



Case Report

Metaphyseal sleeves for revision total knee arthroplasty for patients with bone cement allergy and minimal bone loss: a case series

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ABSTRACT

Background: When evaluating persistent knee inflammation following total knee arthroplasty (TKA), hypersensitivity to implant components should be considered once other causes have been excluded. Revision total knee arthroplasty (rTKA) in patients with bone cement hypersensitivity presents a unique challenge.

Method: This study reports on four patients with clinical failure of TKA, three with confirmed allergy to polymethyl methacrylate (PMMA) and one to benzoyl peroxide, as demonstrated by skin patch testing. All patients underwent rTKA using metaphyseal sleeves. In three cases, diaphyseal stems were also used.

Results: After a mean follow-up of 71.2 months, all patients experienced symptomatic improvement, with a mean increase in range of motion (ROM) of 12.5 degrees. There was a mean increase of 16, 75 points in Knee Society Score. None required additional surgery.

Conclusion: In patients undergoing revision TKA due to confirmed allergy to bone cement and minimal bone loss, the use of metaphyseal sleeves—alone or in combination with stems—provides a viable cementless fixation strategy with promising mid-term outcomes.

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1. Introduction

Patients presenting with joint effusion, pain, erythema, warmth, fever or, at times, component loosening after TKA are typically evaluated for prosthetic joint infection. However, hypersensitivity reactions to implant materials can produce a similar inflammatory response, potentially accelerating aseptic loosening [1,2].

In rare cases, when allergy to bone cement is diagnosed, the surgical strategy must address both the hypersensitivity and the technical challenge of achieving durable fixation without cement, particularly in patients with severe bone loss. In these scenarios, cementless fixation using metaphyseal sleeves offers a promising alternative, though scarcely reported in the literature.

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The absence of infection and the presence of dermatologic symptoms should raise suspicion of an allergic reaction to prosthetic components [2]. However, hypersensitivity to implant materials is often a diagnosis of exclusion due to its rarity and variable presentation. Definitive preoperative diagnosis is challenging, as the sensitivity and specificity of available diagnostic tests remain unclear [3]. Self-reported metal or cement allergies combined with positive patch testing are frequently used for diagnosis, while lymphocyte transformation tests (LTT), migration inhibition factor (MIF) assays, and cytokine measurements via ELISA are used less frequently. A thorough patient history, including exposure to acrylics in dental implants, cosmetics, adhesives, and other materials, is essential before primary or revision surgery [4]. Routine allergy screening is not recommended in asymptomatic patients. If clinical suspicion persists, patch testing is typically the next step, with LTT reserved for patients with suggestive histories but negative skin tests [2,5].

For metal allergies in TKA, studies have shown improved outcomes when hypoallergenic prostheses are used, either in primary implantation [6], or as a revision following postoperative diagnosis [7].

Conversely, fewer studies address hypersensitivity to bone cement components, including PMMA, polymerization initiators (e.g., benzoyl peroxide), stabilizers (e.g., hydroquinone), and radiopaque agents (e.g., zirconium dioxide, barium sulfate) [8,9]. Identifying prior exposure to these substances is crucial, as they are common in medical, cosmetic, and industrial products [4].

In patients allergic to PMMA, achieving stable implant fixation during knee revision is more difficult due to the inability to use bone cement. Additionally, the presence of bone defects further complicates surgery. In such cases, metaphyseal fixation, either alone or in combination with diaphyseal fixation, offers the possibility of implant placement without cement. Porous-coated titanium metaphyseal sleeves have demonstrated the ability to offer robust mechanical stability and long-term biological integration. Their design allows simultaneous bone defect filling and implant fixation, making them a valuable solution for managing substantial bone loss. The stepped geometry facilitates axial load transfer and encourages surrounding bone ingrowth, in line with Wolff's law, thus providing enough axial and rotational stability making cementation unnecessary to achieve secure implant anchorage [10]. Moreover, they can be used without stems, even in AORI 2B defects [11].

The purpose of this study is to present the first case series, to our knowledge, reporting on rTKA using metaphyseal sleeves in cement-allergic patients.

2. Case histories

Four patients (three female, one male) developed symptoms suggestive of hypersensitivity following TKA and were diagnosed with cement allergy via skin patch testing (three to PMMA, one to benzoyl peroxide). All of them had previously undergone primary knee replacement with a NextGen® (Zimmer Biomet, Warsaw, Indiana) prosthesis. All primary TKAs used Palacos® R+G (Heraeus Medical GmbH, Hanau, Germany) bone cement with gentamicin. All patients provided informed consent for anonymous case presentation and radiographic imaging. This study received approval from the Regional Ethics Committee.

Infection was excluded preoperatively through normal ESR, CRP, synovial fluid analysis, microbiological cultures, Alpha-defensin testing, and leucocyte esterase assessment. Other causes of aseptic loosening such as instability, malalignment or component malposition were also ruled out. A detailed allergy profile was recorded for each patient. Two patients reported a history of mild drug hypersensitivity—one to nonsteroidal anti-inflammatory drugs (NSAIDs) and the other to beta-lactam antibiotics. Additionally, all four patients had documented sensitivities to environmental or cosmetic substances, including adhesives, hair dyes, and topical products. These findings suggest an underlying atopic tendency, which may have contributed to the development or recognition of hypersensitivity to bone cement components. None of the patients had a prior history of hypersensitivity to metals, and epicutaneous tests were negative for them in all the cases. Patch tests are performed by directly applying the studied components to the skin and subsequently assessing the presence or absence of a skin reaction, (which identifies dermatitis when contact allergens are exposed to the skin).

Patient demographics, initial TKA components, allergy test results, and intraoperative findings were recorded. Preoperative and end-of-follow-up clinical evaluations were performed using the 2011 Knee Society Score (knee and function) (Table 1). All patients reported pain as the primary symptom. Preoperative radiographs showed no component loosening or malposition.

All patients underwent cementless rTKA using the Attune® varus/valgus constrained revision knee system (DePuy Synthes, Warsaw, IN, USA) with porous coated titanium metaphyseal sleeves both in femur and tibia. In all three female cases, due to poorer bone quality, diaphyseal stems were used in the tibia and femur. Patellar resurfacing was not performed in any of the cases. Surgeries were performed between 2018 and 2020 by the same surgeon. During the study period (2018–2020), 144 revision TKAs were performed at our institution, of which only 4 (2.37 %) were due to confirmed bone cement allergy. Intraoperatively, no component loosening was observed. Clinical, functional, and radiographic outcomes were evaluated postoperatively, along with any complications (Table 1).

Average time between primary and revision TKA was 12.75 months. At a mean follow-up of 71.2 months, all patients experienced symptom improvement; two were asymptomatic, while two reported mild residual pain. Mean ROM improved from 95 degrees preoperatively to 107.5 degrees postoperatively. None required additional surgery.

Preoperative and postoperative radiographic images for representative patients (Figures. 1–7) illustrate the absence of loosening before revision and appropriate osseointegration of the implants after cementless reconstruction.

Table 1

Demographic, preoperative and postoperative patient data.

PATIENT	AGE	SEX	Side	Primary implants	Intraoperative findings	Personal and family history of previous allergies	Preoperative KSS		Pre- rTKA radiography	Symptoms	Skin patch test	Time from TKA to rTKA (months)	Revision implants	Follow-up (months)	Post-rTKA symptoms Knee	Postoperative KSS	
							Knee	Function								Knee	Function
1	72	Female	Right	Next-Gen CR (Zimmer Biomet, Warsaw, Indiana) cemented	No	No	45	78	No loosening signs, AORI 1 femur and tibia	Pain, effusion	+ PMMA	23	Uncemented ATTUNE [®] with stem and sleeves	83	Asymptomatic	60	75
2	69	Male	Right	Next-Gen PS (Zimmer Biomet, Warsaw, Indiana) cemented	No	No	44	75	No loosening signs, AORI 1 femur and tibia	Pain, swelling, effusion, redness	+ benzoyl peroxide	9	Uncemented ATTUNE [®] with sleeves	75	Asymptomatic	40	90
3	78	Female	Left	Persona PS (Zimmer Biomet, Warsaw, Indiana) cemented	No	No	18	79	No loosening signs, AORI 1 femur and tibia	Pain, effusion	+ PMMA	13	Uncemented ATTUNE [®] with stem and sleeves	67	Mild residual pain	30	80
4	74	Female	Left	Persona PS (Zimmer Biomet, Warsaw, Indiana) cemented	No	No	10	64	No loosening signs, AORI 1 femur and tibia	Pain, swelling	+ PMMA	6	Uncemented ATTUNE [®] with stem and sleeves	60	Mild residual pain	55	50

KSS, Knee Society Score; AORI, Anderson Orthopedic Research Institute classification for bone defects; PMMA, polymethyl methacrylat.

3. Discussion

This study highlights the use of porous-coated titanium metaphyseal sleeves as augments to fixation for cementless revision in patients with cement allergy and minimal intraoperative bone loss. Hypersensitivity to bone cement components is rare. A study found the overall prevalence of positive acrylate/methacrylate patch testing to be 1.4 % and 1.0 % in Sweden and Singapore, respectively [12].

Metaphyseal sleeves are implant-specific, step-cut devices with a conical or oval geometry that allows for a large surface area of contact with the bone, enhancing load distribution and providing axial and rotational stability. They are designed for press-fit fixation into the metaphysis after diaphyseal stem sizing and broaching, and are inserted as a unit with the final component using either a Morse taper junction or screws, depending on the manufacturer. The highly porous titanium coating—typically with porosity >50 % and pore sizes between 100–700 μm —facilitates bone ingrowth under micromotion thresholds below 150 μm , promoting durable osseointegration. Unlike cones, sleeves are not standalone implants but are mated directly to their specific prosthetic system. Most designs are modular, available in various sizes (femoral: 20–46 mm; tibial: 29–61 mm), and their oval cross-section in larger sizes improves rotational control compared to circular profiles.

In all cases, intraoperative assessment confirmed preserved metaphyseal cortical rim, good cancellous bone quality, and no cavitory defects or signs of instability. These features correspond to AORI type I defects with sufficient bone stock to ensure primary stability of the sleeves without the need for additional augmentation.

Unlike most studies that emphasize the general effectiveness of metaphyseal sleeves in rTKA, our aim is not to reaffirm their value universally, but to report their use in a rare and specific indication: patients with confirmed cement allergy and minimal bone loss. In this context, cemented fixation is contraindicated, and options are scarce. The present case series is, to our knowledge, the first to document mid-term outcomes (mean follow-up of 71.2 months) of cementless sleeve fixation in this patient subgroup. Our findings suggest that metaphyseal sleeves may be considered a reliable alternative even in cases with preserved bone stock.

Although there is a vast amount of research on allergic reactions to metal components in TKA, less focus has been given to the elements of bone cement. Currently, there is insufficient clinical evidence to establish a direct link between hypersensitivity to acrylics like polymethyl methacrylate, polymerization additives (N, N-dimethyl-p-toluidine), initiators (benzoyl peroxide) and stabilizers (hydroquinone), with knee replacement failure.

To assist in diagnosing an allergy to bone cement, two different testing methods are routinely utilized: LTT, which assesses lymphocyte reactivity when exposed to bone cement components, and patch testing, which detects dermatitis by evaluating skin reactions to contact allergens. In our series, we did not use LTT because skin tests had been positive in



Figure 1. Preoperative AP radiography of patient 2.

all patients. Even though we have to notice that the validity of patch testing has been criticized for over diagnosing hypersensitivity reactions, it has been demonstrated that there is a lack of correlation between LTT reactivity and an immune reaction [13].

In patients allergic to cement, an additional challenge is achieving both primary and long-term fixation without using it. Various strategies have been employed to address this.

Pahlavan et al [9] revised the prostheses of four patients with allergies to cement using custom-made, cementless implants. Clinical improvement was observed, although two of the four patients continued to experience long-term symptoms. Kaplan et al [4] treated a patient with a confirmed allergy before primary surgery using porous, cementless components, achieving good results.

In the case series of Bircher et al [14], two patients underwent revision total knee arthroplasty (TKA) after being diagnosed with an allergy to benzoyl peroxide, a polymerization initiator in PMMA cement. They received non-cemented Natural-Knee® II System (Zimmer) components, with favorable outcomes at five and three years of follow-up, respectively. Similarly, Edwards reported a case of revision surgery in a patient with benzoyl peroxide allergy, who showed good results three months after receiving a cementless prosthesis [15].

Logoluso et al used custom implants for revision TKA in a patient allergic to both methyl methacrylate and cobalt, reporting good outcomes in Patient Reported Outcome Measures (PROMs) after one year of follow-up [16]. Additionally, in a review by Whiteside, six out of 28 patients (patients 3, 5, 18, 19, 20, and 21) had PMMA allergies, with five of them also diagnosed with metal allergies. The patient with only a PMMA allergy underwent revision surgery with cementless implants and showed good clinical results after seven years. Among the patients with both cement and metal allergies, only one underwent revision surgery, experiencing mild joint effusion and slight functional loss three years postoperatively. The remaining four patients declined further surgery and continued to experience knee pain and swelling [17].

A key challenge in rTKA is obtaining stable and durable prosthetic fixation. Morgan-Jones et al [18] described three fixation zones in revision surgery: 1) epiphysis, 2) metaphysis, and 3) diaphysis. Historically, bone grafts and cement have been used for epiphyseal fixation, and stems, with or without cement, for diaphyseal fixation. In recent years, there has been a



Figure 2. Preoperative lateral radiography of patient 2.

growing interest in the metaphyseal area to obtain implant stability in revision knee surgery. Porous-coated titanium metaphyseal sleeves, either isolated or combined with stems, have shown good mid- and long-term results.

A systematic review evaluated the use of metaphyseal sleeves in revision total knee arthroplasty, including both prospective and retrospective studies with a minimum follow-up of two years. The results showed significant improvements in both functional and clinical outcomes, with a reoperation rate of 16.2 %, an overall survival rate of 92.2 %, and an aseptic survival rate of 98.2 %. The authors concluded that metaphyseal sleeves are a good treatment option, achieving good intraoperative stability and rapid osseointegration [19].

In prospective studies with follow-up periods longer than 5 years, clinical improvement was observed, with aseptic loosening rates ranging from 0 % [20] to 6.7 % [21].

To avoid cementation and based on our previous experience [10], we opted for metaphyseal sleeves in four patients with cement allergies. As various studies have demonstrated the feasibility of using isolated cementless metaphyseal sleeves for stable fixation in knee revisions, even in AORI IIA [22] and IIB defects [11], in one of the cases sleeves were used alone. In three of them, where bone quality was considered poor, they were used in combination with stems.

Compared to the studies mentioned, our patients underwent revision surgery within a shorter mean time from the primary procedure, approximately one year. The rapid exclusion of infection and early diagnosis of cement allergy likely facilitated the revision surgery, as none of our patients presented femoral or tibial bone defects on preoperative X-rays. However, if bone defects are present at the time of diagnosis, we believe metaphyseal sleeves remain a strong option for revision surgery in patients with bone cement allergies.

We found no additional evidence in English, French, or Spanish regarding revision TKA in patients with PMMA allergies. To our knowledge, this is the first published case series using cementless metaphyseal sleeves in patients with confirmed bone cement allergy and minimal bone defects, with a mean follow-up over five years. Our experience supports the use of metaphyseal sleeves as a reliable cementless alternative in these cases.

The limitations of this study are that it is retrospective, includes a small number of patients, and all of them had AORI type I bone defects.



Figure 3. Postoperative AP radiography of patient 2, 75 months after rTKA.



Figure 4. Postoperative lateral radiography of patient 2, 75 months after rTKA.

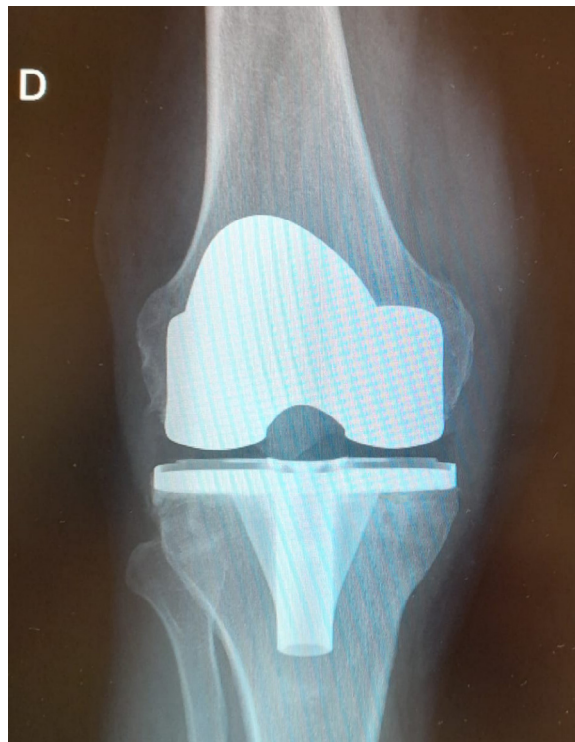


Figure 5. Preoperative AP radiography of patient 1.



Figure 6. Postoperative AP radiography of patient 1 after rTKA with metaphyseal sleeve and diaphyseal stem, 83 months after rTKA.

4. Summary

After ruling out common causes of knee pain, effusion, swelling, and implant loosening after surgery, hypersensitivity to prosthetic components should be considered. Skin hypersensitivity tests are not routinely performed; they are only conducted in cases where the patient has a history of allergy to any of the components of prosthetic surgery or when postoperative symptoms suggest a suspicion of allergy.; therefore, a thorough personal and family history of exposure is crucial before both primary and revision TKA. In this case series of four patients with bone cement allergy diagnosed via skin patch testing (three to PMMA, one to benzoyl peroxide), cementless metaphyseal sleeves and diaphyseal stems fixation resulted in 100 % implant survival at a mean follow-up of 71.2 months, with improvements in symptoms and ROM. We conclude that titanium metaphyseal sleeves are a valuable alternative to achieve implant fixation in rTKA for patients with hypersensitivity to bone cement.

This study is unfunded. The authors declare that they have no known financial interests or relationships that could have influenced the work reported in this article.

CRediT authorship contribution statement

Juan Segura-Nuez: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Julián Carlos Segura-Nuez:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **María Belén Castaño-Doste:** Visualization, Supervision, Methodology, Conceptualization. **Adrián Roche-Albero:** Supervision, Methodology, Conceptualization. **Carlos Martín-Hernández:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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