



PFNA and DHS for AO/OTA 31-A2 fractures: radiographic measurements, morbidity and mortality

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Abstract

Purpose For this retrospective cohort study, we assessed pertrochanteric fracture types AO/OTA 31-A2. PFNA and DHS were the devices used. We determined both devices in relation to peri-operative variables, postoperative radiographic measurements, implant-related complications and mortality up to 2 years. The null hypothesis was no effect between the two devices.

Methods This single-centre study was conducted based on our computerized data. The treatment period ranged from 2006 to 2015. Only patients with type AO/OTA 31-A2 fractures and an age ≥ 65 years were included. Apart from descriptive variables, the following measurements were assessed: (1) duration of surgery, (2) blood loss, (3) transfusion, (4) hospitalization, (5) tip-apex distance (TAD), (6) fracture reduction, (7) screw position, (8) implant-related complications, and (9) mortality. The follow-up was 2 years for each living patient. Missing data were evaluated by telephone call.

Results A total of 375 consecutive patients were enrolled into three groups: (1) 75 patients treated with DHS and antirotation screw (ARS); (2) 100 patients treated with DHS + ARS + TSP (trochanteric stabilization plate); and (3) 200 patients treated with PFNA. Apart from dementia, the descriptive data (e.g., age and BMI) demonstrated no effects between the three groups. Compared to PFNA, DHS with or without TSP was adversely affected by a longer operation time, higher blood loss, increase in transfusion, and more implant-related complications including cut-out, infection and failure. The rate of cut-out was significantly higher in TAD ≥ 25 mm ($p=0.005$), and PFNA demonstrated significantly better TAD measurements ($p=0.001$), better fracture reduction (0.002), more central-central screw positions ($p=0.014$), and less poor screw placement ($p=0.001$). The mortality rate was without effect between the three groups (log rank 0.698).

Conclusions DHS with or without TSP was associated with significantly higher rates of implant-related complications based on inferior radiographic measurements. Therefore, we only recommend PFNA for the treatment of proximal type AO/OTA 31-A2 femoral fractures.

Level of evidence Therapeutic level III.

Keywords Trochanteric fracture · Osteosynthesis · PFNA · DHS · Revision · Complication · Mortality

Introduction

The AO/OTA fracture classification system designates simple trochanteric fractures as type 31-A1, multifragmentary fractures as type 31-A2, and reverse obliquity fractures as type 31-A3 [1]. With few exceptions, all these fractures received operative treatment by two different devices, primarily by an intramedullary nail or a sliding hip screw [2–4].

The latter is still very popular based on similar clinical outcomes, but with lower expenses compared with intramedullary nails [5]. On the other hand, two recent studies worked out the advantages of using a nail compared with a sliding hip screw (SHS) [6, 7]. A meta-analysis of randomized

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studies analysed different results without definite superiority of one over another of these devices [2, 3, 8–10]. However, most randomized studies consisted of selected and small sample sizes without distinctions of simple versus multifragmentary fractures [6, 11–17]. Moreover, any randomized study does not reflect the clinical setting, as elderly patients suffering from dementia are excluded. Therefore, we conducted this single-centre study including exclusively multifragmentary fractures type AO/OTA 31-A2. The null hypothesis was that there was no effect on implant-related complications and mortality between the two devices.

Materials and methods

The study was approved by our institutional review board, and verbal consent for participating in the study was obtained from all contacted patients. We performed this retrospective analysis by records from our level 1 trauma centre electronic database, including any patient with a proximal femoral fracture (PF). In this database, a total of more than 2000 consecutive patients were enrolled who underwent operative treatment between 2006 and 2015 including 14 demographic variables.

For this study, we included only patients with an age ≥ 65 years and with an operative treatment of multifragmentary trochanteric fractures (AO/OTA 31-A2) by a PFNA or a DHS. Between 2006 and 2011, the DHS was the primary device used for this type of fracture, and for the later period, the PFNA. The DHS was placed with or without a trochanteric stabilization plate (TSP) only at the discretion and experience of the different consultants. Without exception, no other device was used within this period of time.

The exclusion criteria were patient age < 65 years, malignant or benign pathological proximal femoral fractures, any open fractures, polytraumatic injuries or segmental fracture. Moreover, any cement-augmented techniques were excluded because this was not used routinely in the treatment period.

For the surgeries, the patients were in a supine position on a fracture table under an image intensifier control. We used the standard operative technique with regard to both devices. PFNA was used with different nail diameters (10, 11, or 12 mm) but exclusively with a short standard length of 240 mm. The DHS was routinely applied by a 135° side plate with four holes and a 7.3-mm antirotational screw with or without a trochanteric fixation plate (TFP).

For the statistical analysis, we performed three groups: the first group included 75 consecutive patients treated with DHS and antirotation screw (ARS); the second group included 100 concurrent patients with DHS + ARS + TSP; and the third group included 200 consecutive patients treated with closed reduction and PFNA, giving a sample size of 375 patients.

The following outcome measurements were additionally evaluated by the electronic records: duration of surgery, blood loss, transfusion, hospital stay, implant-related complications, failure, and mortality.

The endpoint of the study was 2 years postoperatively for every living patient. We reported any death of patients. Any missing measurements were collected by telephone call with patients, relatives, or general practitioners.

Radiographic measurements

We also calculated for each postoperative digitalized radiograph the tip-apex distance (TAD) [18], the position of the screw placement within the femoral head [19], and the type of fracture reduction [18]. Any calculations were performed by a digitalized radiologic monitor for diagnosis.

The TAD is the addition of both the distance (mm) from the tip of the screw to the apex of the femoral head on the a.p. and lateral view, including a radiographic calibration factor [18]. For an almost exact TAD, we always performed three measurements, and their mean value was used for analysis.

Analysis of the screw placement was noted by a separation of the femoral head into nine zones [19] (Figs. 1, 2) whereby zone 5 is central-central (ideal position), and zone 3 is superior–posterior (worse position).

The fracture reduction criteria [19] were a postoperative displacement of less than 4 mm on either the a.p. or lateral X-ray, a neck shaft angulation between 130° and 150° on the a.p. view, and a less than 20° of angulation on the lateral view. A good reduction met these criteria, a moderate reduction violated one criterion, and a poor result violated all criteria.

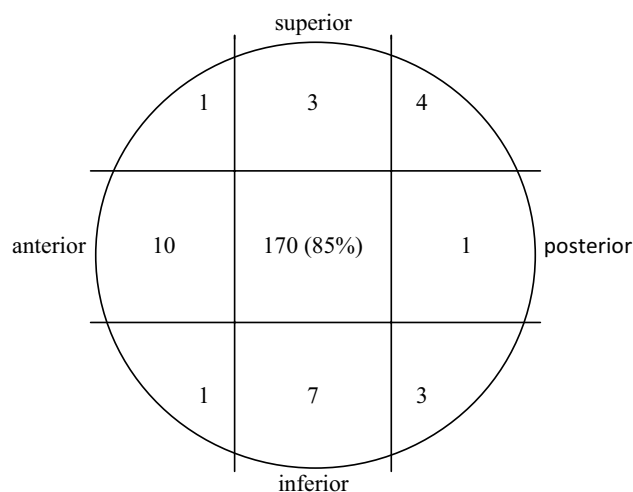


Fig. 1 Diagram showing the blade positions by PFNA demonstrating 85% within ideal zone 5

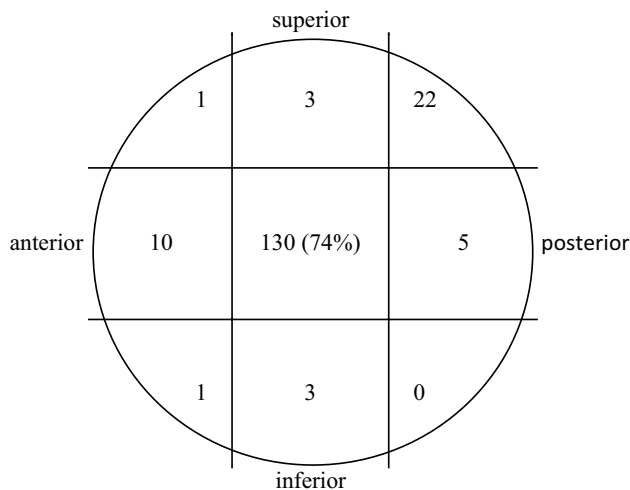


Fig. 2 Diagram showing the screw positions by DHS demonstrating 74% within ideal zone 5, but also 13% within zone 3 (superior-posterior)

Definitions

Infection was defined as positive clinical findings and microbiological detection of a pathogen according to the criteria from the Workgroup of the Musculoskeletal Infection Society [20]. A screw cut-out was a radiological migration of the screw or the blade out of the femoral head, including an acetabular penetration [21]. A radiologic fracture re-dislocation was a postoperatively confirmed loss of reduction (e.g., dislocation by varus angulation) not based on cut-out, but with the need for any re-operation. Failure was a complete removal of the device for an infection control or the treatment of a screw cut-out (e.g., by a hip replacement). Dementia was defined as patients with impaired cognition under disability/legal assistance.

Statistical analysis

Statistical analyses were performed using SPSS for Windows, version 24.0 (SPSS Inc., Chicago, IL, USA). All variables are reported as mean values, whereas measures of dispersion are reported as standard deviations. The categorical and/or nominal data are reported as absolute and relative frequencies. Metric variables were assessed for normal distribution using the Kolmogorov–Smirnov test. The tested variables were not normally distributed (Kolmogorov–Smirnov test: $p < 0.05$). Therefore, non-parametric tests were used for non-normal distribution for sample comparisons. Where the distribution was not normal, the Mann–Whitney U test was used to compare two independent samples and the Kruskal–Wallis H test was used when there were more than two independent samples. In contrast, the categorical data were evaluated using the chi-squared

test and Fisher's exact test. The survival rates were assessed using Kaplan–Meier analysis [22]. The log-rank test was used to compare survival probabilities. All tests of significance were assessed bilaterally, and a p value of < 0.05 was considered statistically significant.

Results

There were 292 women and 83 men, with a mean age of 83.0 years (range 65–99), but the women were considerably older (mean 83.8 vs. 80.0; $p = 0.25$). During the study period, 367 patients were treated for a unilateral femoral fracture, and 4 patients were treated for a uni- and a contralateral femoral fracture. With the exception of dementia, no significant differences in any of the 14 descriptive variables between the three groups were evaluated (Table 1), including time to surgery (time from the arrival in the emergency department to the incision) and ASA score [23].

In the univariate analyses, the following measurements (Table 1) were significantly better when using PFNA: (1) red blood transfusion ($p = 0.005$); (2) duration of surgery ($p = 0.001$); (3) total operative revision ($p = 0.004$); (4) screw cut-out ($p = 0.025$); (5) infection rate ($p = 0.018$); and (6) failure ($p = 0.007$). No significant difference was noted for length of hospital stay ($p = 0.161$), peri-implant fractures ($p = 0.412$), or re-dislocation ($p = 0.260$).

In total, 29/50 operative revisions (58%) were assessed within the first month after the index operation, and only one reported complication occurred later than 1 year. An operative revision for Z-effect, lateral telescoping of the screws/blades or a fracture of the lateral cortex by PFNA were neither indicated nor necessary.

With regard to the radiographic measurements (Table 2), PFNA was associated with a significantly better TAD ($p = 0.001$), fewer TAD > 25 mm ($p = 0.001$), fewer poor fracture reductions ($p = 0.002$), more blade positions within the ideal central-central position (zone 5) ($p = 0.014$), and fewer blade positions within the worse superior-posterior position (zone 3) ($p = 0.001$). The distribution of the different screw/blade positions within the femoral head is illustrated in Figs. 1 and 2.

Screw cutout was significantly associated with a TAD > 25 mm ($p = 0.005$), with a poorer fracture reposition ($p = 0.001$), and with inferior screw placement (not within central-central zone 5, but within zone 3; $p = 0.001$) (Table 2). In our evaluation, a TAD of < 17 mm (113/375; 30.1%) was never associated with a screw cut-out.

The mortality rate up to 2 years postoperatively was not significantly different between the two devices (log-rank test = 0.698), and the Kaplan–Meier analyses showed almost similar survival rates (Figs. 3, 4).

Table 1 Demographic variables

Descriptive variables	PFNA <i>n</i> =200	DHS + AR <i>n</i> =75	DHS + AR + TSP <i>n</i> =100	<i>p</i> value
Female patients	154 (77%)	59 (78.7%)	79 (79.0%)	0.910
Mean age (years)	82.6 (SD ± 8.00)	83.3 (SD ± 7.25)	83.6 (SD ± 6.95)	0.757
Mean body mass index (kg/m ²)	25.6 (SD ± 4.39)	25.1 (SD ± 4.39)	24.7 (SD ± 3.36)	0.404
Right side	110 (55.0%)	40 (53.3%)	52 (52.0%)	0.882
Mean delay to surgery (h)	24.4 (SD ± 17.79)	24.0 (SD ± 16.42)	24.1 (SD ± 15.93)	0.981
ASA score 2	24 (12.0%)	11 (14.7%)	13 (13.0%)	
ASA score 3	160 (53.0%)	61 (81.3%)	81 (81.0%)	
ASA score 4	16 (8.0%)	3 (4.0%)	6 (6.0%)	0.787
Dementia	65 (32.5%)	34 (45.3%)	55 (55.0%)	0.001
Hypertension	154 (77.0%)	53 (70.7%)	75 (75.0%)	0.555
Diabetes mellitus	51 (25.5%)	26 (34.7%)	21 (21.0%)	0.120
Atrial fibrillation	65 (32.5%)	20 (26.7%)	29 (29.0%)	0.605
Cardiac failure/heart disease	76 (38.0%)	37 (49.3%)	37 (37.0%)	0.180
Mean creatinine (mg/dL)	1.2 (SD ± 0.86)	1.1 (SD ± 0.68)	1.0 (SD ± 0.46)	0.364
Mean CRP (mg/L)	17.9 (SD ± 35.17)	11.4 (SD ± 16.66)	19.0 (SD ± 45.29)	0.916
Mean haemoglobin (g/dL)	12.0 (SD ± 1.69)	12.5 (SD ± 1.61)	12.0 (SD ± 1.80)	0.081

PFNA proximal femoral nail antirotation, DHS + AR dynamic hip screw + antirotations screw, DHS + AR + TSP dynamic hip screw + antirotations screw + trochanteric stabilization plate, ASA American Society of Anesthesiology, CRP C-reactive protein

Table 2 Outcome measurements

Outcome variables	PFNA <i>n</i> =200	DHS + AR <i>n</i> =75	DHS + AR + TSP <i>n</i> =100	<i>p</i> value
Mean blood transfusions (units)	1.3 (SD ± 1.45)	1.3 (SD ± 1.44)	2.0 (SD ± 1.57)	0.001
Mean duration of surgery (min)	51.0 (SD ± 19.31)	63.3 (SD ± 18.95)	83.3 (SD ± 27.89)	0.001
Mean hospital stay (days)	14.5 (SD ± 10.35)	14.0 (SD ± 5.31)	15.2 (SD ± 6.39)	0.161
Total operative revisions	16 (8.0%)	13 (17.3%)	21 (21.0%)	0.004
Cut-out	4 (2.0%)	6 (8.0%)	8 (8.0%)	0.025
Infection	6 (3.0%)	2 (2.7%)	10 (10.0%)	0.018
Peri-implant fracture	4 (2.0%)	0 (0%)	1 (1.0%)	0.412
Redislocation	2 (1.0%)	3 (4.0%)	2 (2.0%)	0.260
Total failure	5 (2.5%)	9 (12.0%)	8 (8.0%)	0.007
One-year mortality	59 (29.5%)	20 (26.7%)	33 (33.0%)	
Two-years mortality	85 (42.5%)	28 (37.3%)	43 (43.0%)	

PFNA proximal femoral nail antirotation, DHS + AR dynamic hip screw + antirotations screw, DHS + AR + TSP dynamic hip screw + antirotations screw + trochanteric stabilization plate

Discussion

According to our results, the null hypothesis of this study was not confirmed because the implant-related complications of the both devices were significantly different, even though the mortality rates were not. Additionally, the analysis of the radiographic measurements documented significantly better values with regard to PFNA compared to DHS with or without TSP (Table 3).

At first, the strengths of our study should be stressed: we included a very large number of consecutive patients,

and to our knowledge, 375 subjects represents a very high number of multifragmentary trochanteric fractures in the literature evaluated by a single centre. Second, we had no patients lost to follow-up (e.g., due to the inability to contact or locate patients). Third, a positive selection was not undertaken, and any patient with a comorbidity including a cognitive impairment such as dementia was included. Therefore, the sample size represents the geriatric clinical setting. Finally, a follow-up of 2 years postoperatively for every living patient can be demonstrated by only a few studies [24, 25]. For implant-related complications, it is preferable to evaluate up to 2 years, although few

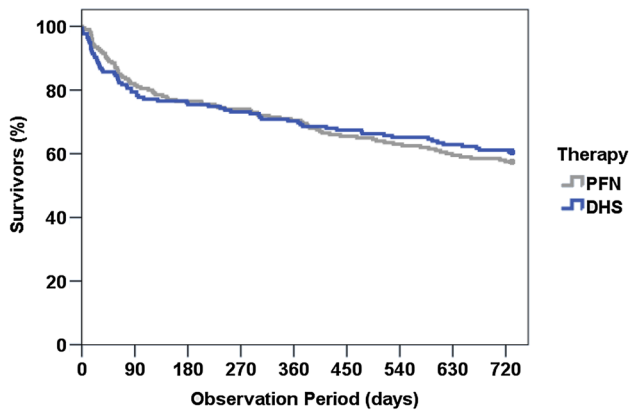


Fig. 3 Kaplan–Meier survival analysis for patients treated by PFNA versus DHS demonstrated no effect (log-rank test=0.698)

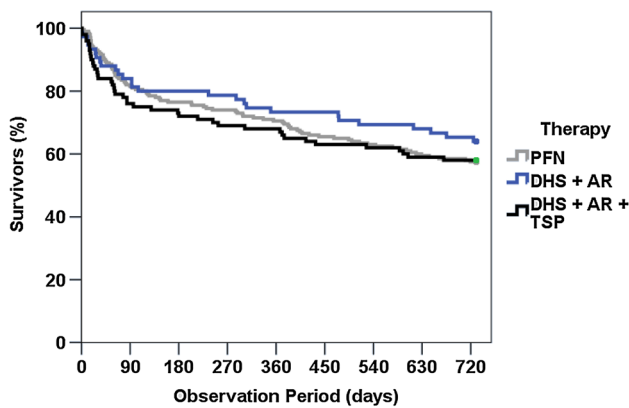


Fig. 4 Kaplan–Meier survival analysis for patients treated by PFNA versus DHS+AR versus DHS+AR+TSP demonstrated also no effect

re-operations will be performed later than 1 year after operation [25, 26]. This was confirmed by our results, with only one reported complication after 1 year of follow-up.

Therefore, our study demonstrated considerable strengths compared with previous studies with the same focus. For example, the European multicentre study primarily included a total of 542 patients for the treatment of the newly implemented PFNA [17]. Nonetheless, 229 patients were excluded without providing explanations, and 80 patients (25%) were lost to follow-up within 1 year postoperatively.

Especially regarding economic reasons, no superiority was identified for the PFN compared with the DHS by a randomized, prospective study with 206 patients and a follow-up of at least 1 year. However, this study also included both simple and multifragmentary fractures without presenting exact numbers [14].

Our basic data are compatible with a number of clinical studies [6, 17, 24, 27]. They represent the clinical setting within a trauma centre, including a large number of geriatric patients with cognitive impairment. However, some studies excluded patients with dementia. Thus, the better outcome regarding morbidity and mortality in such studies must be interpreted with caution [11, 15, 25, 28].

With the exception of dementia, we noted no differences with regard to 14 descriptive variables between PFNA and DHS. Therefore, both implants represent a comparable and similar cohort for the statistical analysis of the outcome measures.

In accordance with other studies, nailing was associated with a significantly shorter operation time [9, 10]. These differences reflect the smaller skin incision for inserting the nail compared with an open placement of a four-hole plate at the proximal femoral shaft. In addition, the transfusion rate was also significantly different between the devices; but it should be emphasized, that the decisive factor for the transfused units was typically not only the surgical access but often the base value of the patients’ haemoglobin level.

Then, the re-operation rate for complications had a significant effect, although our rate was higher than that reported previously. For example, the multicentre study conducted in Northern Ireland with 3,230 patients and multiple devices

Table 3 Radiographic measurements

	PFNA n = 200	DHS n = 175	p value	Cut-out n = 18	No cut-out n = 357	p value
Mean TIP-apex distance (mm)	19.0 (SD ± 6.68)	22.2 (SD ± 7.31)	0.001	27.7 (SD ± 7.14)	20.1 (SD ± 6.96)	0.001
TIP-apex distance > 25 mm	29 (14.5%)	50 (28.6%)	0.001	9/18 (50%)	70/357 (19.6%)	0.005
Poor fracture reposition ^a	4 (2.0%)	16 (9.1%)	0.002	6/18 (33.3%)	14/357 (3.9%)	0.001
Ideal screw placement (central-central; zone 5) ^b	170 (85.0%)	130 (74.3%)	0.014	5/18 (27.8%)	295/357 (82.6%)	0.001
Poorest screw placement (zone 3) ^c	4 (2.0%)	22 (12.6%)	0.001	9/18 (50.0%)	17/357 (4.8%)	0.001

^aPoor fracture reposition due to the Baumgaertner criteria

^bScrew placement due to the Cleveland criteria (Zone 5, central-central)

^cScrew placement due to the Cleveland criteria (Zone 3, superior–posterior)

reported a total revision rate of only 4% [4]. This might be the result of a data transfer not including infection because screw cut-out was the main reason for revision in this study. Without a doubt, infection is a specific complication that should be reported in any study.

Further analysis documented a significantly higher rate of implant-related complications with DHS, especially cut-out and fracture displacement, with failure. This result was independent of an additionally applied TSP despite this plate being recommended, especially for unstable multifragmentary trochanteric type A2 fractures [29]. According to our poor results, we don't recommend an additional TSP.

Screw or blade cut-out represents a typical and severe complication of both devices, and two recent meta-analyses evaluated higher rates of cut-out within SHS compared with nailing but without statistical significance [8, 10]. Again, both meta-analyses included prospective studies with very selected healthy patients not representing geriatric patients [8, 10]. The reasons for screw cut-out are often multifactorial [4, 30], but a TAP > 25 mm is repetitively documented as an independent risk factor for failure [18, 31]. Our study results confirmed that a better TAD and a central-central position of the screw/blade within a good fracture reduction are absolutely essential for preventing implant-related complications [27, 31–33]. Again, both devices were always applied by very experienced trauma consultants or under their supervision. However, it seems that drilling the guide wire for a DHS screw into the ideal positioning (zone 5) is more difficult by the free-handed angled guide at the lateral cortex—and in comparison to the PFNA with the fixed aiming device. Our results reflect this pitfall.

In our study, the risk for an implant revision as a result of a failure was approximately 3.5-fold higher for patients treated with DHS compared with nailing. To date, this endpoint had not been evaluated by previous studies, but it is a fundamental objective from the authors' point of view.

Finally, the mortality rates up to 2 years and the Kaplan–Meier survival analysis demonstrated no significant difference between the two devices. This result was not unexpected. However, our total 1-year mortality rate of approximately 30% was somewhat higher compared with that of other studies [4, 17, 24], reflecting the advanced age of the geriatric sample size in our study.

This study also has limitations: it is a retrospective cohort study; therefore, the level of evidence is low (level III). The authors were also involved in the operative treatment; therefore, a bias may have occurred. The authorship declined any bias; but without a doubt, the three different treatment options for the same fracture morphology provide a bias. The data represented by the PFNA may not be transferred to other types of nails because every nailing device has its own specific features. A final follow-up radiologic and clinical examination (e.g., patients' reported outcome

measurements) was not performed. Against the background of many patients with cognitive impairment, an objective evaluation would probably be very difficult. To date, few studies with very selected cohorts have reported no differences in functional outcome between nail and SHS [14, 15]. In the absence of this examination, the rate of complications may be somewhat higher than the reported numbers.

Conclusions

DHS with or without TSP was associated with significantly higher rates of implant-related complications based on inferior radiographic measurements. Therefore, we only recommend PFNA for the treatment of proximal type AO/OTA 31-A2 femoral fractures.

Author contributions FM collected and analysed data, and wrote the manuscript; MD acquired data; TK has done independently the statistical analysis; BF has corrected the final version of the manuscript. All authors approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest Franz Müller, Matthias Doblinger, Tanja Kottmann, and Bernd Füchtmeier declare that they have no conflict of interest.

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