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Iliac crest reconstruction with a bioactive ceramic spacer

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Abstract This study aimed to investigate the long-term clinical results of the apatite wollastonite-containing glass ceramic (AWGC) iliac spacer and to discuss its efficacy in reconstruction of the bone graft donor site at the iliac crest. Thirty-one patients were studied for more than 10 years. All patients underwent anterior spinal fusion using autogenous tricortical iliac bone graft. After harvest of tricortical iliac bone graft, an AWGC iliac spacer ranging from 15 mm to 70 mm in length was press-fitted into the gap. Long-term clinical results

were obtained from radiological and blood examinations. Thirty patients (97%) were satisfied with the spacer. There was new bone formation around the spacer on the radiograph. There was no abnormal silicon concentration in blood examinations. AWGC iliac spacer appears to be useful in the reconstruction of harvested iliac crest. New bone formation occurs, reducing the defect size.

Keywords Tricortical iliac bone graft · Iliac crest · Reconstruction · Bioactive ceramics

Introduction

The iliac crest has been commonly used as a donor site for bone grafts in various spinal reconstruction surgeries. However, harvesting a large amount of tricortical bone from the iliac crest for thoracolumbar anterior surgery may produce various complications, including persistent pain, myalgia paresthetica, fractures, cosmetic deformity and muscle herniation [1, 3, 9, 12, 18]. There have been several attempts to solve these problems by changing the way of harvesting or by using artificial prostheses such as Proplast and alumina ceramics [4, 11].

We have been using, since 1987, an iliac crest spacer made of bioactive apatite wollastonite-containing glass ceramic (AWGC, Nippon Electric Glass, Ohtsu, Japan) after harvesting tricortical iliac bone graft. The major components of this spacer are oxyapatite ($\text{Ca}_{10}(\text{PO}_4)_5\text{O}_2$) and wollastonite (CaO/SiO_2) [13, 14]. Its mechanical strength and fatigue characteristics are reported to be superior to those of human cortical bone. Asano et al. [2] reported short-term clinical results for the AWGC iliac spacer in 1994. However, until now there have been no reports of long-

term clinical results of the AWGC iliac spacer that would confirm its efficacy in reconstruction of the iliac crest donor site after harvest of tricortical bone graft.

The purposes of this study were (1) to investigate long-term clinical results of the AWGC iliac spacer after harvest of tricortical iliac bone graft and (2) to discuss the efficacy of this spacer in reconstruction of the iliac crest donor site.

Materials and methods

Of 64 patients who underwent, from 1987 to 1989, iliac crest reconstruction using the AWGC iliac spacer after harvest of tricortical iliac crest, there were 31 patients available for a 10-year follow-up study. Follow-up periods ranged 10–13 years, with an average of 12 years. There were 18 men and 13 women. Their ages at surgery ranged 15–63 years, with an average of 37 years. All patients underwent anterior spinal fusion using autogenous tricortical iliac bone graft. The length of the spacer inserted at the donor site was 15 mm in one patient, 25 mm in another, 30 mm in four, 35 mm in four, 40 mm in nine, 45 mm in seven, 50 mm in three, and 70 mm in one. Thirty-three patients were no longer available for follow-up at 10 years after surgery. There were 19 men and 14 women. Their ages at surgery ranged 16–65 years with an average of 37 years.

Table 1 Radiographical classification of new bone formation around the spacer

None	0% of the spacer surface
Slight	Less than 50% of the spacer surface
Moderate	More than 50% of the spacer surface
Remarkable	100% of the spacer surface

The length of the spacer in the patients lost to follow-up was 15 mm in three patients, 30 mm in three, 35 mm in six, 40 mm in eleven, 45 mm in nine, and 50 mm in one.

Surgical techniques to harvest tricortical iliac bone and replace it with an AWGC iliac spacer consisted of a precise skin incision starting from 3 cm lateral and 1 cm below the anterior superior iliac spine and parallel to the iliac crest. The gluteal muscles were detached sub-periosteally to expose the external and internal cortex of the iliac crest. The iliac bone must be taken from at least 3 cm away from the superior anterior iliac spine (SAIS). To remove tricortical iliac crest, an osteotome was placed vertically to the surface of the iliac crest so that the cutting line went away from the SAIS, to avoid fracture. After harvest of the required amount of tricortical iliac crest, a vertical small groove was made using a small rongeur at each side of the defect to fit the spacer. An appropriate sized AWGC iliac spacer was press-fitted into the defect with a nylon hammer. No additional wire fixation was applied around the spacer. The periosteum and gluteal muscles were tightly sutured to cover the spacer.

Long-term clinical results were evaluated regarding cosmetic appearance of the reconstructed area, spontaneous pain, tenderness, discomfort at the site of iliac reconstruction and overall patient satisfaction [2]. Radiological evaluation focused on the radiolucent clear zone and new bone formation around the spacer [2]. The clear zone was classified into three grades: (–) 0 mm, (+) 0–2 mm, and (++) >2 mm. Bone formation was classified into four grades (Table 1). Patients visited the nearest hospital affiliated to ours in order to fill in a questionnaire and to undergo blood examinations and radiographs. The questionnaire asked about spontaneous pain and tenderness at the iliac crest donor site, cosmetic discomfort, awareness of a foreign body and the patient's satisfaction. Answers from patients, radiographs and blood samples were sent from local hospitals to the central hospital for analysis. Radiological evaluations were performed at the central hospital by a single spine surgeon, who did not participate in the initial surgery. Blood concentration of silicon (Si) was also evaluated.

Results

Clinical evaluation

In regard to patients' overall satisfaction, 24 (78%) were satisfied with their reconstructed iliac crest (Table 2). One male patient who did not show remarkable recovery in cervical myelopathy after surgery was dissatisfied with the spacer, because he felt its presence. There were no complications such as infection, muscle herniation, hematoma or myalgia paresthetica.

Radiological evaluation

No radiolucent clear zone was observed in 23 patients (74%) at the final follow-up examination. Eight patients

Table 2 Clinical evaluation of the AWGC iliac spacer (*n*=31) *m* male, *f* female

	Excellent, patients (%)	Good, patients (%)	Poor, patients (%)
Cosmetic appearance ^a	27 (87)	4 (m:1, f:3) (13)	0 (0)
Spontaneous pain ^b	26 (84)	5 (m:3, f:2) (16)	0 (0)
Tenderness ^b	19 (61)	11 (m:5, f:6) (36)	1 (m) (3)
Sense of foreign body ^b	21 (68)	10 (m:6, f:4) (32)	0 (0)
Satisfaction ^c	24 (78)	6 (m:2, f:4) (19)	1 (m) (3)

^aExcellent: smooth and satisfactory outline; good: some alteration of outline but generally satisfactory; poor: obvious irregular outline

^bExcellent: none; good: slight or occasional; poor: some or more than occasional

^cExcellent: satisfied; good: almost satisfied; poor: dissatisfied

Fig. 1 Fifty-six-year-old male. The tricortical iliac crest, 50 mm in length, was harvested for an L2 burst fracture. An AWGC iliac crest spacer, 50 mm in length, was placed at the donor site. At 11 years after surgery, remarkable new bone formation around the spacer was noted on the radiograph (arrows), and the patient did not complain of any discomfort at the reconstructed iliac crest

(26%) had a 0–2 mm clear zone around the spacer. Twenty-six patients (84%) showed remarkable new bone formation around the spacer (Fig. 1) and five patients (16%) showed moderate new bone formation around the spacer.

Blood examination for Si

Blood concentration of Si ranged 0.24–1.22 ppm with an average of 0.74 ppm (normal range: 0.4–5.0 ppm) [5].

Discussion

According to Schnee et al. [17], the harvest of 5–13 mm (in length) of the tricortical iliac crest for use in anterior cervical discectomy was related to only 3.5% of complaints of poor cosmesis and 2.8% of wound symptoms of pain. However, Summers reported that 33% of patients who had undergone anterior lumbar spine fusion with bigger bicortical iliac bone grafts complained of significant donor site pain [18]. Moreover, 88% of those who had undergone tricortical full-thickness iliac crest bone harvest complained of severely disabling pain that was stubbornly resistant to treatment [18]. Therefore, it is desirable to find a way to reduce these complications [15].

There have been many attempts to decrease complications related to autogenous tricortical iliac bone harvesting. First of all, as Ebraheim et al. [8] pointed out, a precise understanding of the anatomic characteristics of the pelvis is indispensable to minimizing the risk of pelvic fracture, such as avulsion fracture at SAIS during harvesting maneuvers. The iliac crest around the iliac tubercle is the thickest part, and so this area is the most suitable for bone harvesting. Hu et al. [12] also reported that removal of iliac bone at least 3 cm posterior to the ASIS leaves the iliac crest 2.4 times stronger than does bone harvesting 1.5 cm posterior to the ASIS.

Banwart et al. [3] reported that minor complications such as scar formation or dysesthesia around the donor site were more frequent than major complications. These minor complications affected the overall clinical results. To minimize them, many important techniques should be adopted. Skin incision should be below the iliac crest, starting 3 cm away from the ASIS. The muscle should also be incised below the crest, leaving a cuff of tissue for reattachment at the time of closure. After dissecting the periosteum below the top of the crest, a sub-periosteal dissection should be performed. Complete hemostasis using electrocautery and a hemostatic agent on the exposed bone surface is also important at closure. The periosteum and the fascia should be sutured in layers. Tension-free skin closure is essential to prevent unsightly scar formation.

There are also several modified methods of harvesting tricortical iliac bone without removing the outline of the iliac crest, such as leaving the outer cortex of the iliac crest intact [4], or the so called “trap-door” method, leaving the pelvis contour intact after graft harvesting.

Another attempt to minimize donor site cosmetic deformity is reconstruction of the harvested iliac crest using either autologous [6, 7, 19] or synthetic materials such as methyl methacrylate [16] or Proplast (polytetrafluoroethylene, Vitek, Houston, Texas, USA) [11]. Summers and Eisenstein [18] pointed out a risk of using bioinert synthetic material for reconstruction of the harvested iliac crest. Harris et al. [10] reported the efficacy of an autogenous rib graft for reconstruction of the anterior iliac crest without using synthetic material. Asano et al. [2] reported short-term clinical results of the AWGC iliac spacer for reconstruction of the anterior iliac crest. Although short-term clinical results for the AWGC iliac crest spacer were satisfactory, the current study is the first to report long-term clinical results for the spacer. Although there was a risk of high blood concentration of Si in patients with an AWGC spacer, because of its composition, there was no abnormal concentration of Si in blood examinations. To prove its long-term innocuousness in human bodies, further histological or biochemical studies are needed that will assess the local biological reactions around the spacer. Another controversial issue is cost-effectiveness when expensive synthetic materials are used [2].

Conclusion

This study investigated the long-term clinical results of the AWGC (apatite wollastonite-containing glass ceramic) iliac spacer and discussed its efficacy in reconstruction of bone graft donor sites at the iliac crest. Thirty-one patients completed a minimum 10-year follow-up study. The AWGC iliac spacer appears to be useful in the reconstruction of harvested iliac crest. New bone formation occurs, reducing the defect size.

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