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Revision of Ceramic Hip Replacements for Fracture of a Ceramic Component

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Revision of a total hip arthroplasty due to fracture of a ceramic component is rare. The fracture rate of ceramic components has been reported to be between 0.004%[1] and 0.05%[2] for femoral heads and between 0.013%[2] and 1.1%[3] for acetabular liners. Nevertheless, this problem is occurring more frequently because of the increasing use of ceramic total hip replacements.

Revision arthroplasty performed because of a fractured ceramic component carries a high risk of failure: the fragments of the failed component are sharp and harder than metal; if left in the articular space, these fragments would act as an abrasive paste, and the use of a metal head against a polyethylene liner in the revision arthroplasty would quickly lead to catastrophic wear and failure of these new total hip implants[4-6] (Fig. 1). Thus, revision arthroplasty performed because of a fractured ceramic component is difficult and the failure rate has been reported to be as high as 31%[6].

The aims of the present study were to evaluate the outcome of revision total hip arthroplasty performed specifically to treat fracture of a ceramic component, to identify technical factors affecting the outcome, to propose some tips and tricks to make the process of revising a total hip arthroplasty for this reason easier, and to suggest guidelines for the treatment of a ceramic component fracture.

Nineteen Years of Experience with Modern Ceramic Hip Prostheses

From 1990 to 2009, 8022 primary ceramic hip prostheses were implanted at our institute; 3275 (40.8%) were in men and 4747 (59.2%) were in women. Additional patient demographic information is given in Table I. Kaplan-Meier curves with revision for ceramic fracture as the end point were computed to evaluate the rate of ceramic fracture. The analysis was performed with use of SPSS software (SPSS, Chicago, Illinois). Forty (0.5%) of the 8022 ceramic-on-ceramic prostheses failed because of fracture of a ceramic component. The estimated survival rate at eighteen years with component fracture as the end point was 98.8% (95% confidence interval, 98.4% to 99.2%). The implant failure involved fracture of the ceramic femoral head in sixteen patients (Table II) and fracture of the ceramic acetabular liner in twenty-four patients (Table III). Fifteen of the sixteen ceramic heads that fractured were 28 mm in diameter and were designed to accept a short neck taper (Table IV). None of the fractured femoral heads was composed of BIOLOX *delta* (CeramTec, Plochingen, Germany) (Table II), although two of the twenty-four fractured liners were composed of this ceramic (Table III).

Hips with a fractured ceramic component were revised with a new ceramic-on-ceramic coupling in thirty patients (mean, 3.3 years of follow-up; range, one to fourteen years); with a ceramic-on-polyethylene coupling in two patients (mean, 7.5 years of follow-up; range, four to eleven years); and with a metal-on-polyethylene coupling in eight patients (mean, 6.1 years of follow-up; range, four to nine years).

No osteolysis or radiographic signs of failure were detected at the time of the latest follow-up in the hips revised with either a ceramic-on-ceramic or a ceramic-on-polyethylene coupling. Both of the patients who had received a ceramic-on-polyethylene coupling had good clinical results at that time, whereas two

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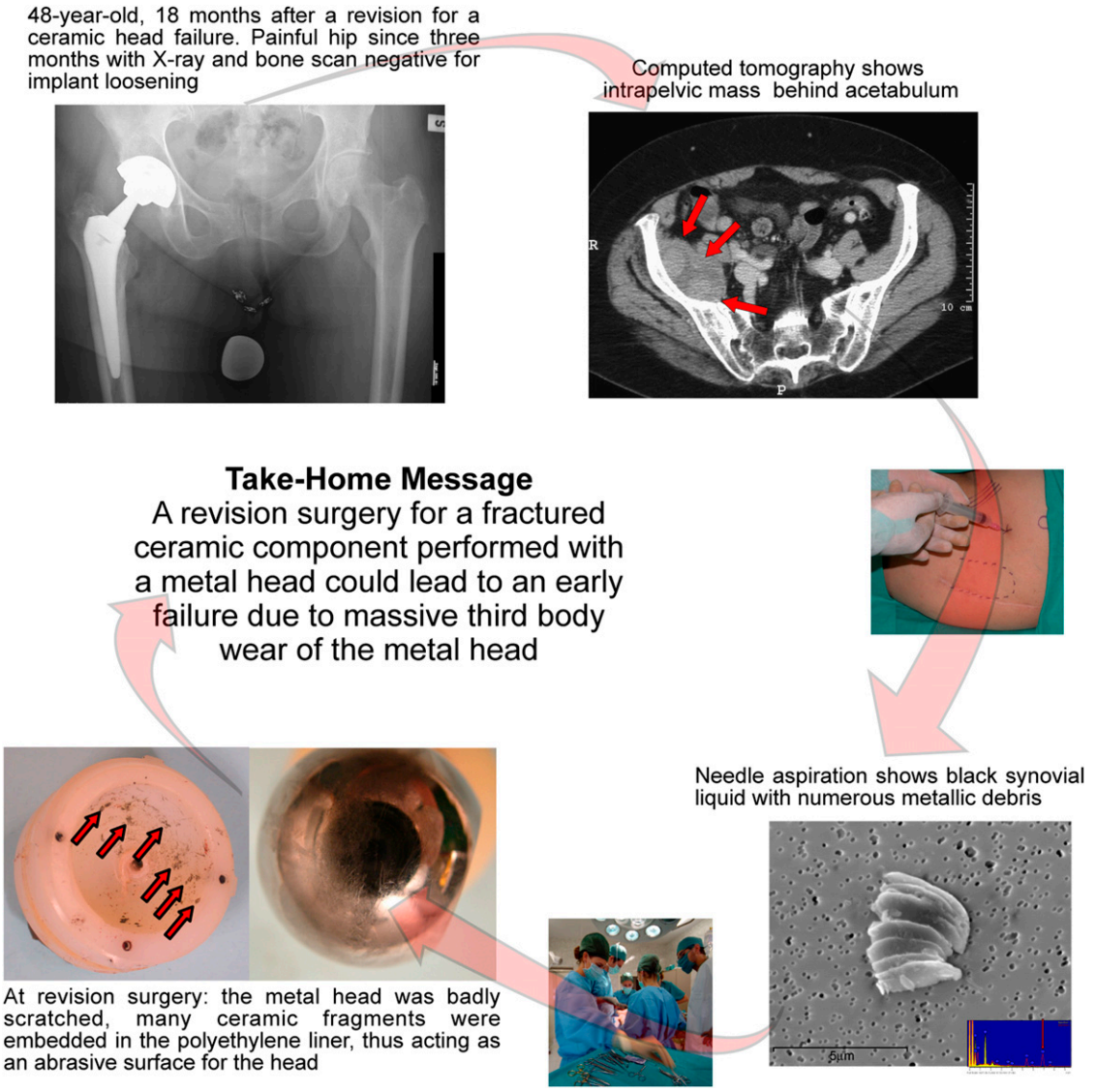

Fig. 1

Early failure of a revision arthroplasty performed because of fracture of a ceramic femoral head.

(7%) of the thirty patients who had received a new ceramic-on-ceramic coupling reported mild pain and limped during ambulation. One of the eight patients who had received a metal-on-polyethylene coupling underwent repeat revision because of massive polyethylene wear and osteolysis, six of the patients had radiographic signs of polyethylene wear and osteolysis and had poor clinical results at the time of the latest follow-up, and the remaining patient had good clinical and radiographic results at that time.

Revision Due to a Ceramic Head Fracture

Fracture of a modern ceramic femoral head can be a consequence of trauma, dislocation, or mishandling[7,8]. The most common types of mishandling involve a mismatch between the design of the head and the metal neck taper, a strong impact on the ceramic head with the hammer, use of a hard (e.g., metal) instrument to impact the head, debris (e.g., blood or fat) entrapped between the head and the metal neck taper, and intraoperative damage to the metal neck taper. Clinically, fracture of a ceramic head manifests itself to the patient in a sudden and dramatic fashion. The hip function is completely impaired, and the patient reports hip noise (crunching) and pain that occurs even at rest. Treatment of the ceramic head fracture must be considered as an emergency. Radiographic diagnosis is almost always straightforward, with large ceramic fragments usually clearly visible.

Once the diagnosis has been established, the limb is immobilized and the patient remains lying down to avoid spread of the ceramic particles and further damage to the neck taper. Fracture of a ceramic femoral head usually produces some large fragments and many fragments of microscopic size. These fragments will be dispersed in the soft tissues about the

TABLE I Demographics of the Study Population

	%
Preoperative diagnosis	
Primary osteoarthritis	55.5
Developmental dysplasia of the hip	18.9
Trauma or sequelae of trauma	10.7
Osteonecrosis	7.3
Rheumatoid arthritis	3.5
Other	4.1
Age in yr	
<40	9.6
40-49	14.7
50-59	21.9
60-69	29.6
70-79	20.4
≥80	3.7

hip, and they should be washed out with extensive joint lavage and removed through an extensive synovectomy. Despite a meticulous operative procedure, however, small ceramic particles will always remain and can lead to third-body wear of a metal replacement femoral head[4,5,9].

It is preferable to replace the fractured ceramic femoral head with a new ceramic head, since this avoids the abrasive effect of the third-body ceramic particles on the surface (because they have the same hardness as the new femoral head). Ceramic heads designed specifically for revision arthroplasty are available (BIOLOX OPTION; CeramTec); these have a modular design consisting of a BIOLOX *delta* ceramic head and a metal sleeve that can be placed over the original metal neck taper to create a smooth surface. Despite the availability of this implant designed to permit reuse of the femoral stem, the damage to the femoral neck taper must be assessed prior to a decision to use a new ceramic head[10]. If there is gross damage to the femoral neck taper, revision of the entire femoral component is necessary[8,10,11] (Fig. 2).

Revision Due to a Ceramic Liner Fracture

Fracture of a modern ceramic acetabular liner can be caused by mishandling, malpositioning, trauma, or instability of the implant[12-14]. Mishandling may involve eccentric orientation of the liner relative to the shell during impaction, a strong impact on the liner with a hammer during insertion of the liner into the metal shell of the acetabular component, use of a hard instrument to impact the liner, failure to remove entrapped debris (e.g., blood or fat) from the metal shell, and intraoperative damage to the metal shell taper.

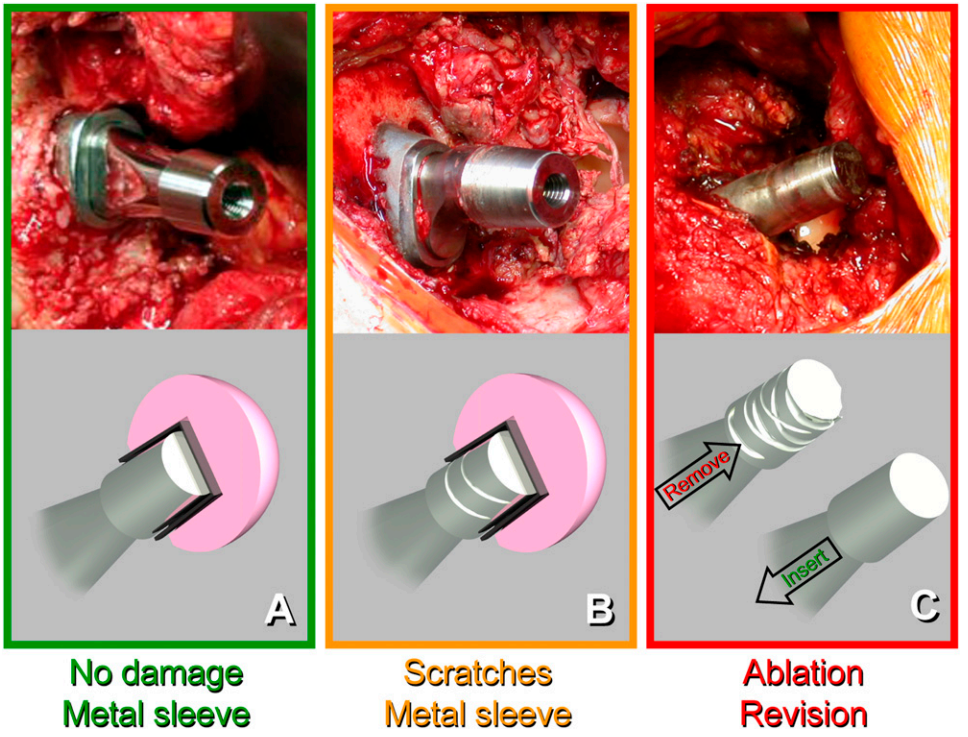

Fig. 2

Evaluation of the neck taper junction of the femoral component and decision-making for revision arthroplasty. A BIOLOX *delta* ceramic head with a metal sleeve can be used if no damage to the neck taper is clearly visible (**Fig. 2-A**) or if scratches are detected but the shape of the neck taper has not been altered (**Fig. 2-B**). If ablation or visible abrasion of the surface of the neck taper is visible (**Fig. 2-C**), revision of the entire femoral component is necessary.

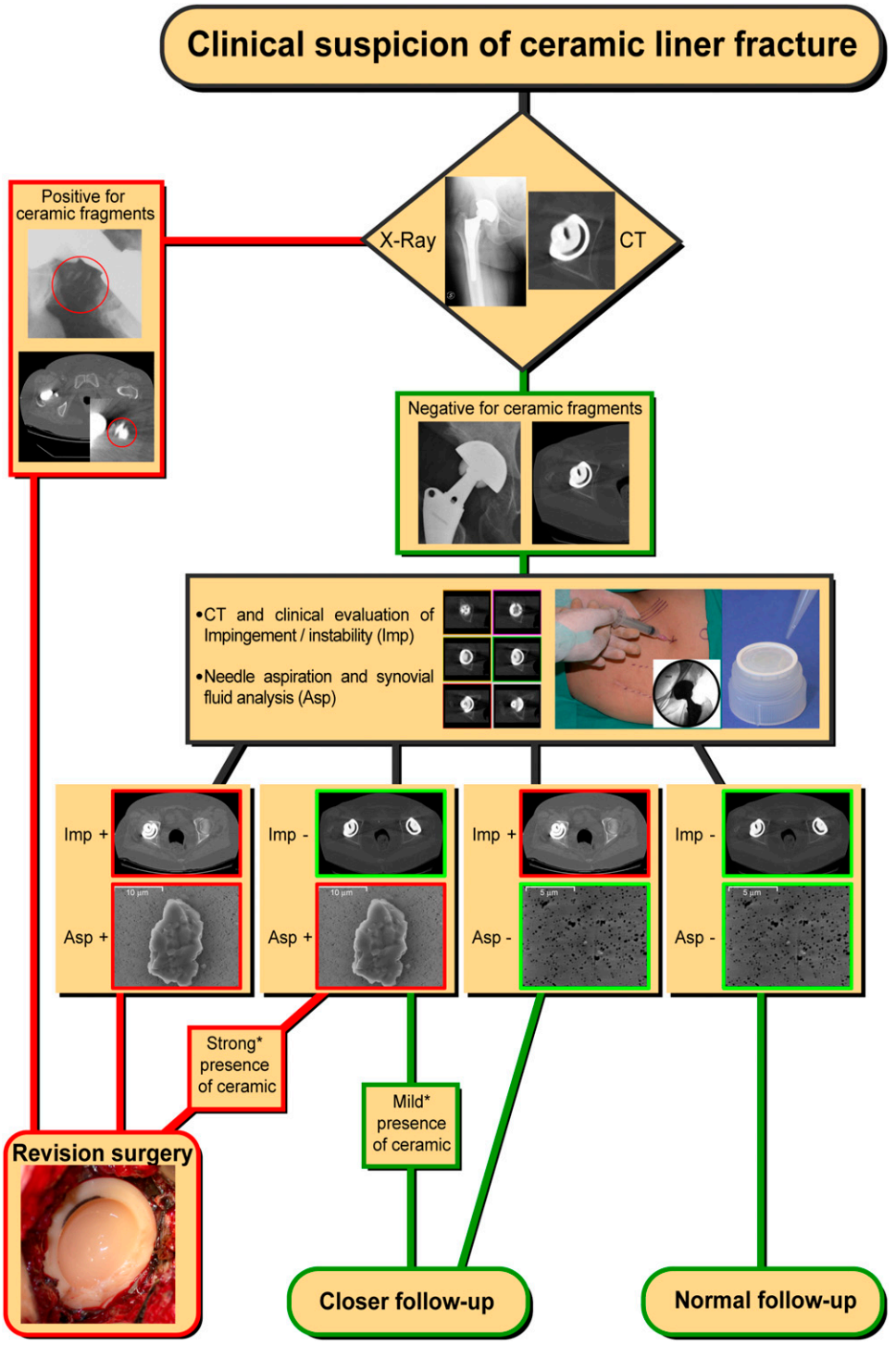

Fig. 3

Algorithm for diagnosis and treatment of a ceramic liner fracture. CT = computed tomography. *See Table V.

The onset of a ceramic liner fracture is usually accompanied by subtle clinical signs and could go undetected[13,15]. The first clinical sign reported to the clinician is usually hip noise[12,13]. Computed tomography (CT) scanning of the pelvis and fine needle aspiration of the hip are advisable if a ceramic liner fracture is suspected. If malpositioning of the acetabular component is observed and ceramic fragments larger than 3 μm are detected in the synovial fluid sample, revision arthroplasty is advisable[12,13,16] (Fig. 3 and Table V).

Once the diagnosis of ceramic liner fracture has been established, the patient must avoid weight-bearing on the involved hip prior to revision arthroplasty in order to prevent

TABLE II Femoral Head Fractures According to Ceramic Composition

	BIOLOX		BIOLOX *Forte*			BIOLOX *Delta*		
	28 mm	32 mm	28 mm	32 mm	36 mm	28 mm	32 mm	36 mm
No. of hips	648	572	3808	1484	767	4	276	463
No. of fractures	5	0	10	1	0	0	0	0
%	0.8	0	0.3	0.07	0	0	0	0

further propagation of the ceramic fracture and dissemination of ceramic particles. As in the case of revision of a fractured ceramic femoral head, profuse joint lavage and an extensive synovectomy are advisable to remove as many ceramic fragments as possible. It is important to remove the damaged ceramic liner without scratching the metal shell of the acetabular component. This is usually possible by tapping the rim of the metal shell to loosen the conical press fit; the ceramic liner can then be removed easily with use of a suction cup instrument or delicate hemostatic forceps. In cases in which the liner remains stuck in the metal shell, the liner can be gently broken inside the shell without dissemination of ceramic fragments.

The liner can be replaced with either a new ceramic liner or a highly crosslinked polyethylene liner; this decision must take into account the damage to the metal shell (Fig. 4) and the stability of the implant. The best choice if a ceramic liner is used is to use a large ceramic head if possible, and the best choice if a highly crosslinked polyethylene liner is used is one with an elevated lip. If the liner fracture resulted from cup malpositioning or if the cup design is monobloc, revision of the entire acetabular component is mandatory[13]. Intraoperative testing of the stability of the revised implant is advisable.

Clinical Case: Revision Due to Fracture of a Ceramic Head

This patient was a fifty-year-old male farmer (body mass index, 33 kg/m^2; Charnley class[17] of the hip, A). Thirty-eight months after primary hip arthroplasty, while sitting in a chair, he suddenly experienced crunching noises and pain in the hip. Radiographs showed a fracture of the ceramic femoral head. The fractured BIOLOX *forte* ceramic femoral head was 28 mm in diameter and was designed to accept a short neck taper. The head was revised to a short BIOLOX OPTION head, and the liner was also revised to a BIOLOX *delta* liner. At the time of the latest follow-up, four years after revision arthroplasty, the

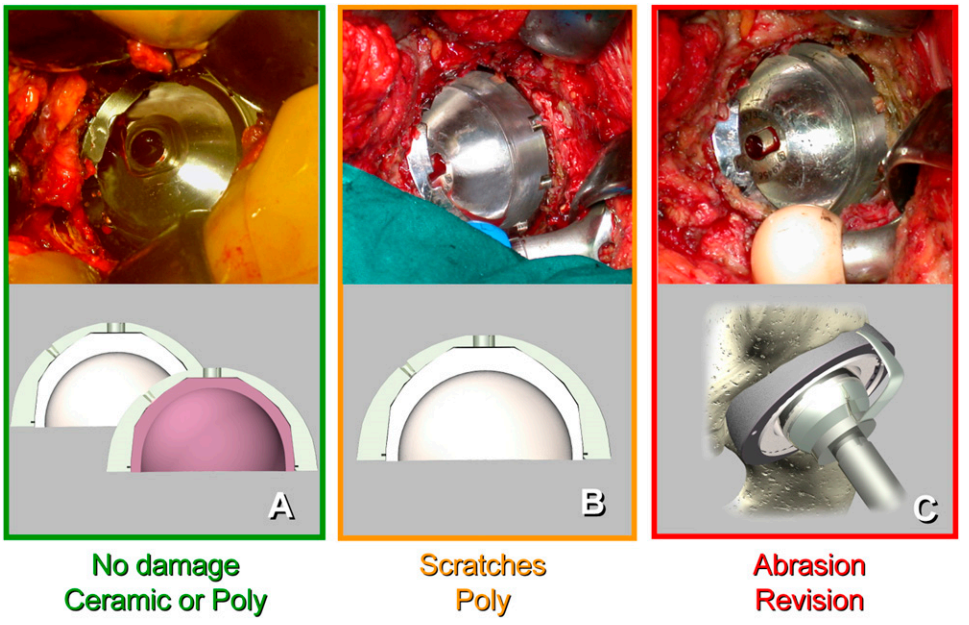

Fig. 4

Evaluation of the taper junction of the metal acetabular shell and decision-making for revision arthroplasty. If no damage to the metal shell is visible (**Fig. 4-A**), a new BIOLOX *delta* ceramic liner is the best choice but a highly crosslinked polyethylene (poly) liner can also be used. If the metal shell is scratched but without gross damage, a highly crosslinked polyethylene liner is the best choice (**Fig. 4-B**). If abrasion of the metal shell is visible (**Fig. 4-C**), revision of the entire acetabular component is necessary.

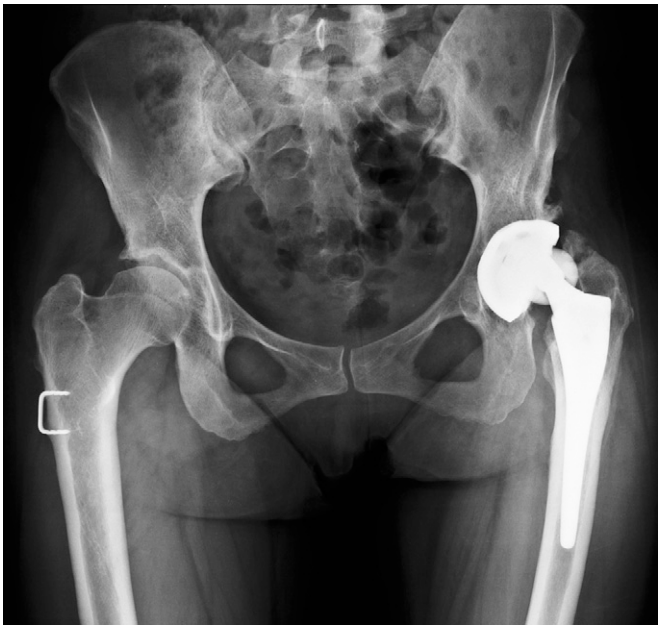

Fig. 5-A

Fig. 5-B

Fig. 5-A Anteroposterior radiograph of the pelvis showing excessive abduction of the acetabular cup in a patient who experienced a ceramic liner fracture.
Fig. 5-B Anteroposterior radiograph of the left hip. After revision of the cup, the bearing surfaces were revised to a new ceramic-on-ceramic articulation. At the time of the latest follow-up, three years after the revision arthroplasty, the implant was stable.

Harris hip score was 89 and the implant appeared stable on radiographs.

Clinical Cases: Revision Due to Fracture of a Ceramic Liner

CASE 1. This patient was an unemployed fifty-eight-year-old woman (body mass index, 36 kg/m^2; Charnley class[17] of the hip, A). She experienced repeated dislocations, which were treated conservatively, after the primary total hip arthroplasty. The last dislocation caused a fracture of the ceramic liner resulting in complete functional impairment. The implant instability had been due to malpositioning of the cup (Fig. 5-A). The BIOLOX *forte* ceramic liner had been implanted in a cup with 60° of abduction and 4° of anteversion. The implant offset was 39 mm, the center of rotation of the total hip replacement was 4 mm higher than the anatomic center of rotation, and the involved limb was 5 mm shorter than the contralateral limb. The liner was revised to a BIOLOX *delta* liner, and the femoral head was also revised to a short 36-mm BIOLOX *delta* head. At the time of the latest follow-up, three years after revision arthroplasty, the Harris hip score was 91 and the implant appeared stable on radiographs with no signs of osteolysis (Fig. 5-B).

CASE 2. This patient was a sixty-three-year-old female teacher (body mass index, 31 kg/m^2; Charnley class of the hip, C). Nine years and eleven months after the primary arthroplasty, she reported clicking in the hip that had begun without accompanying trauma. Radiographs showed a ceramic fragment (Fig. 6-A), and the CT scans showed microseparation of the femoral head from the acetabular liner. The fractured BIOLOX *forte* liner

TABLE III Acetabular Liner Fractures According to Ceramic Composition

	BIOLOX	BIOLOX *Forte*	BIOLOX *Delta*
No. of hips	820	6155	1047
No. of fractures	0	22	2
%	0	0.3	0.2

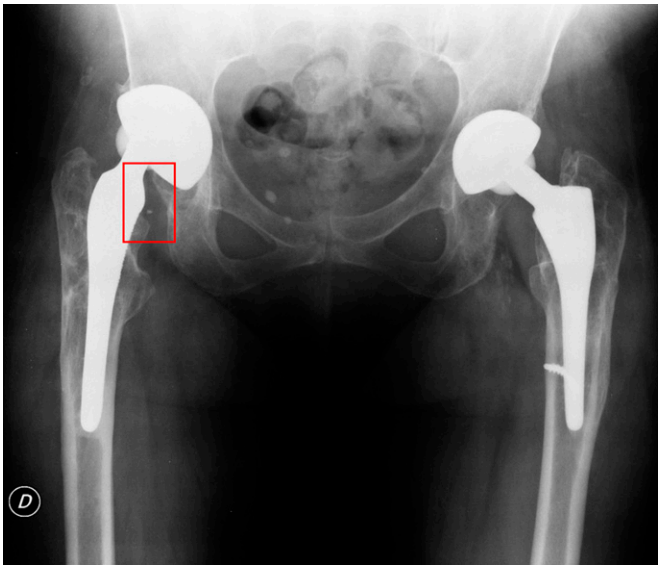

Fig. 6-A

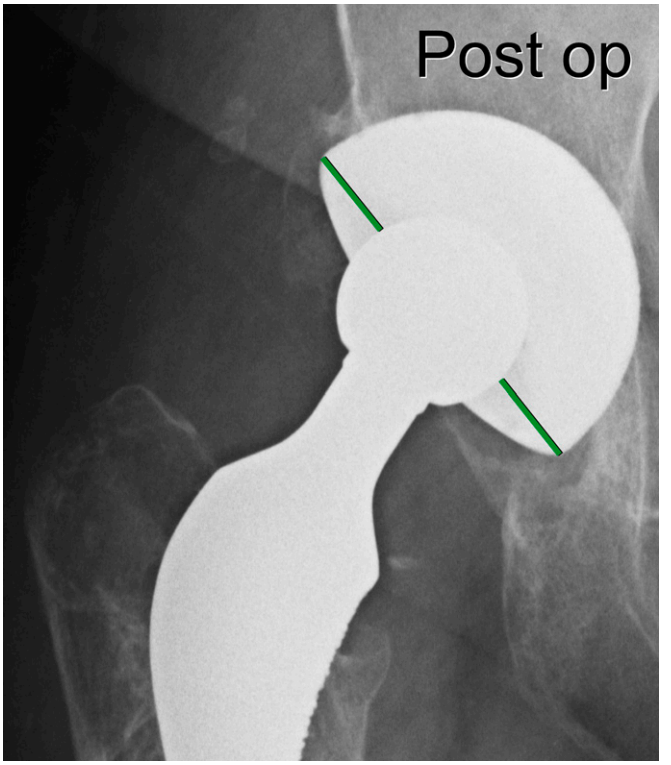

Fig. 6-B

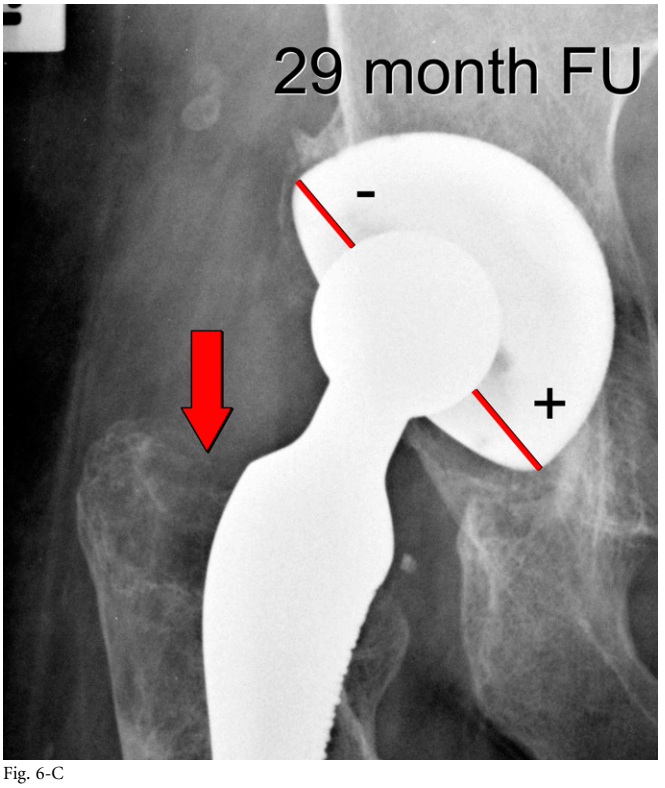

Fig. 6-C

Fig. 6-A Anteroposterior radiograph of the pelvis demonstrating a ceramic liner fracture. Ceramic fragments are visible in the boxed region near the prosthetic femoral neck. **Fig. 6-B** Anteroposterior radiograph of the hip after revision arthroplasty with a metal-on-polyethylene coupling. The green line shows the concentric position of the femoral head in the metal shell. **Fig. 6-C** Anteroposterior radiograph of the hip twenty-nine months after revision arthroplasty. The red line shows the eccentric position of the femoral head in the metal shell. The width of the polyethylene liner has decreased in the superior region because of massive wear. Osteolysis around the greater trochanter (red arrow) has occurred.

had been implanted in a cup with 53° of abduction and 24° of anteversion. The implant offset was 30 mm, the center of rotation was 18 mm higher than the anatomic center of rotation, and the limb was 3 mm longer than the contralateral limb. The fractured liner remained stuck to the metal shell during the revision procedure and was broken inside the shell. The liner

TABLE IV Ceramic Femoral Head Fractures According to Neck Taper Length

	Short	Medium	Long
No. of hips	3506	2936	1580
No. of fractures	15*	0	1†
%	0.4	0	0.06

*28 mm. †32 mm.

TABLE V Ceramic Damage Indicated by Synovial Fluid Analysis

Ceramic Particles/200 μL	Size (*μm*)	Level of Damage
0-5	<3	Physiological
6-10	<3	Mild
>10	<3	Strong
≥1	>3	Strong

was revised to a highly crosslinked polyethylene liner, and the head was also revised to a Metasul head (Zimmer, Warsaw, Indiana) (Fig. 6-B). Twenty-nine months after the revision arthroplasty, the Harris hip score was 63 and massive wear of the liner accompanied by osteolysis of the greater trochanter had occurred (Fig. 6-C). During repeat revision, ceramic fragments were visible in the liner and the femoral head component was seen to be badly scratched. The liner was revised to a BIOLOX *delta* liner and the head was also revised to a medium BIOLOX OPTION head. At the time of the latest follow-up, eleven months after the second revision arthroplasty, the Harris hip score was 85 and the implant appeared stable on radiographs.

The patients were informed that data concerning the case would be submitted for publication, and they consented.

Ten Recommendations for Revision of Failed Ceramic Components

1. Do not waste time after the diagnosis is established; act quickly before the ceramic fragments damage the metal tapers further.

2. Irrigate the articular space thoroughly and carry out an extensive synovectomy to remove as many of the ceramic fragments as possible. Replace both ceramic components even if only one component has failed.

3. It is preferable to use a new ceramic-on-ceramic bearing couple with the latest-generation composition (BIOLOX *delta*) for the revision. Another option would involve use of a highly crosslinked polyethylene liner if the metal shell of the cup has become scratched. If the femoral head has fractured, it is safest to use a modular ceramic femoral head with a metal sleeve that can be placed over the original stem taper to create a smooth surface (BIOLOX OPTION). If the metal taper of a component has become badly damaged, revise the entire component.

4. Pay particular attention to the orientation of both implant components. If the failure may have been due to impingement and/or instability, the component positioning should be addressed during the revision. If a cup revision is required, the first choice should be a ceramic-on-ceramic couple in which the revised femoral head has a large diameter, and the second choice should be use of a highly crosslinked polyethylene liner with an elevated rim.

5. Be very careful in removing damaged ceramic components. When removing the head, a sharp strike made with a plastic-tipped impactor in a direction coaxial with the neck is advisable. When removing the liner, some sharp strikes perpendicular to the rim of the metal shell should be sufficient; the resulting vibration of the metal shell can loosen the conical press fit. The ceramic liner can then be easily removed with the use of delicate hemostatic forceps or a suction cup device.

6. Check the damage to the metal taper surfaces. Revision of the entire component is required if severe damage has occurred to the neck taper of the femoral component or to the inner surface of the metal shell of the acetabular component. Use of a highly crosslinked polyethylene liner is advisable if mild damage to the inner surface of the metal shell of the acetabular component has occurred but revision of the cup is considered too hazardous. Evaluate the damage to the femoral neck taper by feeling how smoothly the head fits onto the neck taper; the coupling should be smooth and easy. Do not use metal surgical instruments to evaluate the damage to the metal shell of the acetabular component.

7. Until the new femoral head has been attached, keep the neck of the femoral component clean; it needs to be protected from bone particles, cement, blood, fat, and gauze thread. We use a plastic cap derived by modifying a 10-cc syringe barrel for this purpose (Fig. 7). Remove blood and fat tissue from the metal shell, and remove all soft tissue adjacent to the cup to avoid interposition between the metal shell and the ceramic liner.

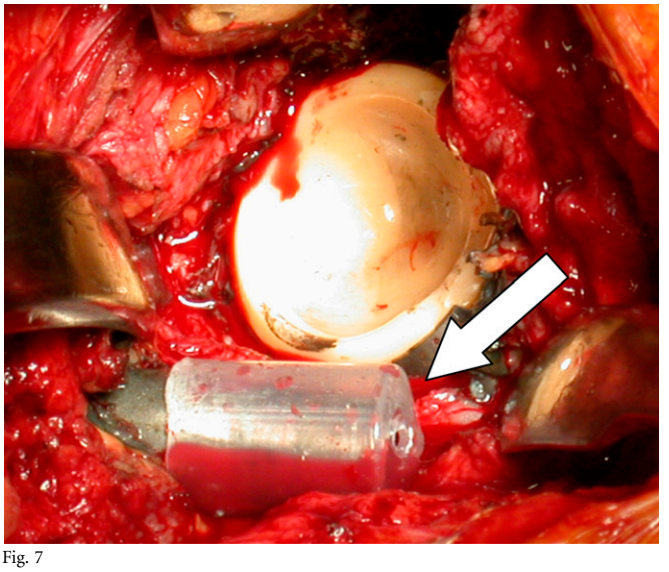

Fig. 7

The femoral neck taper can be protected during revision arthroplasty by a plastic cap (white arrow).

8. Use proper devices to handle the implant components in order to avoid any damage to the metal tapers during surgery; ceramic components should be hammered gently along the correct axis with a plastic-tipped impactor. The femoral head should be screwed gently onto the neck taper until a good grip is achieved.

9. Before final reduction of the hip, check the integrity and proper placement of the ceramic components carefully. ■

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