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ORIGINAL ARTICLE

# Knee arthrodesis using a modular customized intramedullary nail

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## KEYWORDS

Knee arthroplasty;  
Infection;  
Knee fusion;  
Arthrodesis;  
Intramedullary  
nailing

## Summary

**Introduction:** Arthrodesis of the knee, particularly in infectious situations, can be achieved using either an external fixator or an intramedullary device. The objective of this study is to report the clinical, functional, and radiographic outcomes of a continuous series of 19 cases of knee arthrodesis using a customized modular intramedullary nailing system.

**Hypothesis:** The modular intramedullary nail offers a satisfactory functional result while maintaining limb length, in spite of a nonunion risk, since acting like a true endoprosthesis.

**Material and methods:** In our retrospective series of 19 patients, the main source of patients were infected total knee replacements. The nail was customized from assembling a dual surface-sanded titanium component (femoral and tibial). The Lequesne Algofunctional score and the WOMAC score were recorded, as well as the length discrepancy between the lower extremities. Arthrodesis consolidation and the nail's fit in the shaft were verified on anterior-posterior (AP) and lateral radiographs.

**Results:** Five complications were observed: one anterior cortical break, one excessive tibial rotation, two cases of delayed union, and one nail revision due to residual nail instability. The postoperative Lequesne Algofunctional score was 13/24 and the WOMAC score 57/100. The nonunion rate was 32%. From a functional point of view, the patients who did not achieve complete union and those who did had similar scores. The subjective results were not as good in patients who did not achieve final consolidation.

**Discussion:** Modular intramedullary nailing simplifies the technique, shortens the procedure, and reduces the amount of blood loss at surgery. Our nonunion rate was high, although the functional result did not seem compromised by such nonunion. The risk of long-term implant failure was not studied and requires longer follow-up studies.

**Level of evidence:** Level IV therapeutic study.

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## Introduction

Today, the main indication for knee arthrodesis is recurring infection after total knee arthroplasty (TKA) [1]. Knee arthrodesis often makes it possible to salvage the limb and gives better functional results than amputation [1]. This is a difficult intervention that is performed on patients who have often undergone several surgeries with severe pain, poor quality skin tissue, and considerable bone destruction. The results of knee arthrodeses are variable, with the complication rate reaching a mean 40% [2]. These post-operative complications include nonunion, infection, pain with the implant material, fracture, and healing delays. The two most frequently used arthrodesis techniques are intramedullary nailing and external fixation. Mabry et al. [3], Vlasak et al. [4], and Wiedel [2] compared the results of these two types of arthrodesis. They concluded that there are advantages for each of the techniques, but that intramedullary nailing presents a number of advantages. Complications are rarer and consolidation is earlier and more frequent.

In our department, we have long used external fixation arthrodesis with the AO biplane transfixation system. Weight bearing is only allowed after a 3 to 6-month delay and a mean 40 mm shortening is observed. Despite this stable assembly, we obtain a 30% surgical revision rate for nonunion. We therefore decided to use modular intramedullary nailing with a customized nail in a cementless technique, the results of which have already been presented by Volpi et al. [5], attempting to limit the arthrodesed limb shortening to 5–10 mm, at the risk of not obtaining consolidation, with the nail behaving as an endoprosthesis providing permanent immobilization of the knee.

The objective of this study was to present the clinical, functional, and radiographic results of our series of 19 patients and to compare the results of healed arthrodeses versus unhealed arthrodeses.

Our hypothesis postulates that the functional result is independent of bone union with this type of assembly at the medium term.

## Material and methods

### The patient series

In this retrospective series, we performed 20 knee arthrodeses using this technique between 2003 and 2007. The series included 13 females and seven males with a mean age of 62 years (range, 31–81 years). The indications for knee arthrodesis were the following:

- 13 cases of sequelae from infection (six with primary TKA, six with TKA recementing procedures, one case of tubercular osteoarthritis);
- three cases of stiff and painful TKAs;
- two cases of nonunion after an attempt at instrumented arthrodesis using an external fixator;
- two traumatic sequelae (one open dislocation of the knee and one open fracture of the femur after a gunshot wound).

Nineteen of the 20 patients were reviewed by an independent operator. One patient died 16 months after the arthrodesis, from multiorgan deficiency following wasting syndrome, probably secondary to multiple surgical interventions. He was considered cured of his infection. He was excluded from the series.

### The implant

The nail (Link Laboratory, Hamburg, Germany) was made of surface-sanded titanium and comprised a femoral component and a tibial component. The two components were totally separate and customized for the best anatomic fit possible to the femoral and tibial medullary canals. Primary stability was ensured by the surface effect (surface-sanded titanium), which also ensured secondary stability by promoting bone growth when in contact with the titanium. To prevent implant rotation, antirotation flanges were present at the implant zones.

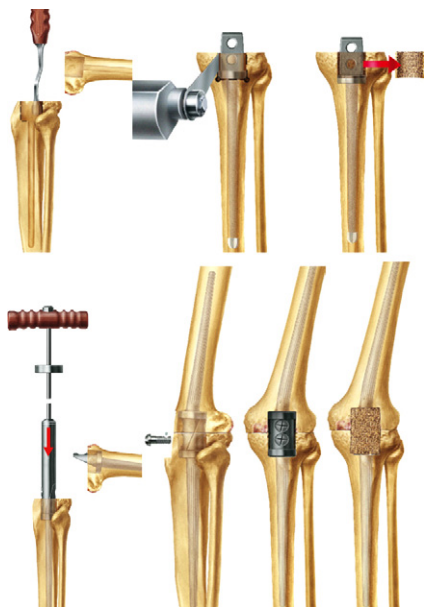
The two femoral and tibial components were assembled by reciprocal interlocking of the baseplates, with two anteroposterior screws locking the assembly. Once assembled, the endoprosthesis had a 5° valgus angle in the frontal plane and 5° flexion in the sagittal plane. These two angles could be modified according to the operator's directions when ordering the implant from the laboratory.

### Surgical technique

Preoperative planning included an anterior-posterior (AP) and lateral X-ray of the entire lower limb, with measurement of diaphyseal canals. Then templates adapted to the anatomy of the femoral and tibial shafts were proposed by Link company and the surgeon validated or rejected these templates, thereby authorizing the production of the nails. The template had to show satisfactory filling of the canals on the AP and lateral views on both the tibia and the femur.

The installation was classic with a knee bar at the end of the table for 90° flexion and a counterweight on the thigh. The tourniquet was not used so as to protect the tissues from ischemia. The contralateral limb underneath allowed assessment of the length of the healthy limb compared to the arthrodesed limb. The incision was most often median and sometimes lateral when the knee had been operated on previously. Aerobic and anaerobic samples were cultured on standard and enriched media (Rosenow medium) on the tibia, the femur, and in the joint. We then preceded to ablation of necrotic tissues and fibrosis, lavage, and preparation of the femoral and tibial shafts. The shafts were reamed cautiously to ensure proper filling. With the trial implants in place, the length and rotation of the limb was checked and we placed the final implants (Fig. 1). We sought external tibial torsion ranging from 10° to 20° and limb shortening limited to 5–10 mm. The femoral implant was attached to the tibial implant with screws. We systematically grafted the arthrodesis area with reaming product and sometimes with graft material harvested from the patella. No bone allograft or substitute was used. The incision was closed with a Redon suction drain.

For all the infected TKA arthrodeses, the procedure was carried out in two operative sessions. The first consisted



**Figure 1** Surgical technique.

in placing the prosthesis associated with multiple samples and placing a spacer with antibiotics (Palacos gentamicin with a dose of vancomycin) and targeted intravenous antibiotic therapy. The second operation was devoted to placing the nail, ranging from 6 weeks to 5 months later, depending on the results of the samples taken. If no bacteria were identified after the second operation, empirical antibiotic treatment associating rifampicin and tavanic was initiated for 3 months. The mean duration of the antibiotic treatment lasted 3–6 months depending on the bacterium found and the efficacy and tolerance of the antibiotic treatment. Efficacy of the antibiotic therapy was judged based on the clinical status and inflammatory markers (CRP and sedimentation rate). No new samples were taken when the antibiotics were discontinued.

## Clinical review

Blood loss was calculated by adding blood loss collected intraoperatively by suction and the blood found in the Redon drains.

During the clinical review, satisfaction was rated as very satisfied, fairly satisfied, fairly unsatisfied, or very unsatisfied. The Lequesne Algofunctional Index [6] for arthrosis of the knee (low score = good result) and the Western Ontario and McMaster Universities Osteoarthritis (WOMAC) Index [7] (high score = good result) were noted by using the 100 mm graduated visual analogic scale for the WOMAC. We removed the stiffness component from the WOMAC score. We clinically quantified the discrepancy in the length of the lower limbs and recorded the use and size of any compensating insoles. We noted any pain in the ankle and the ipsilateral foot, as well as the arthrodesis area, the femur, and the tibia upon palpation. We checked for absence of residual mobility in the knee.

AP and lateral X-rays of the femur and the tibia were taken to analyze consolidation and femoral and tibial shaft

filling. The arthrodesis was considered healed if a bony bridge existed between the femur and the tibia. Filling was judged to be positive when the nail filled the shaft in the AP and lateral views.

## Results

The results are summarized in Table 1.

## Complications

The following complications were noted:

- one anterior cortical break on the proximal end of the femoral nail as noted on the postoperative radiographs. It healed after placing a full leg cast for a duration of 10 weeks;
- one excessive external tibial rotation (75°), secondary to a technical error when placing the nail;
- two cases of delayed healing, one of which required a medial gastrocnemius flap;
- one case of severe residual pain leading to revising the nail. During the revision surgery, the operator noted that the nail was not stable in the femur or the tibia. After removing the nail, a spacer was placed and then 6 weeks later another customized nail was implanted.

A total of 26% of the patients undergoing surgery (5/19) presented complications.

## Clinical results

### Surgical intervention

The mean duration of surgery was 143 minutes (range, 95–250 minutes). Mean blood loss was 710 ml (range, 350–1550 ml).

### Satisfaction index

Nine patients were very satisfied, six were fairly satisfied, and four were fairly unsatisfied.

### Lequesne Algofunctional Index

The mean Lequesne score (Table 2) was 13 (range, 3–22).

Seven patients (37%) continued to have nighttime pain. Eight patients (42%) continued to have pain when walking, three of whom had substantial pain. Fourteen patients (74%) experienced pain when rising in the morning. The mean maximal walking test result was 500 m (range, unlimited to less than 100 m) and 14 patients (74%) needed at least one cane for walking. Climbing stairs was very difficult if not impossible for 11 patients (58%). Fourteen patients (74%) could not walk on rough terrain.

### The WOMAC Index

The stiffness component of the index was removed, reducing the total points to 2200 (Tables 3–5).

For the WOMAC Pain Subscale (Table 3), six patients (32%) no longer complained of pain for any activity and 12 patients (64%) no longer had pain when lying down. Walking was painless for seven patients (37%), moderately painful

**Table 1** Summary.

Patient	Age	Follow-up (months)	Satisfaction index	Lequesne Index	WOMAC Index	Cane use	Length (mm)	Bone union	Insole	Press fit, femur	Press fit tibia
1	34	48	Very satisfied	15	79	1	-15	Yes	0	Yes	Yes
2	74	46	Fairly satisfied	12	43	1	-17	Yes	10	Yes	Yes
3	57	45	Very satisfied	3	95	0	-50	Yes	45	No	Yes
4	73	41	Very satisfied	22	11	2	-40	Yes	0	Yes	Yes
5	66	39	Fairly unsatisfied	15	38	2	-12	Yes	10	Yes	Yes
6	73	31	Fairly unsatisfied	22	27	2	-3	No	0	Yes	Yes
7	48	28	Fairly satisfied	16	32	1	0	No	-10	Yes	Yes
8	53	25	Fairly unsatisfied	18	37	0	-10	Yes	0	Yes	Yes
9	81	25	Very satisfied	9	46	1	0	No	0	Yes	Yes
10	57	21	Very satisfied	18	38	1	-5	Yes	0	Yes	Yes
11	75	21	Fairly satisfied	16	48	1	-8	Yes	5	Yes	Yes
12	55	21	Fairly unsatisfied	12	64	1	-5	No	0	Yes	Yes
13	77	19	Fairly satisfied	3	98	0	-15	No	0	Yes	Yes
14	63	17	Fairly satisfied	21	34	2	-10	Yes	0	Yes	Yes
15	67	17	Fairly satisfied	8,5	70	1	-40	Yes	30	Yes	Yes
16	53	12	Very satisfied	7	84	0	5	Yes	0	Yes	Yes
17	58	6	Very satisfied	14.5	77	0	5	No	-5	Yes	Yes
18	31	5	Very satisfied	7.5	89	1	5	Yes	0	No	Yes
19	79	4	Very satisfied	12	79	1	-15	Yes	0	Yes	No

**Table 2** Lequesne Algofunctional Index.

Patient	Nighttime pain	Morning pain	Pain standing	Pain walking	Pain rising	Distance walked	Cane	Go up one flight of stairs	Go down one flight of stairs	Crouched position	Irregular terrain	Total
1	0	0	0	0	0	6	1	2	2	2	2	15
2	0	0	0	0	1	5	1	1	1	2	1	12
3	0	0	0	0	0	0	0	0	0	2	1	3
4	0	0	2	2	2	6	2	2	2	2	2	22
5	1	1	0	1	1	1	2	2	2	2	2	15
6	1	1	1	2	1	6	2	2	2	2	2	22
7	1	0	1	1	0	4	1	2	2	2	2	16
8	1	2	1	2	1.5	5	0	1	1	2	1.5	18
9	0	0	0	0	1	3	1	1.5	1		1.5	9
10	2	0	0	1	1	5	1	2	2	2	2	18
11	1	1	0	0	1	4	1	2	2	2	2	16
12	0	2	1	0	1	1	1	1.5	1.5	2	2	12
13	0	0	0	0	1	0	0	0	0	2	0	3
14	0	1	2	1	1	6	2	2	2	2	2	21
15	0	0	0	0	1	1	1	1.5	1	2	1	8.5
16	0	0	0	0	0	2	0	1	1	2	1	7
17	1	1	1	1	1	5	0	0.5	0.5	2	1.5	14.5
18	0	0	0	0	0	2	1	0	0.5	2	2	7.5
19	0	0	0	0	1	4	1	1	1	2	2	12

**Table 3** WOMAC Index, Pain Subsection.

Patients	Pain walking	Pain going up & down stairs	Nighttime pain	Pain lying down	Pain standing	Total (/500)	Total (/100)
1	100	100	100	100	100	500	100
2	20	40	100	100	30	390	78
3	100	100	100	100	100	500	100
4	0	0	100	50	0	150	30
5	50	0	80	80	70	280	56
6	20	0	70	70	30	190	38
7	30	0	50	50	40	170	34
8	10	10	20	40	10	90	18
9	60	40	100	100	60	360	72
10	50	40	10	50	100	250	50
11	10	0	50	50	30	130	26
12	20	10	90	100	80	300	60
13	100	100	100	100	100	500	100
14	25	0	100	100	25	250	50
15	100	100	100	100	100	500	100
16	100	100	100	100	100	500	100
17	50	80	80	100	80	390	78
18	100	100	100	100	100	500	100
19	80	60	100	100	80	440	88

for five patients (26%), and very painful for seven patients (37%). Climbing stairs was painless for six patients (32%), relatively painless for five patients (26%), and impossible or very painful for eight patients (42%). The mean overall score for the WOMAC Pain Subscale was 66/100 (range, 18–100).

For the WOMAC Function Subscale (Tables 4 and 5), all the patients could lie down in a bed. Seventeen patients out of 19 (89%) were able to sit with no problems, 15 out of 19 (79%) got on and off the toilet easily.

Fourteen patients (74%) managed to stand upright, get out of a chair or bed, lean forward, and walk on flat ground. Eleven patients (58%) succeeded in putting on and taking off socks without assistance. Eight patients (42%) climbed up and down stairs with no problems. Seven patients (37%) did light housework and five patients (26%) did heavy housework. Three patients (16%) were able to take a bath. Summing the pain and function subscores, our mean WOMAC score was 57/100 (range, 12–98).

**Table 4** WOMAC Index, Functional Subsection 1.

Patients	Going down stairs	Going up stairs	Arising from sitting	Standing upright	Leaning forward	Walking on flat ground	Getting in & out of car	Shopping	Putting on socks
1	100	100	100	0	100	100	90	100	100
2	10	20	30	40	50	70	20	10	20
3	100	100	100	100	100	100	20	100	100
4	0	0	0	0	0	0	0	0	0
5	0	0	70	40	100	40	20	0	35
6	0	0	50	30	10	20	40	0	0
7	0	0	100	20	40	60	40	0	0
8	20	0	20	0	40	20	10	0	80
9	10	10	70	40	100	70	20	0	0
10	0	0	50	50	100	100	30	0	20
11	0	0	40	60	70	90	30	20	100
12	10	10	50	60	60	70	70	70	60
13	100	100	100	100	100	100	85	100	80
14	0	0	0	30	0	50	75	0	0
15	50	40	70	70	80	90	60	20	100
16	60	60	60	100	100	100	50	100	100
17	90	90	100	100	100	100	20	0	75
18	75	100	100	100	100	100	25	50	100
19	85	85	75	60	70	100	100	60	100

**Table 5** WOMAC Index, Functional Subsection 2.

Patients	Taking off socks	Lying on a bed	Taking bath	Sitting	Getting on & off toilet	Heavy chores	Light chores	Total Function (/1700)	Total (/100)
1	100	100	0	80	60	0	0	1221	79
2	20	100	0	70	70	80	0	647	43
3	100	100	100	100	60	100	100	1565	95
4	0	100	0	0	0	0	0	100	11
5	50	50	0	50	40	20	0	545	38
6	0	100	0	50	50	0	0	385	27
7	0	80	0	100	50	0	0	513	32
8	100	100	0	100	100	40	20	712	37
9	0	100	0	40	60	40	0	656	46
10	20	70	0	90	40	0	0	571	38
11	100	100	0	50	50	90	40	923	48
12	50	100	0	100	60	70	10	898	64
13	100	100	100	100	100	100	100	1665	98
14	0	100	0	80	50	0	0	474	34
15	100	100	0	100	50	10	0	1039	70
16	100	100	0	80	80	60	100	1334	84
17	100	100	100	100	100	20	0	1283	77
18	100	100	50	100	100	100	60	1449	89
19	100	100	0	100	100	0	60	1295	79

Palpation of the femur, tibia, and arthrodesis area was painful in 11 patients. We found no residual mobility in the arthrodesis area.

#### Limb shortening

Eleven patients presented shortening of the operated limb between 5 mm and 15 mm, three patients had limb shortening greater than 15 mm (30 mm, 40 mm and 50 mm), two patients' lower limbs were the same length, and three patients presented lengthening of the operated limb measuring 5 mm. The mean shortening was 12 mm (median, 8 mm).

#### Radiographic results

Femur medullary canal filling was satisfactory in 17 patients and tibial canal in 18 patients. The WOMAC score of the three patients in whom this filling was absent was 95, 89, and 79, and all were very satisfied with the surgery.

Thirteen patients (Table 1) achieved bone union (Fig. 2) and six patients did not (Fig. 3), for a 32% nonunion rate.

Of the 13 patients achieving bone union, seven were very satisfied, four were fairly satisfied, and two were fairly unsatisfied with the arthrodesis. The mean WOMAC score was 57, the mean Lequesne score was 13. The mean limb shortening was 16 mm.

Of the six patients who did not achieve bone union, two were very satisfied, two were fairly satisfied, and two were fairly unsatisfied. The mean WOMAC score was 57; the mean Lequesne score was 13. The mean limb shortening was 3 mm.

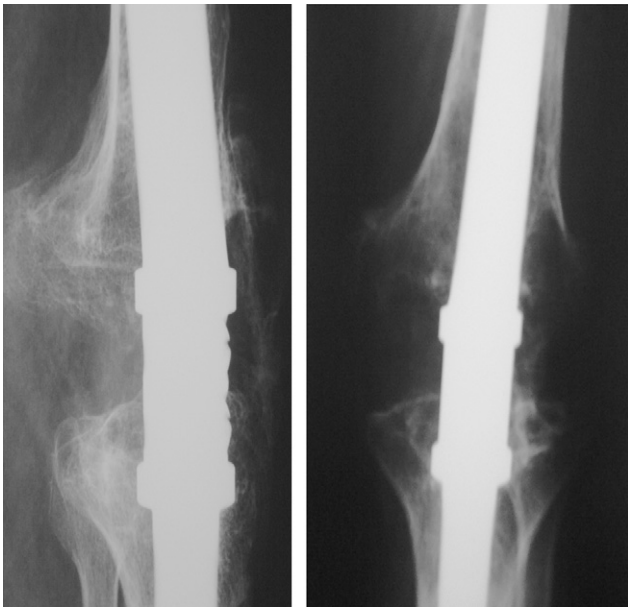
The two groups differed in favor of the group with bone union for the satisfaction index and in favor of the nonunion group for limb shortening. However, there was no difference between the two groups on the WOMAC Index.



**Figure 2** Healed arthrodesis.

#### Discussion

Use of modular intramedullary canal nailing [5,8,9,10,11] simplifies the arthrodesis technique: the duration of the surgery and blood loss are reduced. The mean duration of surgery in our series was 143 minutes, with mean blood loss totaling 710 ml. Crockarell et al. [12] and Ellingsen et al. [13], who used long nails, found a mean surgery duration of 210 minutes and six hours, respectively, and mean blood loss of 1143 ml and 2973 ml. Lai et al. [11] also used a modular nail (33 patients). The mean surgery duration was 104 minutes, the mean time to bone union was 5.2 months,



**Figure 3** Nonconsolidated arthrodesis. Note the interfragmentary space. The implant behaves like an endoprosthesis.

for a 91% bone union rate. They recommend the use of a modular nail because it can be put in place with a hip implant, there is no risk of material migration, and weight bearing is possible immediately because of the immediate axial and rotational stability. Incavo et al. [14] studied the possibilities of removing the modular nail in a series of 22 arthrodeses. Given the problems with extraction, they advised against using this implant. The modular nail was extracted without incident in one patient in our series. The follow-up has been short but we have observed no implant failures, no serious complications, or septic recurrence.

Fifteen patients out of 19 were satisfied with the intervention. In a series using a modular nail, Arroyo et al. [10] had equivalent results (15 out of 16 patients were satisfied).

In our series, the mean postoperative Lequesne score was 13 and the mean WOMAC score was 57/100. Garberina et al. [15] found an International Knee Score (IKS) score totaling 47 in the nine patients achieving bone union (out of 13 patients) with an external fixator. Bargiotas et al. [16,17] used the WOMAC Index and long nails and noted an increase in the WOMAC score from 41 to 64 points. In the series studied by Puranen et al. [18], 31 patients of 33 (94%) needed a cane for walking. This was also true for 10 out of 18 (56%) in the series studied by Ellingsen et al. [13], six out of 11 (55%) in Crockarell et al.'s study [12], four out of 14 (29%) in the series investigated by Volpi et al. [5], and 14 out of 19 (74%) in our series.

As for residual pain, the results differ greatly from one study to another. The results from our series (53% of the patients no longer presented pain when lying down or walking) come between those of Puranen et al. [18] (79%) and Ellingsen et al. [13] (6%).

The mean limb shortening measured 12 mm. In the literature, this shortening is often greater:

- 32 mm for Incavo et al. [14];
- 25 mm for Puranen et al. [18];

- 40 mm for Ellingsen et al. [13];
- 55 mm for Bargiotas et al. [16,17].

Using the same nail as ours, Volpi et al. [5] observed no major limb shortening.

In terms of bone union, our results are not as good as those presented in the literature, with 32% nonunion. With a long nail, Donley et al. [19], Ellingsen et al. [13], and Harris et al. [20] obtained 89% bone union, Punanen et al. [18] 80%, and Incavo et al. [13] 100%. Using a modular nail, Waldman et al. [21] observed 95% bone union, McQueen et al. [8,9] 85%, and Lai et al. [11] 91%. Our nonunion rate is high because we chose to respect the length of the lower limbs as far as possible. Sometimes, in cases of substantial bone destruction, we left an empty area between the femur and the tibia, rather than causing major shortening or grafting with an allograft or a bone substitute in an infectious context. Using the same nail as we did, Volpi et al. [5] observed 100% bone union with a mean 3 months. In cases of major bone destruction, they systematically grafted the arthrodesis area (allograft or bone substitute).

The functional results of the nonhealed arthrodeses in our series were identical to the healed arthrodeses. On the other hand, the subjective results were not as good as for the cases of healed arthrodesis. In our opinion, the risk of implant failure is minor when the arthrodesis is not healed with this type of nail, which behaves like an endoprosthesis. Nevertheless, only a study with a longer follow-up period can confirm whether or not the nail will tend to fail.

## Conclusion

Our functional results are comparable to those in the literature. The operative technique is simple, reliable (absence of serious complications), and can be used in presence of ipsilateral total hip arthroplasty. The attempt to avoid shortening the limb too much results in a high nonunion rate (32%), which has no consequence on the functional result. The good short-term stability, but the risk of failure, not demonstrated over the long-term, of this endoprosthesis encourages us to propose systematic grafting of the arthrodesis area in cases of major bone destruction. This would favor union of the arthrodesis without causing substantial limb shortening.

## Conflicts of interest

None.

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