9]. In PubMed and Embase, we found six articles evaluating the association between FNAL and femoral neck fractures. Of these, only two studies by El-Kaissi et al [14] and Peacock et al [10] found that FNAL was associated with femoral neck fractures, whereas other studies [9,15,16,18] showed otherwise. Our meta-analysis showed that there was no significant association between FNAL and femoral neck fractures [OR 95% CI = 0.36
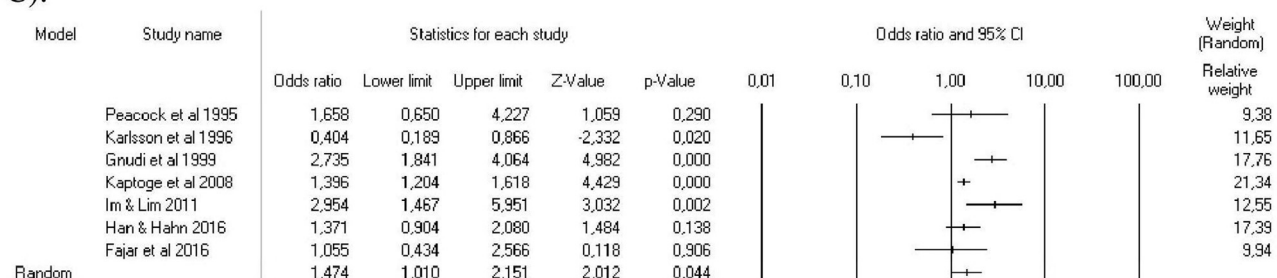
A).

Model	Study name	Statistics for each study					Odds ratio and 95% CI	Weight (Random)
		Odds ratio	Lower limit	Upper limit	Z-Value	p-Value		Relative weight
	Peacock et al 1995	2,710	1,051	6,990	2,062	0,039		7,21
	Karlsson et al 1996	0,389	0,181	0,832	-2,432	0,015		8,66
	Gnudi et al 1999	3,133	2,106	4,662	5,632	0,000		11,82
	Crabtree et al 2002	2,638	1,635	4,255	3,977	0,000		11,14
	El-Kaissi et al 2005	1,607	1,000	2,583	1,958	0,050		11,17
	Dincel et al 2008	1,069	0,488	2,345	0,167	0,867		8,47
	Leslie et al 2009	1,815	1,431	2,303	4,912	0,000		12,96
	Im & Lim 2011	2,016	1,010	4,026	1,987	0,047		9,26
	Han & Hahn 2016	0,721	0,475	1,094	-1,540	0,124		11,66
	Fajar et al 2016	1,437	0,589	3,502	0,797	0,425		7,63
Random		1,527	1,055	2,211	2,243	0,025		

B).

Model	Study name	Statistics for each study					Odds ratio and 95% CI	Weight (Random)
		Odds ratio	Lower limit	Upper limit	Z-Value	p-Value		Relative weight
	Peacock et al 1995	0,000	0,000	0,000	-11,278	0,000		3,38
	El-Kaissi et al 2005	2,148	1,335	3,456	3,149	0,002		19,77
	Kaptoge et al 2008	0,886	0,765	1,027	-1,607	0,108		20,27
	Dincel et al 2008	1,023	0,467	2,244	0,057	0,954		18,88
	Im & Lim 2011	1,207	0,608	2,396	0,538	0,590		19,20
	Fajar et al 2016	1,269	0,521	3,090	0,525	0,599		18,50
Random		0,359	0,100	1,290	-1,570	0,117		

C).

Model	Study name	Statistics for each study					Odds ratio and 95% CI	Weight (Random)
		Odds ratio	Lower limit	Upper limit	Z-Value	p-Value		Relative weight
	Peacock et al 1995	1,658	0,650	4,227	1,059	0,290		9,38
	Karlsson et al 1996	0,404	0,189	0,866	-2,332	0,020		11,65
	Gnudi et al 1999	2,735	1,841	4,064	4,982	0,000		17,76
	Kaptoge et al 2008	1,396	1,204	1,618	4,429	0,000		21,34
	Im & Lim 2011	2,954	1,467	5,951	3,032	0,002		12,55
	Han & Hahn 2016	1,371	0,904	2,080	1,484	0,138		17,39
	Fajar et al 2016	1,055	0,434	2,566	0,118	0,906		9,94
Random		1,474	1,010	2,151	2,012	0,044		

D).

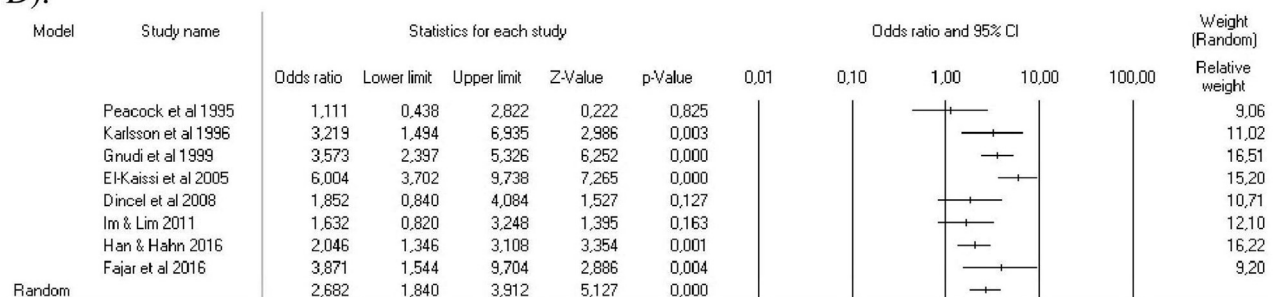| Model	Study name	Statistics for each study					Odds ratio and 95% CI	Weight (Random)
		Odds ratio	Lower limit	Upper limit	Z-Value	p-Value		Relative weight
	Peacock et al 1995	1,111	0,438	2,822	0,222	0,825		9,06
	Karlsson et al 1996	3,219	1,494	6,935	2,986	0,003		11,02
	Gnudi et al 1999	3,573	2,397	5,326	6,252	0,000		16,51
	El-Kaissi et al 2005	6,004	3,702	9,738	7,265	0,000		15,20
	Dincel et al 2008	1,852	0,840	4,084	1,527	0,127		10,71
	Im & Lim 2011	1,632	0,820	3,248	1,395	0,163		12,10
	Han & Hahn 2016	2,046	1,346	3,108	3,354	0,001		16,22
	Fajar et al 2016	3,871	1,544	9,704	2,886	0,004		9,20
Random		2,682	1,840	3,912	5,127	0,000		

Figure 2 (A) Forest plot regarding the association between HAL and the risk of femoral neck fracture. (B) Forest plot regarding the association between FNAL and the risk of femoral neck fracture. (C) Forest plot regarding the association between FNA and the risk of femoral neck fracture. (D) Forest plot regarding the association between NW and the risk of femoral neck fracture. FNA = femoral neck angle; FNAL = femoral neck axis length; HAL = hip axis length; NW = neck width.

(0.10−1.29), p = 0.117]. See Table 1 and Fig. 2B. There was no reason to explain this result. We tried to associate these results with several factors that may affect such as age, gender and ethnicity, as reported by Christensen et al [28] and Jiang et al [29]. However, we did not find any trends.

FNA is the angle between the derived axes of the neck and shaft [9]. We found seven articles form PubMed and Embase evaluating the correlation between FNA and femoral neck fractures. Of these studies, two retrospective studies [11,18], one cross-sectional study [12] and one prospective [16] study found that FNA was associated with femoral neck fractures, whereas one cross-sectional [9], one retrospective [19], and one RCT study [10] found that no association between FNA and femoral neck fractures

existed. Our meta-analysis found that there was significant association between FNA and the risk of femoral neck fractures [OR 95% CI = 1.47 (1.01−2.15), p = 0.044]. See Table 1 and Fig. 2C.

The last parameter of hip geometry is NW, which is defined as the width of the femoral neck [9]. We searched articles in PubMed and Embase, evaluating the correlation between NW and femoral neck fractures, and we found eight articles. Of these, three retrospectives [11,14,19] and two cross sectionals [9,12] found that there was strong association between NW and femoral neck fractures. However, one retrospective [18], one cross-sectional [15] and one RCT study [10] showed that no association between NW and femoral neck fractures existed. Our meta-analysis revealed that elevated NW was associated with the risk of femoral neck fractures [OR 95% CI = 2.68 (1.84−3.91), $p < 0.001$]. See Table 1 and Fig. 2D.

Our results revealed that increases in HAL, FNA and NW were associated with the risk of femoral neck fractures. This is the first meta-analysis regarding the association between hip geometry and femoral neck fractures. Therefore, we were not able to compare our result with that of others. Increases in HAL, FNA and NW mean that the femoral neck fractures were categorised as type III and IV, according to the Garden classification [30]. Type III and/or IV femoral neck fracture in patients with minimal trauma implies that osteoporosis has a significant role in the development of fractures. An imbalance between osteoblast and osteoclast activity triggered by the lack of osteoprotegerin in menopausal women is the most responsible factor for the osteoporosis—femoral neck fractures [31]. Osteoporosis is defined as a bone disease, when the bone mineral density (BMD) is 2.5 standard deviations or more below than the young adult mean value [32]. However, correlated with femoral neck fractures, a study [33] found that the incidence of osteoporosis assessed by BMD was only 40−50% of all patients with femoral neck fractures. It means that BMD alone does not fully reflect femoral neck fractures. However, bone strength is determined by several factors, including BMD, hip geometry, microarchitecture, matrix components, tissue mineral density and bone damage [34]. Therefore, further studies combining hip geometry and BMD to predict femoral neck fractures are needed to get a better result.

The study has a number of limitations. First, several factors, such as age, gender, ethnicity, menstrual status, history of osteoporosis and drug use, were not included in the study. Second, false positive finding could be occurred because of small sample size even when combined. Third, it is difficult to determine the standard value of hip geometry because these values are different in each tribe.

Conclusions

It can be concluded that HAL, FNA and NW are indicated to be correlated with the risk of femoral neck fractures. Our results may contribute to develop better understanding of the correlation between hip geometry and femoral neck fractures. In addition, the study also showed that hip geometry remains valuable as an easy and widely available predictor of femoral neck fractures.

Conflicts of interest

The authors declared that there is no conflict of interest.

Author contributions

Conceived and designed the experiments = Jonny Karunia Fajar (JKF). Performed the experiments = JKF. Contributed reagents/material/analysis tools = JKF, Taufan Taufan (TT). Wrote the manuscript = JKF, TT, Azharudin Azharuddin (AA), Muhammad Syarif (MS). Reference collection and data management = JKF, TT, AA. Statistical analyses = JKF, TT, AA. Revised manuscript = JKF, AA, MS.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jot.2017.12.002.

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