A-W glass ceramic as a bone substitute in cemented hip arthroplasty

15 hips followed 2–10 years

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We retrospectively reviewed hip arthroplasties in 13 patients (15 hips), in whom we had used apatite-wollastonite (A-W) glass ceramic together with auto- or allograft for augmentation of severe bone deficiency. 11 cemented sockets and 4 stem revisions were included and followed for 2–9.6 years. There were no radiolucent lines between A-W glass ceramic and surrounding bone, and remodeling of the bone graft containing A-W glass ceramic was observed.

No migration of cemented sockets was seen except in 1 case, which was revised. In this case, direct bonding between bone and A-W glass ceramic granules was present histologically. In 4 stem revisions, 5 mm subsidence occurred in 1 case. However, the stem became stable and remodeling of the grafted bone occurred. An artificial bone material, such as A-W glass ceramic, can be used under high-load conditions, because of its good mechanical properties.

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Submitted 97-04-29. Accepted 97-12-27

As more hip arthroplasties are revised, deficiencies in bone stock are likely to become an increasingly serious problem. We have used apatite-wollastonite (A-W) glass ceramic clinically since 1987 in the form of granules in combination with autogenous bone chips and fibrin glue, to compensate for bone deficiencies in acetabulum or femur. A-W glass ceramic can bond directly to living bone and has a high mechanical strength (Nakamura et al. 1985). We reviewed hip arthroplasties in which A-W glass ceramic had been used.

Patients and methods

Between October 1987 and May 1995, we performed 11 total hip arthroplasties (THAs) and 4 bipolar arthroplasties using A-W glass ceramic in combination with autogenous bone chips, to compensate for bone deficiencies. 2 patients were men and 11 were women. The average age at surgery was 57 (37–73) years. Osteoarthrosis secondary to congenital dislocation was the most frequent diagnosis (10 hips). The remaining diagnoses were rheumatoid arthritis (3 hips), avascular necrosis of the femoral head (1 hip) and femoral neck fracture (1 hip). The average follow-up period was 5 (2–9.6) years and all patients were available for review (Table 1).

All patients, except 2, had undergone previous major hip surgery. These procedures included Charnley LFA (7 hips) and cemented bipolar arthroplasty (5 hips). The reason for revision was aseptic loosening with bone deficiences in all cases (Tables 2 and 3).

A-W glass ceramic was used in 11 THAs on the acetabular side and in 4 revisions of the femoral stem. Of the 11 THAs, 4 were Charnley LFA (Thackeray, Leeds, England) and 7 were 22 or 26 mm alumina ceramic heads with titanium stems (Kyocera THA, Kyocera Cooporation, Kyoto, Japan). The Kyocera physio hip systems (Kyocera Bipolar), in which the outer head and 22 mm modular head made of alumina ceramic with a polyethylene bearing insert, were used in the bipolar arthroplasties.

Preparation of bone and A-W glass ceramic grafts

A-W glass ceramic has greater mechanical strength than hydroxyapatite, a compressive strength of 10,800 kg/cm^2 and a bending strength of 2,000 kg/cm^2. The chemical composition of A-W glass ceramic in wt% is MgO 4.6, CaO 44.9, SiO_2 34.2, CaF_2 0.5. It contains oxyfluorapatite ($Ca_{10}(PO_4)_6(O,F_2)$) and ß-wollastonite ($CaSiO_3$). The approximate wt% of the materials are apatite 35, wollastonite 40 and glass 25. The method of synthesis was reported by Kokubo et al. (1986).

Table 1. Patient data

Case	Age	Sex	Diagnosis[a]	Previous op.[b]	Location and type of A-W glass ceramic	Revision op.[b]	Migration	Follow-up months
1	63	F	SOA	CLFA	Socket, granules	CLFA	None	115
2	63	F	SOA	CLFA	Socket, granules	CLFA	None	96
3	60	F	SOA	None	Socket, granules and block ×2	CLFA	None	91
4R	65	F	SOA	CLFA	Socket, granules	KTHA	None	59
4L	65	F	SOA	CLFA	Socket, granules	KTHA	None	57
5	73	F	SOA	CLFA	Socket, granules and block ×2	CLFA	None	49
6	43	M	SOA	Bipolar	Socket, large granule (2–3 mm)	KTHA	None	36
7	49	F	SOA	CLFA	Socket, large granule (2–3 mm)	KTHA+KCS	None	31
8	40	F	RA	Bipolar	Socket, large granule and block ×1	KTHA+KCS	None	30
9R	57	F	RA	None	Socket, large granule, porous granules	KTHA	Migration, revision	29
9L	57	F	RA	None	Socket, large granule, porous granules	KTHA	Migration, revision	25
10	71	F	Fracture	THA	Femoral stem, granule and block ×6	K-B	5 mm subsidence	82
11	63	F	SOA	CLFA	Femoral stem, granule	K-B	None	50
12	37	M	ANF	Bipolar	Femoral stem, granule	K-B	None	46
13	44	F	SOA	Bipolar	Femoral stem, granule	K-B	None	34

[a] SOA secondary osteoarthrosis, RA rheumatoid arthritis, ANF avascular necrosis of the femoral head
[b] CLFA Charnley low friction arthroplasty, KTHA Kyocera total hip arthroplasty, KCS Kerboul cross-shell, K-B Kyocera-bipolar

Table 2. Acetabular deficiences

Classification		Cases
Type I Segmental		
A Peripheral		
B Central (medial wall absent)		
Typ II Cavitary		
A Peripheral	II A	1
B Central (medial wall intact)	II B	4
	II AB	
Type III Combined segmental and cavitary		
A Superior segmental-superior cavitary	III A	3
B Protrusion with deficient medial wall	III B	1
	III AB	3

Acetabular and femoral (Table 3) bone deficiencies classified according to the American Academy of Orthopaedic Surgeons (AAOS), Committee on the Hip (D'Antonio et al. 1989, Steinberg et al. 1990).

Table 3. Femoral deficiences

Classification	Cases
Type I Segmental	
A Proximal	
B Intercalary	1
C Greater trochanter	
Typ II Cavitary	
A Cancellous	
B Cortical	2
C Ectasia	1
Type III Combined segmental and cavitary	

A-W glass ceramic granules of about 350–500 μm to 2–3 mm and autogenous bone chips from the anterior iliac crest or allograft were prepared in almost equal volumes, and were mixed with fibrin glue (Behringwerke, Marburg, Germany), which was made after mixing the fibrinogen solution with thrombin solution, and the mixture was implanted into the bone defect. The amount of A-W glass ceramic granules used was mean 29 (10–51) g. In some cases of severe bone deficiency, a few A-W glass ceramic blocks (9–12 mm long) were used, in combination with the granules.

Surgical technique

The transtrochanteric approach was employed. Autogenous bone chips and A-W glass ceramic granules were impacted with a bone tamp. A solid structural bone graft from ilium was fixed to the superolateral portion of the acetabulum with 2 or 3 AO cortical screws or ceramic screws in those cases which had a superior segmental defect in the acetabular rim. In revisions of the femoral stem, A-W glass ceramic granules and bone chips were impacted into the femoral cavitary defect. The bipolar stem and THA socket were fixed by bone cement, using a second generation cementing technique.

Assessment of clinical results and radiographic evaluation

Clinical results were evaluated, using a method for the assessment of hip function proposed by the Japan Orthopedic Association (JOA hip score based on pain 40%, range of motion 20%, ability to walk 20% and ADL 20%). Serial radiographic evaluations were performed to assess migration of the socket and femoral stem, which was measured on an anteroposterior radiograph of the pelvis taken with the patient in the supine position.

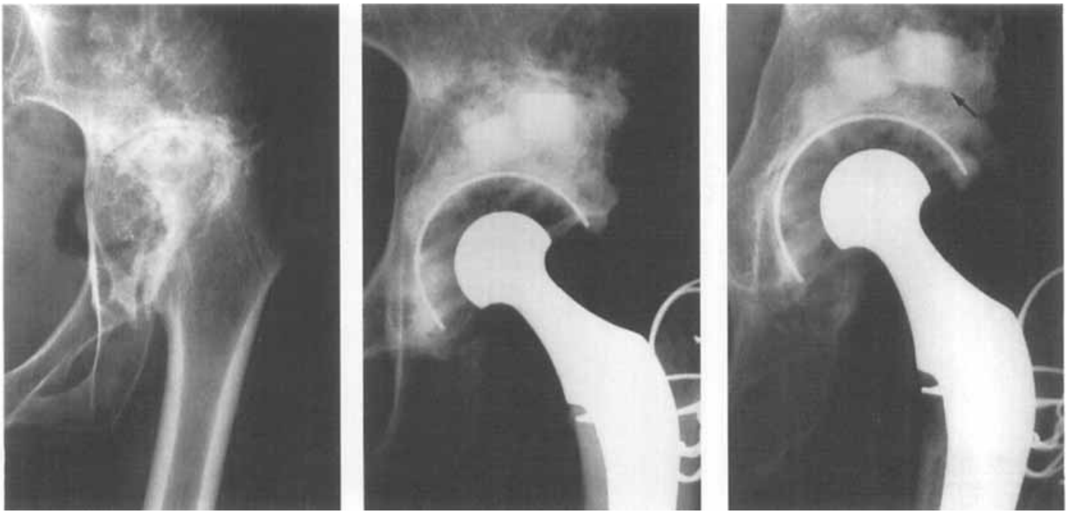

Figure 1. Case 3, a 60-year-old woman with osteoarthrosis.

4 weeks after the operation, in which a bone graft from the ilium was fixed by two ceramic screws, and two blocks of A-W glass ceramic and bone chips from the femoral head were implanted.

7.6 years after the operation, showing no migration of the socket and good incorporation of the A-W glass ceramic block and acetabular bone. Arrows indicate A-W glass ceramic blocks.

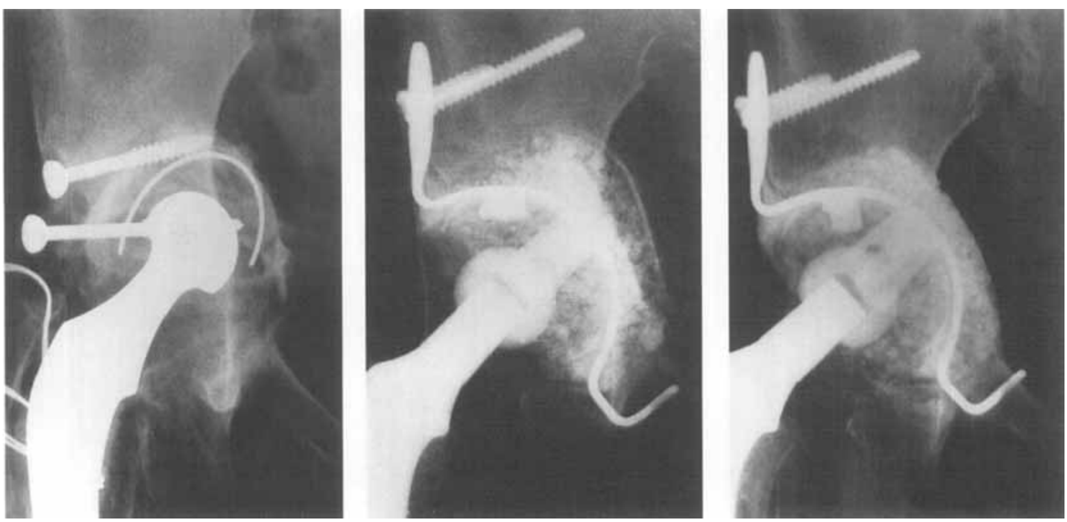

Figure 2. Case 7., a 49-year-old woman. 4 years after a Charnley LFA with central migration of the socket.

Immediately after revision surgery, using large A-W glass ceramic granules (2–3 mm diameter) and a Kerboull cross-shell.

2.6 years after revision surgery reveals remodeling of the bone graft, which became homogeneous.

Results

The mean preoperative JOA hip scores were 55 (31–67) points and 78 (57–94) points at the end of the follow-up period. 11 patients had a score of good or excellent.

Migration of the socket was only observed in case 9, who underwent subsequent revision. Stem subsidence only occurred in case 10: 5 mm of subsidence in 6 months. However, there was no progression of subsidence and remodeling of the bone graft was observed.

No collapse of the bone graft and no demarcation lines between the bone and the A-W glass ceramic were present (Figure 1). Remodeling of the bone graft

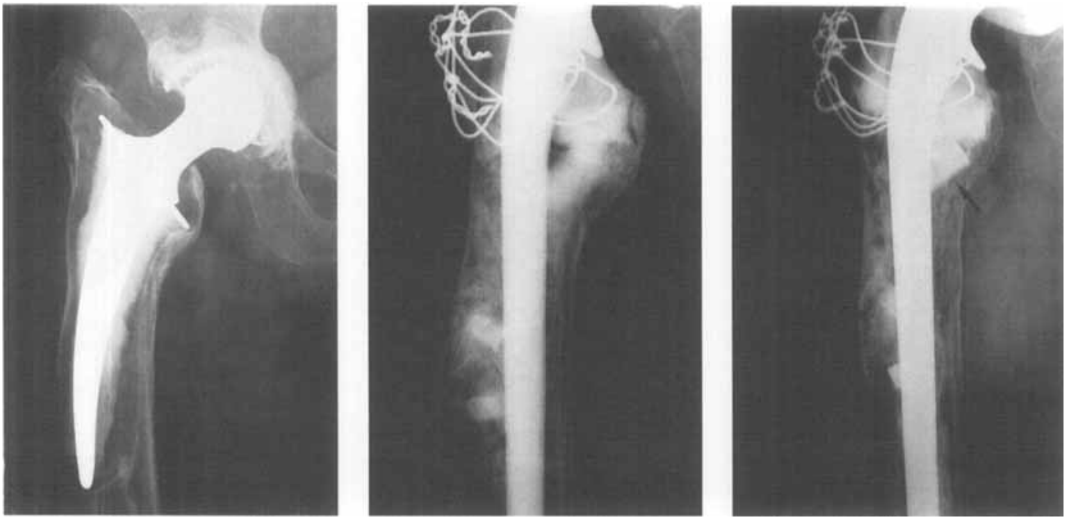

Figure 3. Case 10, a 71-year-old woman 8 years after THA for a femoral neck fracture, with loosening of the stem.

4 weeks after revision surgery. Several blocks and granules of A-W glass ceramic were inserted into the medullary cavity and compressed and the femoral stem was fixed with bone cement.

5 years after revision surgery. There was a 5 mm subsidence of the femoral stem; however, there is no demarcation around A-W glass ceramic blocks and there is remodeling of the grafted bone. Arrows indicate A-W glass ceramic blocks.

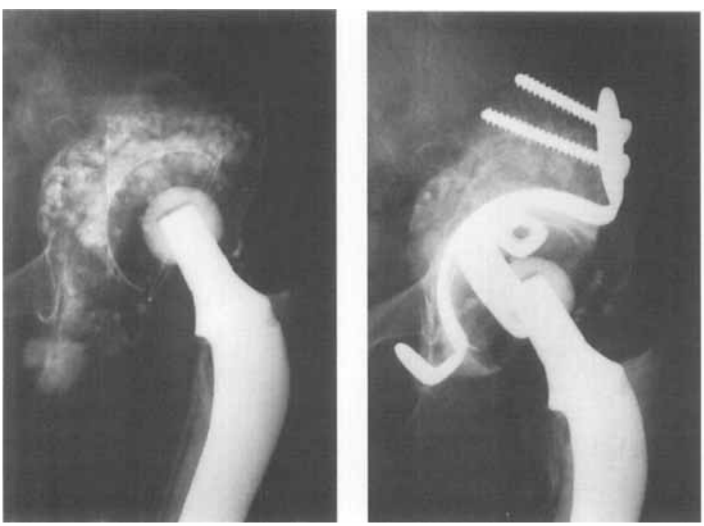

Figure 4. Case 9. A 57-year-old woman with rheumatoid arthritis and severe protrusio acetabuli in both hips. 6 months after the operation the left socket had migrated. The socket could not be fixed to the acetabulum by bone cement, because the layer of A-W glass ceramic granules was too thick.

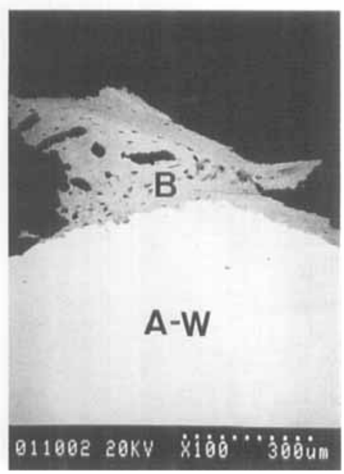

Figure. 5 Scanning electron microscope shows an A-W glass ceramic granule retrieved at revision surgery in case 9. The granule is bonded directly to bone, ×100. A-W glass ceramic granule, B bone.

containing A-W glass ceramic granules were seen in cases 6 and 7 on the socket side and in case 10 on the femoral side (Figures 2 and 3).

Case 9, a 57-year-old woman with RA, showed severe protrusio acetabuli in both hips and migration of the sockets 6 months after surgery on both sides, because the layer of A-W glass ceramic granules was so thick that the socket could not be fixed to the acetabulum with bone cement. At revision surgery, several A-W glass ceramic granules were firmly attached to the acetabulum (Figure 4). The histological specimen showed that a large A-W glass ceramic granule was bonded directly to bone (Figure 5).

Discussion

Many authors have reported the use of allograft bone to reconstruct deficient acetabuli, using cemented conventional acetabular components or bipolar sockets (Harris 1982, Mankin et al. 1983, Slooff et al. 1984, Trancik et al. 1986, Convery et al. 1990). Despite the widespread use of bone allografts, concerns persist regarding the rate and extent of their incorporation and their ability to resist resorption. Incorporation of allografts seems to follow the same pattern as that of autografts, but is probably slower and less complete (Friedlaender 1987). Wilson et al. (1989) reported that allografts thicker than 15 mm that are used to correct peripheral defects perhaps cannot be repaired completely. Follow-up studies of large autografts and allografts have revealed a tendency towards late failure of fixation of the socket (Gerber and Harris 1986, Pallock and Whiteside 1992). Springfield (1987) reported that a human autogenous cortical transplant develops its maximal weakness, 60% of its original strength, from the 12th to at least the 48th week after the operation and will have returned to its original strength 2 years after the operation. Therefore, artificial bone materials might be preferable to autografts or allografts under high-load conditions.

Oonishi et al. (1997) reported the application of hydroxyapatite (HA), to correct massive bone defects in loose THA, to avoid postoperative morphological changes or a volume decrease. HA forms a chemical bond with bone in vivo, but its mechanical strength is inferior to that of human cortical bone. In contrast, A-W glass ceramic, which is also capable of bonding to living bone, has a mechanical strength substantially higher than that of human cortical bone (Nakamura et al. 1985, Yamamuro 1991); it has already been used in clinical cases to correct large bone defects in the iliac crest and to replace vertebrae (Kaneda et al. 1992, Asano et al. 1994). Results of our animal experiments show that the A-W glass ceramic and fibrin mixture has good osteoconductive potential and accelerates the bone repair process (Ono et al. 1990). Furthermore, when bone substitutes, such as HA or A-W glass ceramic, are used, the method of preservation is simple and there is no risk of disease transmission from a donor to the recipient.

In our patients, the cemented sockets were stable and the graft did not collapse, and there was no demarcation line between the A-W glass ceramic, bone cement and the surrounding bone. Remodeling of the bone graft containing A-W glass ceramic granules was observed and the graft became homogeneous. Because A-W glass ceramic provides osteoconduction and no postoperative mechanical change, we prefer the ceramic without bone chips.

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