Functional outcomes and implications of limb length discrepancy after total knee arthroplasty

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Background
The occurrence and perception of LLD after TKA may lead to unsatisfactory results and its consequences are not well studied as the LLD occurring after THA. The objective of this study was to evaluate the incidence, magnitude, implications as well as functional outcomes of LLD in patients after TKA using the WOMAC (Western Ontario and McMaster Universities Arthritis Index) functional score 6 months after surgery.
Materials and Methods
This was a prospective case series study and included 34 cases. Cases were subjected to pre and postoperative clinical, radiological assessment to detect clinical LLD, flexion deformity (FD), radiological LLD, hip knee angle (HKA), and functional assessment using WOMAC score. The degree of osteoarthritis (OA) according to Kellegren Lawrence classification (KL) was assessed and documented. In addition, the polyethylene insert thickness was documented as well.
Results
Change in limb length occurred in the 38 (30 cases unilateral, 4 cases bilateral) knees with a mean increase of 1.3 cm ±SD 0.9. The mean improvement of the FD angle was 9.9° ± SD 8.7. The mean HKA before surgery was 11.2° ±SD 6.2 while the mean post-operative HKA was 2.7° ±SD 3.5. WOMAC score of cases included in the study with postoperative radiological LLD < 1 cm didn't show a significant difference from that of cases with LLD≥ 1 cm. WOMAC score improvement after surgery didn't correlate with perceived LLD. Also, age, sex, BMI, degree of arthritis, insert size, and FD showed no correlation with postoperative radiological LLD. Increased preoperative HKA showed a significant correlation with increased postoperative radiological LLD. There was a significant difference between postoperative radiological LLD in both groups (< 1 cm and ≥ 1 cm) regarding their postoperative perception of LLD.
Conclusion
This prospective case series study suggested that there is no significant correlation between LLD and the functional outcome after TKA. Patients with postoperative radiological LLD more than 1 cm are more likely to perceive LLD.

Keywords:
Limb length discrepancy, total knee arthroplasty, functional outcome, knee osteoarthritis

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Introduction

Limb length discrepancy (LLD) is a well-known complication after total hip arthroplasty (THA). It was widely studied as a cause of pain, limping, and bad outcomes after surgery. It may be a cause of revision in severe cases. Nevertheless, this issue is still questionable in the total knee arthroplasty (TKA) [1]. Occurrence and perception of LLD after TKAs may lead to unsatisfactory results [2]. LLD after TKA operations may be accompanied by low back pain, gait abnormalities, and nerve palsies [3].

Several factors may play a role in the change of limb length after TKAs. These factors may include age, sex, BMI, preoperative LLD, polyethylene insert thickness, degree of osteoarthritis (OA), and preoperative coronal and sagittal plane deformities [1]. Understanding the influence of these factors on limb length change after TKAs would help surgeons address such a problem [4]. There are not comprehensive studies about LLD after TKA regarding incidence, predisposing factors, magnitude, consequences, relation to patient satisfaction, and functional outcome after operations [5].

Some surgeons do not think limb length change after TKA is very importance like THA. Their belief is based on the principles of matched resection adopted by TKA; the damaged articular cartilage is replaced by a prosthetic component with almost equal thickness of the part of the joint removed with the same constraints (capsular and ligamentous structures surrounding the knee) [6].

Fang *et al.* [7] found no statistically significant difference between conventional and customized patient-specific implants regarding change in limb length. Robotic-assisted surgery and navigation systems could predict sizes of bone resection, implant sizes, postoperative limb length, and alignment however, there was not enough data regarding their role in avoiding LLD after surgery [8].

Aim

The objective of this study was to evaluate the incidence, magnitude, functional outcomes, and implications of LLD in patients after TKA using the Western Ontario and McMaster Universities Arthritis Index (WOMAC) functional score 6 months after surgery.

Patients and methods

A prospective case series study was held in a tertiary care hospital from September 2020 to September 2022. The study population included patients who were candidates for TKA, suffering from advanced knee OA, presenting to the orthopedic clinic. Cases of revision TKAs, cases with posttraumatic knee OA, and cases associated with hip OA or previous hip arthroplasty were excluded from the study.

Preoperative evaluation

After documentation of BMI, all cases were asked if they perceived LLD or did not. The knee function was assessed using the WOMAC Knee Score. Range of motion was assessed manually in the supine position in both knees using a goniometer to detect the presence of flexion deformity (FD) and its severity.

Radiograph bilateral knee anteroposterior and lateral views (standing) were done to determine the degree of OA according to Kellgren Lawrence (KL) classification [9]. As well, a radiograph bilateral lower limb anteroposterior view (full-length standing) was done with the determination of limb lengths and preoperative LLD between both sides (a line drawn perpendicular from the center of the femoral head to the level of the tibial plafond). The femoral head center was determined by a point from which two equal perpendicular radii (medial, superior) could be drawn to the head's medial and superior edges, respectively. It was essential to check that the patella was centered on the distal femoral condyles. The source of the radiograph beam was placed 180 cm away from the patient, who stood in an erect position. The radiograph unit used in imaging was DRGEM GXR system (Gyeonggi-do, South Korea). The limb lengths were measured on digital bases using PHILIPS EBW 2.1 (San Jose, California, USA) workstation software.

Coronal deformity and hip knee angle (HKA) (the angle between a line from the center of the femoral head to the center of the intercondylar notch and another line from the center of the tibial plateau to the center of the tibial plafond) was measured in the preoperative long radiograph films. Two individuals carried out a radiographic assessment of the HKA to ensure interobserver reliability. Cases with bilateral TKAs had undergone the same preoperative assessment for both lower limbs, including bilateral assessment of HKA.

This study received ethical approval from the Institutional Review Board of the Faculty of Medicine, Fayoum University. Informed consent was obtained from all patients. The whole procedure was explained to the patients and their relatives. Also participating in the study was explained, and their acceptance was approved. All cases were operated on using a medial parapatellar approach using NexGen Complete Knee Solution Legacy Knee Posterior Stabilized fixed bearing system. Polyethylene insert size was documented as well.

Postoperative evaluation

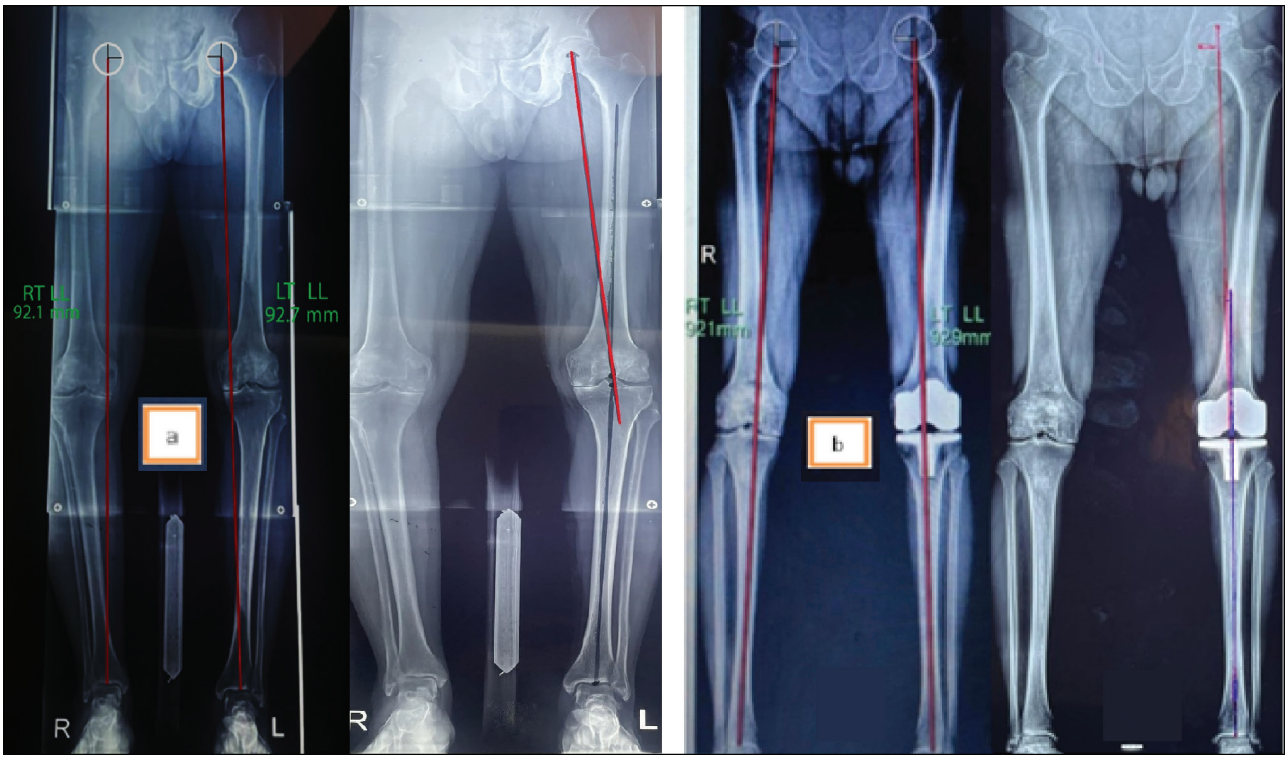
Early mobilization with a full range of motion was recommended with weight bearing aided by crutches immediately after the operation, and then physiotherapy was allowed. After 6 months of surgery, evaluation of patient perception of LLD, functional score, and knee FD were done the same way as before surgery. Radiograph bilateral lower limb standing films were obtained under the same conditions before surgery on which postoperative limb lengths and postoperative LLD between both limbs could be detected and the HKA could be measured (Fig. 1).

Cases with bilateral TKAs were not done in the same session. A policy of 3-month intervals between both surgeries was adopted. Patients were assessed after the second operation by 6 months.

Statistical analysis

The sample size was calculated using G power, version 3.0.10. A sample size of 34 patients was needed to achieve the power of 80%, an alpha error

Figure 1



(a) Preoperative limb lengths of both lower limbs in a case of unilateral total knee arthroplasty with measuring of HKA and (b) postoperative limb lengths and HKA of the same case. HKA, hip knee angle.

of 5%, and a moderate effect size of 0.50 for LLD between preoperative and postoperative TKA [10]. The collected data were organized, tabulated, and statistically analyzed using SPSS software statistical computer package, version 22 (SPSS Inc., Armonk, New York, USA). For quantitative data, the mean and SD were calculated. Independent *t* test or paired *t* test was a test of significance. Pearson correlation was used to assess the relationship between the quantitative variables. Qualitative data were presented as numbers and percentages; the χ^2 or Fisher exact test was used as a test of significance. For interpretation of results of tests of significance, significance was adopted at *P* value less than or equal to 0.05.

Results

Thirty-four cases were included in the study. Twenty-eight (82.4%) cases were females, six (17.6%) were males. The mean±SD age was 60 ± 6.6 years. Mean±SD BMI 33.2 ± 5.5 (Tables 1, 2). Fifteen (44.1%) cases were operated on their right side, 15 (44.1%) on their left side, and four (11.8%) cases had both knees operated on. All the knees included in the study were found to have advanced degenerative changes (KL classification 3 and 4); 30 knees out of 38 were classified as grade 4, while the remaining eight were classified as grade 3.

Table 1 Patient demographics of the study, including age and BMI

	Mean±SD
Age (years)	60 ± 6.6
BMI	33.2 ± 5.5

Table 2 Sex distribution among cases of the study

	n (%)
Sex	
Female	28 (82.4)
Male	6 (17.6)

Table 3 Preoperative and postoperative results regarding Western Ontario and McMaster Universities Arthritis Index score, radiological limb length discrepancy, and hip knee angle

	Preoperative	Postoperative	*P* value
WOMAC score	79.4 ± 9.4	16.6 ± 9	<0.001 (S)
Radiological LLD	0.8 ± 0.7 cm	0.7 ± 0.6	0.548
HKA	11.2 ± 6.2°	2.7 ± 3.5°	<0.001 (S)

HKA, hip knee angle; LLD, Limb length discrepancy; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

There was a statistically significant change (*P*<0.001) in the HKA between preoperative (11.2 ± 6.2°) and postoperative (2.7 ± 3.5°) HKA values. The WOMAC score showed significant improvement (*P*<0.001) between preoperative (mean±SD=79.4 ± 9.4) and postoperative (mean±SD=16.6 ± 9) assessments (Table 3).

The change in the operated limb length was increasing in all knees (mean±SD 1.3 ± 0.9 cm). However, the correlation of that change with the change in the WOMAC score was nonsignificant, with a *P* value of 0.793. Also, there was a nonsignificant correlation with each of the degrees of OA (*P*=0.281), the insert size (*P*=0.726), the preoperative HKA (*P*=0.12), the change in HKA from pre to postoperative (*P*=0.507), and the improvement of FD (*P*=0.239).

Regarding the postoperative radiological limb length discrepancy (between both limbs), the results were as follows:

The cases included in the study were classified into two groups according to their postoperative radiological LLD (<1 cm group; 27 patients and ≥1 cm group; seven patients).

The preoperative mean±SD of radiological LLD=0.8 ± 0.7 cm, while after surgery=0.7 ± 0.6 cm. There was no significant correlation between both (*P*=0.548) (Table 3).

In all cases, there was a nonstatistically significant correlation (*P*=0.67) between the change in WOMAC score and the postoperative radiological LLD in all cases. Also, after classification into two groups the correlation with the postoperative WOMAC score showed a nonstatistically significant difference (*P*=0.467).

There was no statistically significant correlation between the postoperative radiological LLD and each of the degrees of OA (*P*=0.757), the insert size (*P*=0.071), the change in HKA from preoperative to postoperative (*P*=0.565), and the improvement of FD (*P*=0.622) in unilateral cases included in the study. Meanwhile, the correlation with the preoperative HKA was statistically significant (*P*=0.047).

Regarding the postoperative perception of limb length discrepancy (between both limbs) the results were as follows:

Change in WOMAC scores was correlated to patient's postoperative perception of LLD (either yes or no) in all cases. There was no statistically significant difference between cases who felt and those who did not feel LLD after surgery regarding their WOMAC score improvement (*P*=0.083). Also, there was no statistical significance between postoperative LLD perception when correlated to age (*P*=0.614), sex (*P*=0.354), and BMI (*P*=0.603).

In the 34 cases included in the study, 24 cases reported no LLD perception before the operation (70.6%), while 10 cases reported that the arthritic limb with the knee indicated for arthroplasty is shorter than the other side (29.4%). All cases who perceived LLD preoperatively were candidates for unilateral knee arthroplasty. They reported no perception of LLD after surgery except for one case that reported that the operated-on limb became longer. Five cases reported LLD perception after surgery. One of them had undergone bilateral knee arthroplasty (14.7%). There was a statistically significant difference between both groups of postoperative radiological LLD (<1 cm and ≥1 cm) regarding their postoperative perception of LLD (*P*=0.048).

Discussion

Unlike THA, change in LLD after TKA is still questionable regarding the magnitude and functional outcome. Authors reported that limb length inequality may be complained by cases after TKA. Usually, surgeons prioritize the correction of preoperative deformity and ligament balancing rather than accurate leg length control [11].

Several factors may affect limb length change after TKA. Correction of coronal alignment, bony cuts, and adequate soft tissue releases to achieve gap balancing would significantly affect anatomical and functional limb length [12]. This study evaluated the incidence and magnitude of LLD after primary TKA and its relation to functional outcomes. Also, an assessment of factors that may influence this change would take place.

The mean±SD radiographic increase of limb length after TKA in our study was 1.3 ± 0.9 cm. There was no statistically significant difference between both groups of radiological postoperative LLD (<1 cm and ≥1 cm) regarding their postoperative WOMAC scores (*P*=0.467).

The patient demographics such as age, sex, and BMI seem to have no impact on postoperative radiological and perceived LLD (*P*>0.05). Also, the degree of OA according to KL classification and insert size appears to have no impact on postoperative radiological and perceived LLD (*P*>0.05).

The significant improvement of the lower limb alignment after TKA may be reflected by the improvement of HKA (mean±SD HKA before surgery was 11.2 ± 6.2° improved to 2.7 ± 3.5°) (*P*<0.001). Preoperative HKA showed a statistically

significant relationship with postoperative radiological LLD (P=0.047). Preoperative FD was improved by a mean±SD of 9.9 ± 8.7°, although its impact on postoperative radiological and perceived LLD did not show statistical significance (P>0.05).

Correlation between preoperative and postoperative radiological LLD did not show statistical significance (insignificant P=0.548). The correlation between postoperative radiological LLD in both groups (<1 cm and ≥1 cm) regarding their postoperative LLD perception (yes or no) showed a statistically significant difference between both groups (P=0.048).

Ten (29.4%) cases out of 34 included in the study perceived LLD before surgery (all of them were with unilateral TKA). All these cases did not feel LLD after surgery during follow-up except one case that felt the operated-on limb became longer. While only five cases were perceived as LLD after surgery, one of them was with bilateral TKA.

The increase in limb length after TKA may be due to the release of tight medial and posterior structures, as well as the correction of the coronal and sagittal plane deformities. This increase is thought to represent the normal joint space and limb alignment restoration field [11].

The absence of a significant relationship between functional outcome and postoperative perceived and radiological LLD suggests that LLD after TKA does not affect the functional outcome after surgery. Controlling limb length change seems less important than gap balancing and restoration of native joint line level regarding the functional outcome.

The statistically insignificant relation between patient demographics, insert size, and preoperative degree of OA with postoperative radiological or perceived LLD suggests that surgeons should not depend on these factors to predict postoperative perceived or radiological LLD. Preoperative radiological LLD cannot be used as a predictive factor for postoperative radiological LLD.

The preoperative HKA may be of good predictive value for postoperative radiographic LLD (P=0.047). The increased coronal plane deformity may be a risk factor for increased radiological LLD after surgery. Meanwhile, the improvement of FD did not show the same impact on postoperative radiologic LLD.

The statistically significant difference between the postoperative radiological LLD in both groups (<1 cm and ≥1 cm) regarding postoperative LLD perception may reveal that cases with postoperative radiological LLD more than 1 cm are more likely to feel this discrepancy.

Unilateral cases that showed improvement in LLD perception after TKA suggest that cases who are candidates for unilateral TKA and complaining of perceiving LLD would improve LLD perception. While unilateral cases that experienced LLD perception after surgery may be attributed to suffering degenerative and arthritic changes on the other side, they refused to do it for personal issues. We have no explanation for the postoperative perception of LLD for the bilateral case. This would raise the attention of counseling patients with bilateral severe knee OA about LLD perception risk if they had only unilateral TKA, especially in societies where the limited insurance systems and financial and bureaucratic issues would discourage patients from such surgical interventions.

Regarding the impact of postoperative LLD (in both groups) on functional outcome, our results were similar to the findings of both Chinnappa *et al.* [1] and Kim *et al.* [13], although Pradhan *et al.* [14] and Hinarejos *et al.* [5] found that there was the significant lower functional outcome in cases with postoperative radiological LLD more than or equal to 1 cm (Table 4).

Table 4 Different studies that include functional outcomes in their assessment with postoperative radiological and perceived limb length discrepancy

Study	Chinnappa *et al.* [1]	Pradhan *et al.* [14]	Kim *et al.* [13]	Hinarejos *et al.* [5]	This study
Functional outcome correlation with					
Postoperative Radiological LLD	Nonsignificant correlation between cases (<1 cm and ≥1 cm)	Significant lower outcome in cases ≥1 cm	Nonsignificant correlation between cases (<1.5 cm and ≥1.5 cm)	Significant lower outcome in cases ≥1 cm	Nonsignificant correlation between cases (<1 cm and ≥1 cm)
Postoperative Perceived LLD	Significant lower outcome in cases perceiving LLD	Nonsignificant correlation between cases that did and did not perceive LLD	Nonsignificant correlation between cases that did and did not perceive LLD	Not addressed	Nonsignificant correlation between cases that did and did not perceive LLD

LLD, limb length discrepancy.

Table 5 Results of different studies and this study regarding the change in limb length (average lengthening)

Study	Pradhan *et al.* [14]	Chalmers *et al.* [12]	Fang *et al.* [7]	Ohmori *et al.* [15]	Khalifa *et al.* [16]	This study
Change in limb length	0.92 ± 0.98 cm (91.1% of limbs showed lengthening)	0.7 cm	0.53 ± 0.42 cm	0.94 ± 0.6 cm	1.07 ± 0.95 cm (92.6% of limbs showed lengthening)	1.3 ± 0.9 cm (100% of limbs showed lengthening)

Table 6 Results of different studies and this study regarding limb length discrepancy perception

Study	Chinnappa *et al.* [1]	Kim *et al.* [13]	This study
Perception of LLD	None of the patients with a perceived LLD 6 months after operation had a radiographic LLD of <1 cm	Kim and colleagues found that patients who had a postoperative radiological LLD <1.5 cm are more subjected to perceive LLD than those with less postoperative LLD	Cases with radiological LLD after surgery <1 cm are more likely to perceive LLD

LLD, limb length discrepancy.

Regarding the impact of postoperative perceived LLD (in both groups) on functional outcome, our results were similar to the findings of both Kim *et al.* [13] and Pradhan *et al.* [14], although Chinnappa *et al.* [1] reported a significantly lower functional outcome in cases perceiving LLD (Table 4).

The change in limb length in our study was compared to the change in limb length in other studies. The large mean of limb lengthening in our study compared to other studies (Table 5) may be attributed to the severe deformity and arthritis of cases participating in our study.

Regarding patient demographics and its correlation with postoperative LLD, our findings were similar to other studies [1,5,13,14] as a nonsignificant correlation, although Chinnappa *et al.* [1] reported that female patients are more likely to feel LLD after surgery, while Chalmers *et al.* [12] found that female sex is more likely to have radiological LLD after TKA.

Regarding the correlation between the degree of OA and postoperative radiological LLD, our study was comparable to other studies with the same consensus that the degree of OA cannot be considered a predictor for postoperative LLD [4,11,13,14,17].

We think that the coronal plane alignment (HKA) changes after surgery were more evident in our study (mean±SD=8.5 ± 5.5°) if it is compared to other studies like Chinnappa *et al.* [1] (5.8 ± 3.6°), Fang *et al.* [7] (3.83 ± 0.74°) and Ohmori *et al.* [15] (7.7 ± 5.1) due to the large number of more advanced knee arthritis with varus deformity that were enrolled in our study.

Our study reported a nonsignificant correlation between preoperative coronal plane alignment (HKA) and postoperative radiological LLD. This was comparable to the findings of Hinarejos *et al.* [5], although Chinnappa *et al.* [1] and Kim *et al.* [13] reported a nonsignificant correlation as well.

The mean preoperative FD angle in our study was 11.77°. Aaron *et al.* [10] found that knee FD did not affect the measurement of overall leg length until it exceeded 15°, but their study was based on cadavers. Regarding FD improvement after surgery and its correlation with postoperative radiological LLD, the findings of our study were the same as Chinnappa *et al.* [1], who reported a nonsignificant correlation as well.

Regarding the preoperative radiological LLD and its correlation to the postoperative values, our findings were similar to Pradhan *et al.* [14]. Meanwhile Chinnappa *et al.* [1] and Kim *et al.* [13] reported a significant relationship between preoperative and postoperative LLD.

The findings in our study regarding postoperative LLD perception were comparable to other studies (Table 6).

This study included the perceived and radiological LLD to determine its occurrence after TKA. This may add further precision to the results. The follow-up period of 6 months after surgery may allow rehabilitation to take place and improve the function, range of motion, and LLD perception. This, in turn, allows better assessment of function and radiological LLD. Including different factors that may influence the occurrence and perception of LLD in this study may allow surgeons to identify predictors and inform and counsel patients about risk factors.

Limitations of this study include the small number of cases with a single follow-up time. Some unilateral cases may have degenerative changes in the other knee, but they did not want to have TKA on the other side for personal issues. This study does not include cases with valgus deformity.

We would recommend longer follow-up periods for further research, with repeated clinical and functional

assessments. Deformities with all their types and degrees of severity should be included. Considering the other side – in cases with unilateral TKA – with their degenerative changes, coronal and sagittal plane deformities should occur among variables. Further studies should be carried out to find a cut-off value for symptomatic or unaccepted postoperative LLD. We also suggest that delaying postoperative full-length radiographs to detect LLD may allow the rehabilitation to take place and restore full limb length.

In conclusion, there is no significant relationship between the occurrence of postoperative radiological LLD and functional outcomes after TKA. Patients with postoperative radiological LLD, more than 1 cm after surgery are more likely to perceive LLD.

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Conflicts of interest
The authors declare that they have no conflict of interest.

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