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Comparable results for the Femoral Neck System and three-screw fixation in femoral neck fracture treatment

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Abstract

Objectives: To report outcomes of femoral neck fractures (FNFs) treated with Femoral Neck System (FNS) and to compare the risks of later conversion to arthroplasty for FNS and fixation with cannulated screws (CNSs).

Design: A retrospective study.

Setting: A single-center study (Turku University Hospital, Finland).

Patients: Data on 51 patients with FNFs treated with FNS between January 1, 2019, and May 31, 2021, were retrospectively reviewed. In addition, data on 301 patients treated with cannulated screws were collected and analyzed in a previous study.

Intervention: Patients with FNFs underwent osteosynthesis with FNS.

Main Outcome Measurements: Patients' preoperative and postoperative radiographs were analyzed and measured to determine preoperative displacement, preoperative posterior tilt, and quality of reduction. Later conversion to arthroplasty and other reoperations were recorded. The risk of later conversion to arthroplasty was compared between the FNS group and CNS group.

Results: The overall reoperation rate in the FNS group was 20%, and 16% of the patients treated with FNS underwent later conversion to arthroplasty. In the multivariate analysis, age, sex, and fracture displacement were not associated with increased risk of later conversion to arthroplasty. In comparison with fixation with cannulated screws, there was no statistically significant difference in the probability of later conversion to arthroplasty between the groups.

Conclusion: FNS seems to have a comparable reoperation rate and conversion-to-arthroplasty rate compared with the gold standard treatment.

Level of Evidence: III.

Key Words: internal fixation, FNS, hip fracture, femoral neck fracture, reoperation, arthroplasty

1. Introduction

Femoral neck fractures (FNFs) are among the most common and devastating injuries for the elderly, and their numbers are expected to rise drastically in the next few decades.[1] Surgical treatment is the gold standard for FNFs because it is associated with lower mortality and nonunion rates than conservative treatment.[2]

FNFs are divided into nondisplaced and displaced fractures according to the Garden classification,[3,4] and the operative treatment options for FNFs are internal fixation (IF) and arthroplasty. In previous studies, displaced fracture patterns and inadequate fracture reduction have been associated with an increased risk of fixation failure and the conversion to arthroplasty of FNFs treated with IF.[5–7] Several studies have also indicated that preoperative posterior tilt (PT), measured using a lateral shoot-through radiograph, has an impact on reoperation rates. Preoperative PTs of 20 degrees or more and anterior tilts have been shown to be independent risk factors of failure in FNFs treated with IF,[8–11] and according to the existing literature, IF is recommended in nondisplaced FNFs.[12] Reoperations after IF most commonly include implant-removal surgeries and later conversions to arthroplasty due to nonunion or fixation failure.[10,13,14] There are no national guidelines on FNF treatment in Finland; however, most of the hospitals rely on international suggestions on FNF treatment.

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The most common IF method uses 3 parallel screws, but an alternative IF system has recently been introduced (Femoral Neck System [FNS], DePuy Synthes, Switzerland). FNS was originally designed to reduce nonunion and fixation failure rates[15] and was found to be mechanically more durable than cannulated screw fixation in unstable femoral neck fracture models in a cadaver study.[16] Although FNS is currently widely used worldwide, very few outcome studies have been reported.[16–19]

The main aim of this study was, therefore, to report outcomes of FNFs treated with FNS. We also sought to compare the risks of later conversion to arthroplasty for FNS and fixation with cannulated screws (CNSs).

2. Patients and Methods

A retrospective study was conducted with all patients with FNFs treated with FNS between January 1, 2019, and May 31, 2021. A data search was performed using the patient record system (Uranus Miranda, CGI Finland) for the ICD-10 diagnosis code for FNF (S72.0) and the NOMESCO surgical procedure code (Finnish version) for FNS surgery (NFJ52). Ethical approval was obtained from the Local Ethical Review Board in Turku University Hospital (T01/007/21).

Data retrieved from the patient records included the patients' age, sex, fracture laterality, mechanism of injury, and American Society of Anesthesiologists classification (ASA 1–5). The mechanism of injury was assessed from the patient records and divided into 2 groups: low-energy trauma (fall at the same level) and high-energy trauma (all other injury mechanisms).

Patients' preoperative and postoperative radiographs were analyzed and measured using Carestream Picture Archiving and Communication Systems software. For outcome analysis of FNFs treated with FNS, the radiographic parameters included preoperative displacement, preoperative PT, and quality of reduction. Preoperative fracture displacement was classified as either displaced or nondisplaced according to the Garden classification[3] using the anteroposterior (AP) radiograph. Preoperative PT was measured from a shoot-through lateral radiograph using the technique described by Palm et al[9] (Fig. 1). The fractures were then divided into 2 groups: group 1 included nondisplaced fractures (Garden 1 and 2) with $0° < PT < 20$ degrees, and group 2 included nondisplaced fractures (Garden 1 and 2) with $PT \leq 0°$ or $PT \geq 20$ degrees and displaced fractures (Garden 3 and 4). Displaced fractures were also analyzed as a separate group, regardless of the level of PT.

If preoperative displacement occurred, closed reduction was performed. The postoperative PT was measured to determine the quality of the reduction (Fig. 2). The patients were then divided into 3 groups: nondisplaced in the AP view and $0 < PT < 10$ degrees, nondisplaced in the AP view and either $PT \leq 0°$ or $PT \geq 10$ degrees, and displaced in the AP view. Displacement in the AP view was determined by drawing a Shenton line on the postoperative AP radiograph. If the line was not intact, the case was considered displaced. A fracture was considered well reduced if the Shenton line was intact and the postoperative PT was 0–10 degrees. All measurements were performed by the authors and were supervised and confirmed by a musculoskeletal radiologist.

Data on reoperations were collected from the patient records, and the risk of later conversion to arthroplasty was analyzed as a separate end point. Comparisons between FNS and CNSs were performed by analyzing the treatment groups' risk of later arthroplasty at 12 months. Data on patients treated with CNSs were collected and analyzed in our previous study and included the same variables and similar group classifications based on fracture displacement.[8] Most of the fixation with CNSs was performed according to OTA/AO principles, using 3 CNSs in an inverted-triangle configuration.

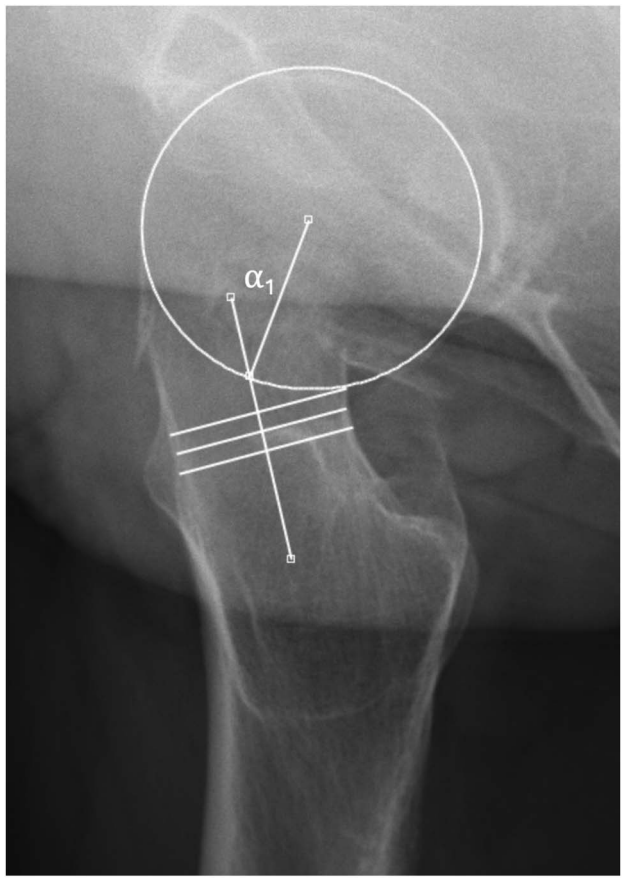

Figure 1. X-ray, measurement of the preoperative posterior tilt, $\alpha_1 = 33$ degrees.

2.1. Patients

Information was found for 53 FNS patients. Two were excluded, one because of missing postoperative data and one because of a missing preoperative lateral radiograph, leaving 51 FNS patients eligible for the data analysis.

The mean age of the patients was 69 years (range 31–92); 26 patients (51%) were women, and 8 (16%) died during the follow-up period. The mechanism of injury was classified as low-energy trauma in 37 cases (73%), and the mean follow-up was 1.7 years (range 0.1–2.9).

Data on patients treated with CNSs were collected and analyzed in our previous study and included FNFs operated with cannulated screws between January 1, 2012, and December 31, 2017. Similar group classifications based on fracture displacement were used.[8] The CNS group included 301 patients, the mean age was 73 years (range 20–101), 168 patients (56%) were women, and 42 patients (13.9) died during the follow-up period (Table 1). The follow-up time was limited to 12 months.

2.2. Statistical Methods

Categorical variables were characterized using frequencies and percentages, and continuous variables were characterized with mean and range. Between the CNS and FNS groups, categorical

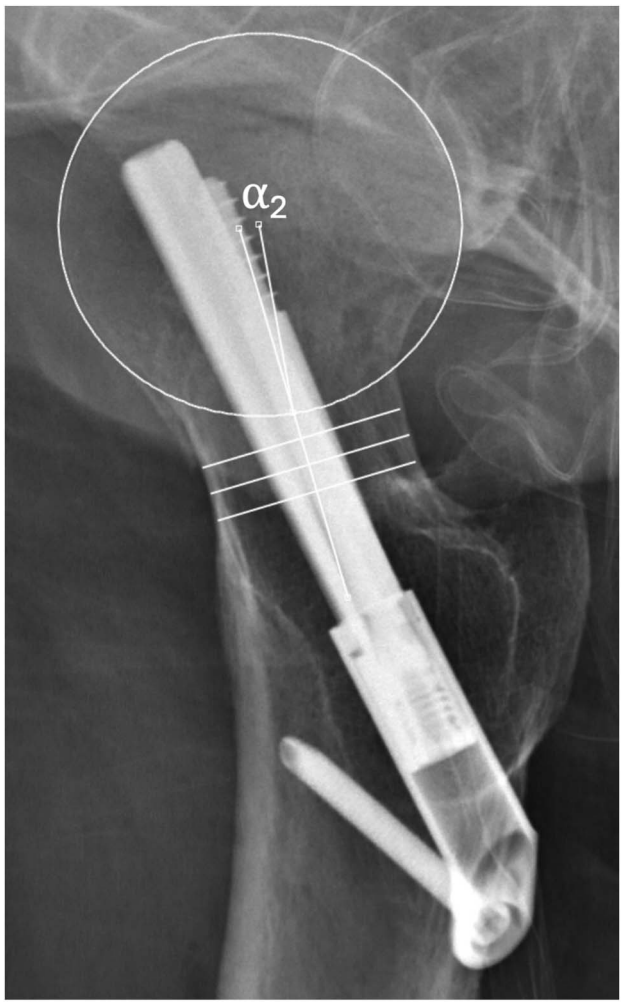

Figure 2. X-ray, measurement of the postoperative posterior tilt, α_2 = 6 degrees.

variables were compared using chi-squared tests or the Fisher exact test and the mean age was compared using a 2-sample *t* test.

Logistic regression analysis was used to examine the univariate and multivariate associations with conversion to arthroplasty within the FNS data and to compare FNS data with CNS data. The independent variables in the univariate analyses were age, sex, fracture laterality, mechanism of injury, ASA score, displacement, Garden displacement, and reduction. The multivariate model included age, sex, and displacement. The results are presented as odd ratios (ORs) with 95% confidence intervals (95% CIs).

All statistical tests were 2-tailed, with a significance level of 0.05. The analyses were conducted using SAS System, version 9.4 for Windows (SAS Institute Inc., Cary, NC).

3. Results

3.1. Patients Treated with FNS

During the follow-up period, 10 patients (20%) underwent reoperation: 8 (16%) underwent later conversion to arthroplasty, one (2%) had a fixation device removed, and one underwent re-fixation with a shorter bolt because of perforation of the joint. The mean time to conversion to arthroplasty was 11 months after the initial osteosynthesis (range 0.1–2.7 years). In 7 cases, the conversion to arthroplasty was performed with total hip arthroplasty and in one case with hemiarthroplasty (Table 2).

TABLE 1.

Comparison Between FNS and CNS at 12 Months From Surgery

	CNS (%)*	FNS (%)*	*P*
Total	301	51	
Sex, female	168 (55.8)	26 (51.0)	0.5
Mean age in years	73 (20–102)	69 (31–92)	0.03†
Fracture laterality, right	124 (41.2)	20 (39.2)	0.8
Number of deaths	42 (13.9)	4 (7.8)	0.2
ASA score			0.06
1–2	77 (26)	21 (41)	
3	169 (57)	21 (41)	
4–5	52 (17)	9 (18)	
Data missing	3		
Displacement			0.7
Nondisplaced, posterior tilt 0–20 degrees	192 (63.8)	34 (66.7)	
Nondisplaced, posterior tilt ≥20 degrees or <0° or displaced	109 (36.2)	17 (33.3)	
Garden displacement			1.0
Garden 1–2	254 (84.4)	43 (84.3)	
Garden 3–4	47 (15.6)	8 (15.7)	
Reduction			0.1
Nondisplaced on AP view, posterior tilt 0–10 degrees	209 (69.4)	34 (66.7)	
Nondisplaced on AP view, posterior tilt ≥10 degrees or <0°	88 (29.2)	14 (27.5)	
Displaced	4 (1.3)	3 (5.9)	
Conversion to arthroplasty	33 (11.0)	6 (11.7)	0.9
Any reoperation	50 (16.6)	7 (13.7)	0.6

* Percentage of the total for the group in parentheses.
† Statistically significant.

In the univariate analysis, neither fracture displacement nor preoperative PT was associated with later conversion to arthroplasty. Nondisplaced fractures with 0–20 degrees of preoperative PT were no more or less likely to lead to arthroplasty than displaced fractures or nondisplaced fractures with PT ≥ 20 degrees or PT < 0° (OR 1.6, 95% CI 0.3–9.0, $P = 0.6$). Fracture reduction, age, sex, ASA score, mechanism of injury, and fracture laterality were also not associated with conversion to arthroplasty (Table 3).

In the multivariate analysis, age, sex, and fracture displacement were not associated with increased risk of later conversion to arthroplasty (Table 3). A separate analysis was performed to determine the risk factors of any reoperation; none were identified (Table 4).

3.2. Comparison with Fixation with CNSs

The FNS group was compared with the group with CNS fixation. The follow-up time was 12 months, and the end point was either conversion to arthroplasty or the death of the patient, whichever occurred first.

At 12 months, 42 patients (14.0%) in the CNS group and 4 (7.8%) in the FNS group had died. In the CNS group, 33 patients (11%) had undergone conversion to arthroplasty while only 6 (12%) had done so in the FNS group. There was a statistically significant difference between the mean age of the groups (mean age 73 years [CNS] versus 69 years [FNS], $P = 0.03$), but there was no statistically significant difference between the groups according to any of the other variables tested (Table 1).

In the univariate analysis, there was no statistically significant difference in the probability of later conversion to arthroplasty

TABLE 2.

Characteristics of the Study Population (FNS)

	Total	Any Reoperation (%)*	Conversion to Arthroplasty (%)*
Total	51	10 (19.6)	8 (15.6)
Mean age in years	69 (31–92)	64 (47–82)	65 (47–82)
Sex			
Male	25	4 (16)	3 (12.0)
Female	26	6 (23.1)	5 (19.2)
Fracture laterality			
Right	20	5 (25.0)	5 (25)
Left	31	5 (16.1)	3 (9.7)
Mechanism of injury			
Low-energy	37	8 (21.6)	7 (18.9)
High-energy	14	2 (14.2)	1 (7.1)
ASA score			
1–2	21	4 (19.0)	3 (14.3)
3	21	4 (19.0)	3 (14.3)
4–5	9	2 (22.2)	2 (22.2)
Displacement			
Nondisplaced, posterior tilt 0–20 degrees	34	8 (23.5)	6 (17.6)
Nondisplaced, posterior tilt ≥20 degrees or <0° and displaced fractures	17	2 (11.8)	2 (11.8)
Garden displacement			
Nondisplaced	43	8 (18.6)	6 (14.0)
Displaced	8	2 (25)	2 (25)
Reduction			
Nondisplaced on AP view, posterior tilt 0–10 degrees	34	5 (14.7)	4 (11.8)
Nondisplaced on AP view, posterior tilt ≥10 degrees or <0°	14	4 (28.6)	3 (21.4)
Displaced	3	1 (33)	1 (33)

* Percentage of the total for the given row in parentheses.

between the groups (OR 0.9, 95% Cl 0.4–2.3, $P = 0.9$). In the multivariate analysis, after adjusting for age, sex, and fracture displacement, the results remained nonsignificant (OR 0.9, 95% CI 0.34–2.34, $P = 0.8$) (Table 5).

4. Discussion

Twenty percent of patients with FNFs treated with FNS had a reoperation, and 12% went through conversion to arthroplasty during our follow-up time. We found no association between either preoperative fracture displacement or preoperative PT and later conversion to arthroplasty among patients with FNFs treated with FNS; however, our number of patients with displaced fracture was too small to draw any conclusions. Patient sex, age, ASA class, and fracture laterality also had no associations with reoperations. When comparing FNS with fixation with CNSs, there was no statistically significant difference in the risk of later arthroplasty or other reoperations.

High risk of later reoperation and conversion to arthroplasty has been reported with the gold standard operative treatment of FNFs.[20] The FNS was developed to provide better stability and, therefore, to decrease the reoperation rate. In our study, the total reoperation rates and risk of undergoing conversion to arthroplasty were comparable with those of earlier studies. In a retrospective study of 34 patients, Stassen et al reported a reoperation rate of 24% and conversion to arthroplasty for 18% of the patients within the first 12 months.[18] In a prospective observational study of 125 patients, Stoffel et al reported slightly lower complication rates compared with ours at 12 months: 9% of the patients had a treatment-related complication; implant removal and/or conversion to arthroplasty was performed for 9 patients (7%); and conversion was recommended but not performed for an additional 2.[19] At 12 months, 32 of the 125 patients were lost to follow-up, which may explain the lower reoperation rate. In previous studies using other IF methods, the reoperation rates have varied between 16% and 30%, depending on which operations were considered as the end point.[10,13,14,21] Earlier data and our results suggest that reoperation rates are similar between FNS and other IF methods.

Fracture displacement is considered a risk factor of later reoperations in patients treated with IF.[12,22] However, it may be used even in displaced fractures for younger patients when the goal is to preserve the hip joint. In the FNS group in our study, 6 patients had a preoperatively displaced fracture, according to the Garden classification, and the average age among these patients was 60 years. Two of them underwent later conversion to arthroplasty, making conversion-to-arthroplasty rates high for displaced fractures. Although we did not find a statistically significant association between fracture displacement and reoperations, we cannot draw any strict conclusions based on our material as the small number of patients creates a clear risk of bias. However, Stassen et al also found no correlation between fracture displacement and reoperation rates, and 47% (16/34) of their patients had displaced fractures according to the Garden classification.[18] Preoperative PT was not correlated with later conversion to arthroplasty in patients treated with FNS in our study, but several previous studies have indicated that increased preoperative PT is a risk factor of conversion to arthroplasty in patients with FNFs treated with IF.[8,11,23,24] In those studies, the fixation method was CNSs, and we are not aware of any previous studies regarding PT and FNS. However, in our study group, the number of patients with preoperative PT ≥ 20 degrees was small, which might cause bias to analysis.

TABLE 3.

Analysis of Risk of Conversion to Arthroplasty

	Univariate Analysis			Multivariate Analysis		
	OR	95% CI	P	OR	95% CI	P
Age	0.98	0.92–1.0	0.4	1.0	0.9–1.0	0.2
Sex						
Male	0.6	0.1–2.7	0.5	0.6	0.1–3.0	0.5
Female	1			1		
Fracture laterality						
Right	3.1	0.7–14.8	0.2			
Left	1					
Mechanism of injury						
Low-energy	3.0	0.3–27.2	0.3			
High-energy	1					
ASA score						
1–2	0.6	0.1–4.3	0.7			
3	0.6	0.1–4.3	0.7			
4–5	1					
Displacement						
Nondisplaced, posterior tilt 0–20 degrees	1.6	0.3–9.0	0.6	2.7	0.3–21.9	0.4
Nondisplaced, posterior tilt ≥20 degrees or <0° or displaced	1			1		
Garden displacement						
Garden 1–2	0.5	0.08–3.0	0.4			
Garden 3–4	1					
Reduction						
Nondisplaced on AP view, posterior tilt 0–10 degrees	0.3	0.02–3.7	0.3			
Nondisplaced on AP view, posterior tilt ≥10 degrees or <0°	0.5	0.04–8.3	0.7			
Displaced	1					

TABLE 4.

Analysis of Risk of Conversion to Any Reoperation

	Univariate Analysis		
	OR	95% CI	P
Age	1.0	0.9–1.0	0.2
Sex			
Male	0.6	0.2–2.6	0.5
Female	1		
Fracture laterality			
Right	1.7	0.4–7.0	0.4
Left	1		
Mechanism of injury			
Low-energy	1.7	0.3–9.0	0.6
High-energy	1		
ASA score			
1–2	0.8	0.1–5.6	0.9
3	0.8	0.1–5.6	0.9
4–5	1		
Displacement			
Nondisplaced, posterior tilt 0–20 degrees	2.3	0.4–12.3	0.3
Nondisplaced, posterior tilt ≥20 degrees or <0° or displaced	1		
Garden displacement			
Garden 1–2	0.7	0.2–4.0	0.7
Garden 3–4	1		
Reduction			
Nondisplaced on AP view, posterior tilt 0–10 degrees	0.3	0.03–4.6	0.4
Nondisplaced on AP view, posterior tilt ≥10 degrees or <0°	0.8	0.06–11.5	0.9
Displaced	1		

TABLE 5.

Analysis of Risk of Conversion to Arthroplasty by Group at 12 Months

	Univariate Analysis			Multivariate Analysis		
	OR	95% CI	P	OR	95% CI	P
CNS	0.9	0.4–2.3	0.9	0.9	0.3–2.3	0.8
FNS	1			1		

In this study, we compared FNS with IF using CNSs—a study population from a previous article.[8] Because of such previous studies, PT is routinely measured preoperatively in our hospital, and primary arthroplasty is suggested with patients with PT > 20 degrees; the total number of fractures with PT ≥ 20 degrees was, therefore, small in the FNS group. To match the groups, we compared FNS and fixation with CNSs using 2 subgroups, in which patients with nondisplaced fractures but with PT ≥ 20 degrees or PT < 0° were combined with patients with displaced fractures. We, nevertheless, found no statistically significant difference between the groups regarding later arthroplasty or reoperation. Besides conversion to arthroplasty, other reoperations at 12 months were performed only for one patient (2%) in the FNS group and for 17 (6%) in the CNS group—16 of which were implant-removal surgeries. This indicates that implant migration leading to implant removal may be less common with FNS than with CNSs, as also found by Stoffel et al in their cadaver study.[16] Similar to our results, Tang et al[25] found no difference in complication rates between FNS and CNSs, but no reoperations were reported in that study. Rajnish et al found similar results in a meta-analysis comparing FNS and CNSs,[17] but postoperative complications were not stated in all the studies analyzed and, again, no information on reoperations was reported.

FNF is associated with high overall morbidity and mortality.[26,27] In this study, 8% of patients in the FNS group died during the first postoperative year while 14% died in the CNS group. The mean age was 4 years higher in the CNS group, which could explain the higher mortality rate, but the difference in mortality was not statistically significant regardless. Most of the FNFs in our study were low-energy fractures, which indicates that the patients were frail and might explain the high overall mortality. No statistically significant difference in death was observed during the first year between the FNS and CNS groups, indicating that the overall high mortality can be explained by patient-related factors rather than the fixation method.

We acknowledge that this study has several limitations. First, owing to its' retrospective nature, the surgical method was thus chosen by the surgeon in charge, which is likely to have caused some bias in patient selection. Second, the number of patients with a displaced fracture and PT ≥ 20 degrees was also small in the FNS group and, therefore, we cannot draw any strict conclusions on displacements effect on reoperation rates. In addition, when choosing the fixation method, economical aspect should be taken into consideration, and we did not have data on the matter. The strength of the study is that both groups were treated in the same hospital, by the same surgeons, and with similar perioperative treatment. We believe that preoperative PT is equally important when using FNS as with other IF methods, which has also been shown in previous studies, but further study with a larger patient group is needed.

In conclusion, FNS seems to have a comparable reoperation rate and conversion-to-arthroplasty rate compared with the gold standard treatment. There is a possibility that FNS might result in

less implant migration than CNS; however, this and its' effect on long-term outcomes after FNF surgery still need further research.

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