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Case Report

Revision of a Fractured Titanium Modular Revision Hip Stem Without Removal of the Well-Fixed Part of the Stem: A New Approach Using a Cemented Tube

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ABSTRACT

Component fracture is a rare cause for revision in total hip arthroplasty. For a fractured well-fixed long femoral stem, the options are limited. We sought to develop a technique to address this problem with lower morbidity. A newly developed cemented tube was constructed and cemented onto a fractured Revitan revision hip femoral stem to retain the distal well-fixed component. At the 2-year follow-up, the Harris Hip Score, pain level, and radiographic images were analyzed. At the 2-year follow-up, no radiological signs of loosening or failure could be observed. The patient's preoperative Harris Hip Score improved from 42.8 to 97 points. The pain level improved from 7/10 to 0/10. Our case report depicts excellent clinical and radiographic outcomes at 2-year follow-up by a newly developed cemented tube technique. This technique is a potential new option for revision of fractured well-fixed diaphyseal stems without major bone loss. Our successful results suggest this technique is worthy of consideration and further study.

Introduction

The implant failure rate after total hip arthroplasty (THA) is not defined and could include multiple failure mechanisms [1]. However, besides some case series, the overall implant failure rate is reported as 0.23%-0.27% [2–4]. Predisposing factors are patient specific, such as excessive weight or high levels of physical activity, or not patient specific, such as deficient osseous integration or malposition of the stem and stress riser [5]. Improvements of implants by the use of cobalt-chromium-molybdenum or titanium alloys have helped to reduce the failure rate [6–9]. The introduction of modularity to revision arthroplasty has helped the development of patient-specific solutions in cases of major bone loss and revision surgery by means of semi–custom-made modularity, but it is also reported to have raised failure rates up to 1.4% [8,10,11]. Few operative strategies for the management of modular arthroplasty implant failure have been published. One option is the retrograde punchout and the implantation of a single solid shaft [12]. Other options for periprosthetic fractures or implant failures are the implantation of megaprostheses such as proximal or total femur replacement, which are associated with high complication rates [13].

We describe a case of a fractured modular Revitan® revision stem (Zimmer GmbH, Winterthur, Switzerland). A proximal component (available in cylindrical and spout shapes in different lengths) is connected to a shaft component (available in straight and curved forms in different sizes) via a Morse taper junction [8]. The proximal and distal components are manufactured from titanium-niobium alloy ($TiAl_6Nb_7$) to allow bone ongrowth, and the taper is made of forged cobalt chromium (CoCr) alloy, which is stronger than other materials such as titanium alloy [8,12,14,15].

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Because of the poor femoral bone quality at the metaphyseal and diaphyseal area (Paprosky Type IV, isthmus cortical thickness: 2.5 mm) and the associated higher risk for periprosthetic fractures and further bone loss, we decided to leave the well-fixed part of the stem in place [16–18].

Preoperative discussion with the manufacturer gave only the option of explantation of the stem and reimplantation of a longer, thicker stem. We therefore developed a novel cemented tube to connect the well-fixed distal stem to a new proximal component.

The purpose of this article is to report the 2-year functional and radiological results of a 69-year-old male patient with a femoral stem fracture after connecting the well-fixed part of the broken stem to a new proximal component using a cemented connecting tube.

Case history

An active 69-year-old hunter, who regularly climbed a raised blind, presented to our clinic in 2016 with increasing left hip pain that was interfering with his quality of life. His walking distance was restricted to 50 m, and he was holding a crutch with the contralateral hand.

The patient reported that he had been in a high-energy car accident more than 40 years ago (in 1975). Among other injuries, he suffered a dashboard injury with posterior hip dislocation that was treated conservatively with a closed reduction. Treatment of the relevant side was performed in an external clinic in 2001. Four years later (in 2005), the patient had his first revision for aseptic loosening of the left femoral stem. A second revision surgery for aseptic loosening of the left cup and stem was performed 3 years later (2008). A cementless Allofit S cup (Zimmer, Sulzer Orthopedics Ltd., Baar, Switzerland) and a cementless Revitan shaft (cylindrical proximal component: 95 mm, 200-mm shaft, 32 cobalt-chromium head XL, Zimmer, Sulzer Orthopedics Ltd.) were implanted. All procedures had been performed in an external clinic. No medical records were available for further clarification.

After a pain-free period of 8 years, the patient presented for the first time in our outpatient clinic with severe left hip pain (7/10 on the visual analogue scale [VAS]) despite opioid and nonopioid pain medication taken every day for the last 3 months. The range of motion was limited (fixed flexion: 10°, flexion: 95°, external rotation: 0°, internal rotation 5°, abduction and adduction: 20°). A limb length discrepancy of 2 cm (left shorter than right) and a partial lesion of the peroneal nerve were recorded. The Harris Hip Score (HHS) was 42.8.

Preoperative infection workup

At first, a chronic infection was ruled out by erythrocyte sedimentation rate and C-reactive protein measurement and hip aspiration. Preoperatively, the white blood cell count was 84,000/μL, and the C-reactive protein was 3.3 mg/L. We used intraoperative and postoperative microbial probes to further rule out infection. Diagnosis was based on international consensus for the diagnosis of periprosthetic infection [19]. No signs of metallosis were observed.

Preoperative workup

A careful analysis of the anteroposterior radiograph of the left hip led to the suspicion of a failure of the femoral stem at the

Figure 1. Radiograph of the left femur shaft. (a) Initial presentation in our outpatient clinic with hip pain after revision THA in 2008. (b) After the analysis, we diagnosed an implant failure and assigned the patient for revision surgery. On conventional radiograph, we saw a broken Revitan shaft at the connection point between both modular components. (c) Postoperative radiograph showing the left femur shaft component with the added Endo-CAST and the replaced proximal femur component. Bone components of the osteotomy were fixed using a cerclage wire. An angulated head was used to reduce offset due to the bulkiness of the implants and to maintain length for stability. (d) At the 2-y follow-up, no displacement of the components could be observed. Further osseous integration can be observed.

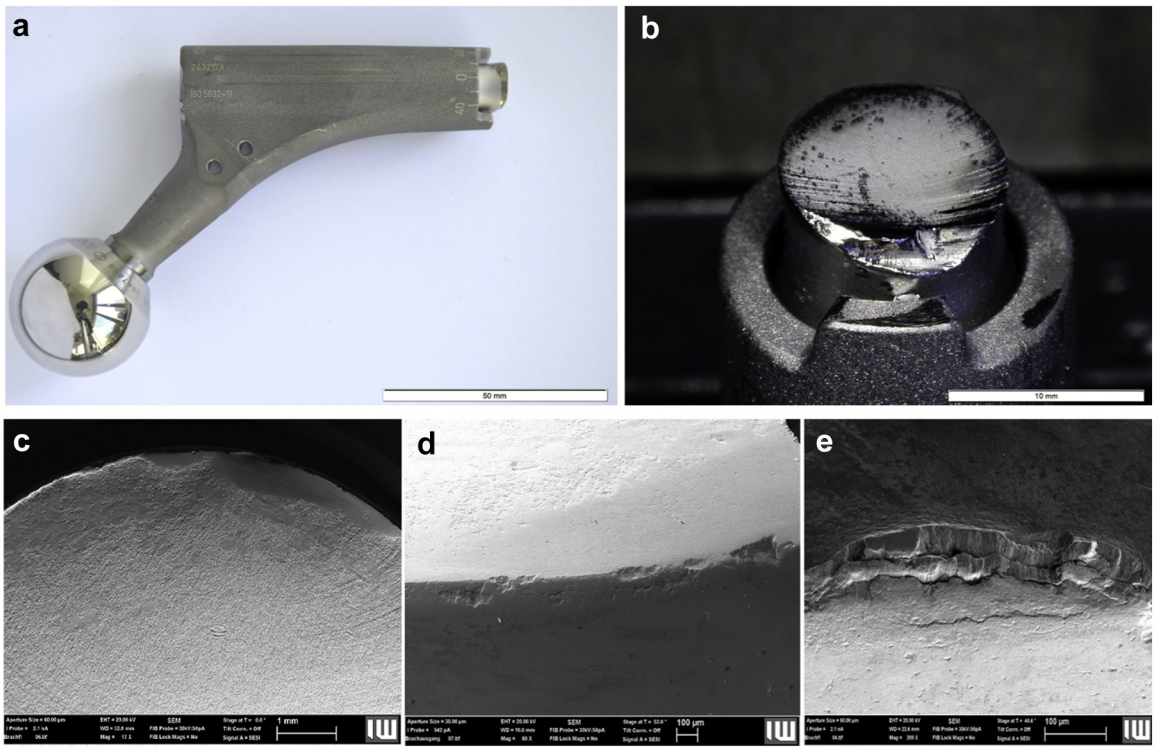

Figure 2. Intraoperative images of the broken components. (a) Overview of the broken prosthesis. Scale bar: 50 mm. (b) The origin of fracture is on the side of the prosthesis with the largest tension force. Scale bar: 10 mm. (c) Scanning electron microscopy: The failure started from superficial damage to the cylindrical part of the shaft. On the upper part of the image, the surface is very smooth. Further down, a rougher surface can be seen as a sign of the line of rest. Scale bar: 1 mm. (d) Superficial damage, possibly the result of iatrogenic damage, can be seen. Scale bar: 100 µm. (e) Further magnification of the surface. Scale bar: 100 µm.

docking side (Fig. 1). A computed tomography scan of the hip confirmed the suspected diagnosis and furthermore showed limited bone stock at the diaphyseal and metaphyseal regions (Paprosky Type IV). Because of the poor results associated with a nonsupportive isthmus and the high risk for periprosthetic fracture (cortical thickness: 2.5 mm), we considered leaving the well-fixed shaft component in situ and using a cemented tube (Endoprosthetic Cement Augmented Shaft Tube [Endo-CAST], K-Implant, Garbsen, Germany), to connect the well-fixed shaft component to a new proximal component. The custom-made cylindrical component was designed after thorough analysis of the geometrical particularities of the proximal part of the Revitan stem so it could be

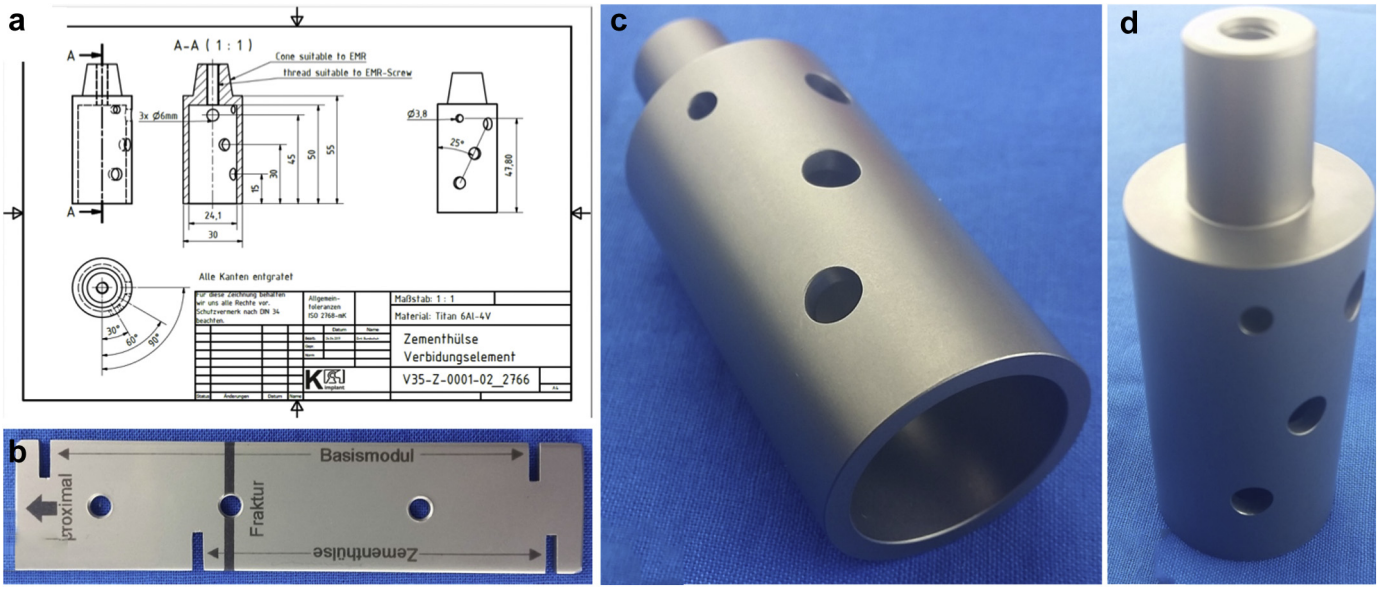

Figure 3. Preoperative planning of the new Endo-CAST. (a) Overview of the planning of the Endo-CAST by K-Implant. (b) Further development of individualized resection tool. (c) Inferolateral view of the Endo-CAST. The bottom insert of the shaft component is visible. Holes for cement application for rotational stability or potential screw fixation can be seen, as shown in the drawing in panel a. (d) View of the Endo-CAST. The top insertion tube for connection with the head component and screw fixation can be seen.

placed over the stem during surgery (Figs. 1 and 3). A preoperatively constructed scale bar was also custom fabricated for femur osteotomy to remove the proximal part of the prosthesis (Fig. 3b).

The Endo-CAST was purchased from K-Implant® and fabricated of titanium alloy (Ti_6Al_4V), with an inner diameter of 24.1 mm and an outer diameter of 30 mm. It fit on the well-fixed stem with a cone suitable to the proximal EMR component. Implant-specific information on the EMR component was purchased from K-Implant® too. A cement layer between the stem and tube for a length of 5 cm was planned to ensure safe screw insertion for the proximal component and adequate distal stem fixation without major bone loss. Three systematically distributed holes of 6 mm diameter were placed at 30°, 60°, and 90° angulation every 15 mm for cement application, to give rotational stability. Owing to the urging situation with the patient's increasing pain, no prior biomechanical or finite-model study was performed. However, biomechanical calculation and new segment design were performed by a well-experienced graduated biomechanical engineer. As the proximal shape of the cemented tube was designed to fit the EMR component, no further stress on the modular junction was expected.

Patients' permission for publication was obtained. Permission to guidelines concerning medical devices, that is, the German Act on Medical Devices (MPG), was obtained (ISO 2768-mK) (V35-Z-0001-02_2766).

Surgical technique (video)

Revision surgery was performed with general anesthesia in the right lateral decubitus position. A posterior approach to the hip was performed. A partial release of the gluteus maximus tendon was performed to reduce the tension of the sciatic nerve [20]. After dislocation, the loose proximal component and the old trunnion were removed by hand. Next, the preoperatively constructed scale bar was fixed over a central hole with a K-wire at the site of the implant fracture (Fig. 3b). The distal and proximal marks on the constructed scale bar depicted the proximal and distal parts of the tube for length referencing of the osteotomy. By thermocoagulation, the proximal and distal osteotomies were marked. By performing the distal circumferential osteotomy at this distal mark, we ensured a cement layer between the stem and tube for a length of 5 cm. The proximal and distal transverse osteotomies were performed at the previously marked sites over the whole circumference of the femur, as in a subtrochanteric femoral shortening osteotomy—in this case, without shortening, but by reinsertion of both sided cortical bone fragments after insertion of the cemented Endo-CAST (Fig. 1c). This was performed to create a space to allow implantation of the tube.

Afterward, the cemented tube was slid and fixed onto the distal shaft component using bone cement (Biomet Optipac 2 × 40 g). An interim screw was placed in the tube to protect the threads to be used for later fixation of the proximal component (EMR, 68 mm, K-Implant GmbH). Cement was then inserted at the outer surface of the tube, and the osteotomy was closed using cerclage wires. The interim screw was removed, and the proximal component was then fixed at the appropriate anteversion by inserting a definite screw into the tube. After performing trial reductions with various heads, we decided to use a metal XL-10° angled head 32 (K-Implant GmbH, Garbsen, Germany). The angle was used to achieve an equal limb length without increasing the femoral offset, which could cause irritation of the soft tissue because of the bulkiness of the implants. Rotational stability of the Endo-CAST was achieved (1) by the holes that were created in different angles on the tube and (2) by the polyhedral shape of the Revitan stem (Fig. 1). Wound closure was performed as usual. Total operation time was 217 minutes. Total blood loss was 300 ml. Postoperative full weight-bearing was allowed.

The extracted implant was analyzed at the Institute of Material Science, Leibniz University of Hanover.

Outcome

At the 2-year follow-up after the revision surgery, no radiological signs of loosening or failure of the novel cemented tube were observed. No signs indicating further revision surgery were observed (Fig. 1).

The patient's preoperative HHS improved from 42.8 to 97 points. Pain improved from 7/10 on the VAS to 0/10 without the use of any painkillers. Walking on uneven ground was pain free without crutches and without the Trendelenburg sign. Scanning electron microscopy of the failure side of the original implant was performed and showed an oscillating break (Fig. 2).

Discussion

Failure of the modular junction after THA is a rare, challenging situation and is often associated with reduced postoperative functional outcome. Patient-specific reasons known to raise the risk for implant failure are high activity levels, bilateral hip disease, increased height and weight, lumbar spine disease, and, as in our patient, the presence of bilateral THA [5,12]. Implant-associated factors are poor osseous integration, malposition of the stem and stress riser, fretting or crevice corrosion especially at the modular junction, improper material selection, and manufacturing defects, all of which lead to increased stress [5,10,12,21,22]. Furthermore, modular systems seem to raise the risk for corrosion of the taper and higher revision rates [12,23]. The risk of implant failure rises with higher bending moments caused by higher loading forces or larger lever arms. This leads to increased cantilever bending because of a well-fixed distal stem and a loose component proximal to the junction [3]. Scanning electron microscopy was performed at the failure side and showed an oscillating break similar to a fatigue break initiated by an indentation in the prosthesis [23]. Nasr et al. [12] stated that the reasons for implant failure are intrinsic to the implant design, which concentrates the stress on the narrow taper. For this reason, we thought about alternative surgical options that would stabilize the implant fracture.

The prevailing trend in cemented primary hip arthroplasty is the "taper slip concept" using highly polished surfaced steel alloy stems [24]. The stem is allowed to subside and lodged as a wedge [24]. This concept has shown good in vivo long-time survival rates. Despite this, the "composite beam concept" with, for instance, a rough titanium alloy (Ti_6Al_4V) with bone cement, has shown good results in several situations. Reasons are the biocompatibility of titanium alloys with its high resistance to fatigue and corrosion [24]. However, once the stem debonds at the interface, the stress within the cement increases, and this leads to mechanic failure of the cement mantle and subsequent femoral loosening [24]. Nevertheless, at both the femoral [24] and acetabular sides [25], with superior interface strength [26], the combination of titanium alloy and bone cement has proven to have excellent stability, in in vitro models. In 2013, Citak et al. [27] described for interprosthetic fracture an interposition prosthesis that can be attached to both sides of the prosthesis by cement augmentation using interprosthetic femoral sleeves in case of revision surgery (Waldemar Link, Hamburg, Germany). It is made of cobalt-chromium-molybdenum alloy, and the double-ended 2-piece sleeves are cemented to the prosthetic end and connected with screws [27,28]. Full weight-bearing is possible postoperatively, and good results with a survivorship of 4.6 years were observed, with a mean HHS of

69.9 points [28]. However, the complication rate was 47.8%, with a mechanical failure rate of 21.7% [28]. The complication rate and functional outcome were better than is typical after total femur replacement, which would be the alternative therapeutic option in those cases [13].

Patel et al. [11] described a reconstruction technique using a custom-made mega-prosthesis, which is cemented to the femoral stem and made of titanium alloy (Ti_6Al_4V) (Stanmore Implants Worldwide, Stanmore, UK). It has longitudinal grooves designed to resist both pull-out and torsional forces. The survival rate was 93.3% at a mean follow-up of 5.3 years. The mean postoperative Musculoskeletal Tumor Society score was 22.6 (range: 15-28) [29].

One major limitation is that we could observe only one patient treated with this Endo-CAST. However, treatment with the new connection device was successful, with the patient showing excellent clinical function at the 2-year follow-up. One minor limitation is that it can hardly be a general solution, as an individual custom-made device must be constructed in each unique case of implant failure.

The goal was to leave the stable stem component in place because of the patient's poor bone quality. One common problem with stem removal is good osseous integration, which makes it difficult to remove the stem without suitable removal instrumentation. Consequently, unsatisfying compromises, such as extended trochanteric osteotomy or retrograde punchout with femoral cortical bone loss, must be found [12,30]. Alternative options for our patient would have been at least proximal or total femur replacement. Both have shown good results in initial surgery, for instance, after tumor resection, but are associated with high complication and infection rates—up to 50% in case of revision surgery [13]. The goal of leaving the stem in situ necessitates proper fallback options and excellent preoperative planning, taking removal of the shaft component into consideration [22]. We therefore considered a new connection device, the Endo-CAST, which gave us the option of attaching a new proximal modular component to the shaft component with the help of bone cement without any significant bone loss. As described by Stronach et al., bone loss is a major problem and we have presented an alternative option that avoids large loss of the bone such as that which occurs in trochanteric osteotomy. Furthermore, soft-tissue complications such as loss of muscle function due to lost insertion points at the endoprosthesis can be avoided.

We observed excellent clinical function as measured by the HHS of 97 points. Reference values in the literature range from 42 to 95 points [31]. The reduction of preoperative pain of 7/10 on the VAS to 0/10 without the use of any analgesic is also an excellent result. Owing to the preservation of the greater trochanter, we did not observe any sign of Trendelenburg, and walking was therefore as pain free as possible without a crutch.

Summary

The Endo-CAST is a new option for treating implant failure at the proximal femur. It offers excellent clinical short-term outcome 2 years postoperatively without major bone loss and without the need to implant a mega-endoprosthesis.

Conflict of interest

The authors declare there are no conflicts of interest.

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Supplementary Data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.artd.2020.04.018.

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