FEMORAL BONE GRAFTING IN PRIMARY AND REVISION TOTAL KNEE ARTHROPLASTY

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The purpose of this study was to evaluate the clinical and radiographic results of TKA's with morsellized and solid femoral bone grafting. From April 1989 to February 1996, 6 primary and 18 revision TKA's with femoral bone grafting were performed in 22 patients with an average age of 62 years. Eleven knees were affected by rheumatoid arthritis, 10 by osteoarthritis, 2 by osteonecrosis and one by hemophiliac arthropathy. The femoral bone defects were large in 12, medium in 9, small in 3, contained in 10 and uncontained in 14 cases. Reconstruction was done with impacted morsellized fresh frozen trabecular bone grafts in 13 knees, with solid bone grafts in 7 knees and with combined grafts in 4 knees. Twenty-one cases were clinically evaluated at an average of 38 months (range : 9-89 months). The average Knee Society knee score increased by 39 points to 85 points at follow-up. The average functional score increased by 22 points to 48 points. Two cases with solid femoral bone grafts failed due to aseptic loosening. There were no infections. Radiographic follow-up revealed osteopenia around the femoral component in 10 knees. Two knees showed circumferential radiolucency around the femoral stem, and 5 knees had minor radiolucency at the anterior part of the femoral component. Radiographic incorporation was present in 5 of the 6 cases that could be evaluated. Histologic analysis of two biopsies revealed incorporation of the morsellized bone graft. The authors advocate impacted morsellized bone grafting for contained and small-to-medium uncontained femoral bone defects in combination with cemented TKA.

Keywords : total knee arthroplasty ; revision ; bone graft.

Mots-clés : prothèse totale de genou ; reprise chirurgicale ; greffe osseuse.

Revision total knee arthroplasty (TKA) and primary TKA with a severe valgus or varus deformity often have femoral bone defects that require reconstruction. Solid bone grafts, morsellized bone grafts, custom-made TKA's and metal or cement augmentation have been used to fill these bone defects. Many surgeons favor bone grafts for reasons of economy, physiology and versatility (5). Incorporation of bone grafts leads to restoration of bone stock and thus simplifies a future revision. Disadvantages of solid bone grafts include slow incorporation, disintegration, nonunion and fracture (4). Morsellized bone grafts have a more open structure with the advantage of rapid revascularization and incorporation (2). Impacted morsellized bone grafts were successfully used in revision total hip arthroplasty (THA) (22). In contradistinction to revision THA, however, femoral bone defects in revision TKA are often uncontained. In a cadaver study, reconstruction of an uncontained unicondylar femoral bone defect with impacted morsellized bone grafts and cemented TKA gave adequate initial stability without collapse of the grafts or breakage of the cement mantle (14). These findings support our hypothesis that contained and small-to-medium uncontained femoral bone defects can be reconstructed with impacted morsellized bone grafts.

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The aim of this study was to evaluate the clinical and radiographic results of TKA's with morsellized and solid femoral bone grafting.

MATERIALS AND METHODS

During the period April 1989 to February 1996, 6 primary and 18 revision cemented TKA's with femoral bone grafting were performed in 22 patients (9 female and 13 male) with an average age of 62 years (range : 38-79 years). The predominant pathology was rheumatoid arthritis in 11 cases, osteoarthritis in 10 cases, osteonecrosis in 2 cases and hemophiliac arthropathy in 1 case. The primary prosthesis in the revision TKA's was a Kinematic (Howmedica) in 4 cases, a Geomedic (Howmedica) in 3, a GSB (Allopro) in 2, and a Luebeck System (S & G Implants), a Freeman (Protek), an Omnifit 3000 (Osteonics), a Guepar (Benoist Girard), and a Low Contact Stress (DePuy) TKA in one case each. In 4 cases the primary TKA could not be identified or traced. The reason for revision was aseptic loosening in 8 cases, septic loosening in 5, wear in 2 and malposition, instability and flexion contracture in 1 case each. Bone defects were considered small if less than 4 cm^3 and large when more than 10 cm^3 (24). The femoral defects in our patients were large in 12, medium in 9, small in 3, contained in 10 and uncontained in 14 cases (table I). In 13 knees the femoral bone defects were reconstructed with impacted morsellized fresh frozen trabecular bone grafts, in 7 knees with solid bone grafts and in 4 knees with combined grafts. The authors preferred to use morsellized bone grafts if the stability was not compromised. Solid bone grafts were fixed with Kirschner pins. Autologous grafts were used in 8 TKA's and homologous grafts in 16 TKA's. Tibial bone defects were present in 19 knees and treated with mostly morsellized bone grafts (table I). In 7 cases with severe deformity a soft tissue release was done to achieve adequate soft tissue balance. The cemented Press Fit Condylar TKA (Johnson & Johnson) system was used with unconstrained or posterior stabilized TKA's in 14 cases, and stemmed revision TKA's in 10. A stemmed femoral component was not routinely used. In cases of extensive bone loss or marked instability, a femoral stem was applied without cement around the stem.

Five days after surgery, the knee was placed on continuous passive motion, until knee flexion reached 90 degrees. Full weight bearing was postponed until graft incorporation was suspected, usually after 6 months.

All but one of the patients were clinically and radiographically followed at yearly intervals. Two patients had three reinterventions for patellofemoral complications, at which time core biopsies of the morsellized bone grafts were taken. During the biopsy procedure, diagrams were made of the location of the biopsy needle. Only biopsies that remained intact during the whole embedding procedure were used for evaluation. The specimens were fixed in phosphate-buffered (0.1 M, pH 7.4) 4% formalin and embedded non decalcified in methylmethacrylate. Serial sections (7-micron thick) were stained with hematoxylin eosin and Masson trichrome staining to visualize osteoid. Normal and polarized light were used to detect woven bone or remodeling sequences.

Two TKA's were revised for aseptic loosening. One patient was lost to follow-up and appeared to have had an above-the-TKA amputation for peripheral arterial insufficiency 4 years after surgery. This patient died of a cerebral vascular accident 3 months later. Five other patients died of unrelated causes during the follow-up period and were included in the results. The mean clinical follow-up period for the 21 knees was 38 months (range : 9-89 months). The Knee Society clinical rating system was used for the preoperative and follow-up clinical and functional score (10). The postoperative and follow-up radiographs were assessed for areas of osteopenia, radiolucent lines, migration of the prosthesis and incorporation of the graft. The mean radiographic follow-up period was 37 months (range : 3-89 months).

RESULTS

Complications

Two wound hematomas, 1 rupture of the patellar tendon and 1 patellar fracture with loosening of the patellar component occurred. Manipulation under general anesthesia for decreased range of motion was done in 3 cases. There were no infections.

Reoperations

One patient with bilateral TKA's and solid femoral bone grafting had a revision of both TKA's (table I : case 20 and 21) for aseptic loosening. The solid femoral bone graft appeared to have disintegrated at revision. The defect was

Table I. — Data of 22 patients with 24 TKA's with femoral bone grafting

Case	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	63	F	OA	R	unknown	2	1	S	U	H	M	1	13	0	64	30	55	13	3	2	1
2	76	F	OA	P	—	1	3	M	U	A	S	2	89	15	97	45	80	89	3	1	3
3	50	M	OA	R	GSB	1	1	L	U	H	S	1	82	38	93	50	100	82	1	1	1
4	60	M	OA	R	Freeman	2	4	M	U	A	C	1	27	46	99	40	70	27	3	2	2
5	69	M	OA	R	Kinematic	1	5	L	C	A	M	1	15	87	85	70	70	12	3	2	1
6	65	M	RA	P	—	1	3	M	C	A	M	1	47	68	95	50	20	47	3	1	3
7	61	M	RA	P	—	1	3	L	C	A	M	1	55	55	100	0	60	50	1	1	3
8	69	M	RA	R	Geomedic	1	1	L	U	H	S	1	75	40	81	30	50	75	3	1	3
9	70	F	OA	R	Omnifit	2	6	M	U	H	M	1	10	44	78	0	0	10	3	2	3
10	60	F	OA	R	Luebeck	2	5	L	U	H	M	1	38	39	72	15	0	38	3	2	3
11	58	M	HEM	R	Kinematic	1	1	M	U	A	S	2	23	70	84	55	80	35	3	2	3
12	42	M	OA	R	GSB	2	1	M	C	H	M	1	13	48	64	30	50	13	3	1	2
13	77	F	OA	R	Kinematic	1	2	S	C	H	M	1	60	18	86	30	15	60	1	1	3
14	62	M	OA	R	Geomedic	2	1	L	C	H	M	1	12	65	93	45	80	12	3	2	3
15	79	F	RA	R	Geomedic	2	1	L	U	H	M	1	9	40	75	10	10	3	3	2	3
16	68	M	RA	R	Guepar	2	1	L	U	H	C	1	50	37	95	15	60	50	1	2	1
17	69	F	ON	P	—	1	3	M	C	A	M	2	30	57	94	0	65	30	3	1	3
18	69	F	ON	P	—	1	3	M	C	A	M	2	31	57	99	0	65	31	1	1	3
19	72	M	RA	P	—	1	3	L	C	H	C	1	—	—	—	—	—	—	—	—	—
20	41	M	RA	R	unknown	1	2	L	U	H	S	1	—	—	—	—	—	—	—	—	—
21	41	M	RA	R	unknown	1	2	L	U	H	S	1	—	—	—	—	—	—	—	—	—
22	62	F	RA	R	unknown	2	2	L	U	H	M	1	26	31	78	0	0	13	3	1	3
23	49	M	RA	R	LCS	2	2	M	C	H	C	1	19	49	98	0	65	19	2	2	3
24	38	F	RA	R	Kinematic	1	7	S	U	A	S	2	73	64	50	40	20	73	3	1	1

A Age at operation (years)
B Sex M = male
F = female
C Diagnosis
OA = osteoarthritis
RA = rheumatoid arthritis
ON = osteonecrosis
HEM = hemophiliac arthropathy
D Primary or revision surgery
P = primary
R = revision
E primary TKA in revision cases
F implanted TKA at grafting
1 = nonconstrained/post. stab.
2 = stemmed
G Indication
1 = aseptic loosening
2 = septic loosening
3 = degeneration
4 = malalignment
5 = wear
6 = instability
7 = flexion contracture
H Size of femoral bone defect
S = small, < 4 cm^3
M = medium, 4-10 cm^3
L = large, > 10 cm^3
I Containment of bone defect
U = uncontained
C = contained
J Source of bone graft
A = autologous
H = homologous
K Structure of bone graft
M = morsellized
S = solid
C = combined
L tibial bone graft
1 = yes
2 = no
M Clinical follow-up period (months)
N Preoperative KS knee score (points)
O Follow-up KS knee score (points)
P Preoperative KS functional score (points)
Q Follow-up KS functional score (points)
R Radiographic follow-up period (months)
S Radiographic femoral findings at follow-up
1 = incorporation of graft
2 = no incorporation of graft
3 = assessment impossible
T Osteopenia around femoral component
1 = yes
2 = no
U Radiographic sign at femoral component
1 = minor, nonprogressive radiolucency
2 = circumferential radiolucency
3 = no radiolucency

reconstructed with cement in combination with a stemmed femoral component. A periprosthetic femoral fracture on the right side necessitated a second revision to a megaprosthesis. This patient had Knee Society knee scores of 93 and 52 points after 17 and 7 months respectively ; the functional score was 30 points. Other reinterventions included patellar component removal for patellar fracture, patellar component revision with soft tissue release for dislocation of the patella, reconstruction of a patellar tendon rupture, removal of a metal staple and additional posterior release for flexion contracture in one case each.

Clinical results

The average preoperative Knee Society score of 46 points (range : 0-87 points) increased by 39 points to an average knee score of 85 points (range : 50-100 points) at follow-up. The average preoperative functional score of 26 points (range : 0-70 points) increased by 22 points to 48 points (range : 0-100 ; table I).

Radiographic results

Osteopenia was observed around the femoral component in 11 knees at follow-up. In all these cases the osteopenic area was behind the anterior flange of the femoral component. An additional osteopenic area was seen around the posterior and medial aspect in 1 case each. In two cases there was a circumferential radiolucent line around the stem of the femoral component, and in 5 cases there was a nonprogressive radiolucent line of less than 2 mm at the anterior part of the femoral component. In the 2 failed cases with solid bone grafting the femoral component had migrated. Only in 6 cases could incorporation of the femoral graft be judged on the follow-up radiographs : it was complete in 5 of them. In the other knees superimposition of the intercondylar box, the intramedullary stem or the fixation pegs impeded radiographic assessment of graft incorporation.

Histologic analysis

Remnants of the graft in the biopsies of both patients were extremely scarce. The bone had been remodeled into a vital structure with vital, cell-rich medullary tissue (fig. 1). At the periosteal side the bone was rather dense with a trabecular structure (fig. 1 a). Behind this "cortical wall", the bone was osteopenic with scarce trabeculae. The newly formed bone was of the lamellar type with a normal structure. Bone remodeling was present (fig. 1 c, d, e), but was not abundant.

DISCUSSION

Bone grafting is a mode of reconstruction of bone defects that is often applied in primary and revision TKA. After incorporation of the graft, the prosthesis is biologically supported by bone mass with the same biomechanical characteristics as the host bone. In case of future revision, bone loss will be less extensive compared to reconstruction with cement or metal augmentation. In addition, bone grafting reduces the need for expensive custom-made TKA's. Numerous studies have proven that tibial bone defects can be successfully treated with bone grafting in combination with a TKA (1, 9, 20, 24, 25, 27, 28). In the present study, the authors focused on the outcome of femoral bone grafting in 24 cases of contained and uncontained femoral bone loss.

Uncontained femoral bone loss can be reconstructed by rebuilding a cortical rim with solid bone grafts to support the femoral component. Results of solid femoral bone grafting in TKA's are good at short-to-medium term follow-up (16, 17, 23). Ghazavi *et al.* (8) recently reported an 85% success rate with massive femoral bone grafting in 20 knees. Kraay *et al.* (11) successfully applied large segment distal femoral allografts with cemented stemmed, semiconstrained TKA's in the treatment of supracondylar fractures above a TKA. In our study, bilateral TKA with solid femoral bone grafting in a single patient failed due to aseptic loosening. Fortunately, both TKA's could be revised with an acceptable clinical outcome. Massive allografting after oncologic resection, however, yields less predictable results. In a retrieval study on 16 massive allografts, Enneking and Mindell (6) reported only a 20% internal repair of the graft-host surface after 4 to 65 months. It was concluded that massive allografts were osteoconductive rather than osteoinductive.

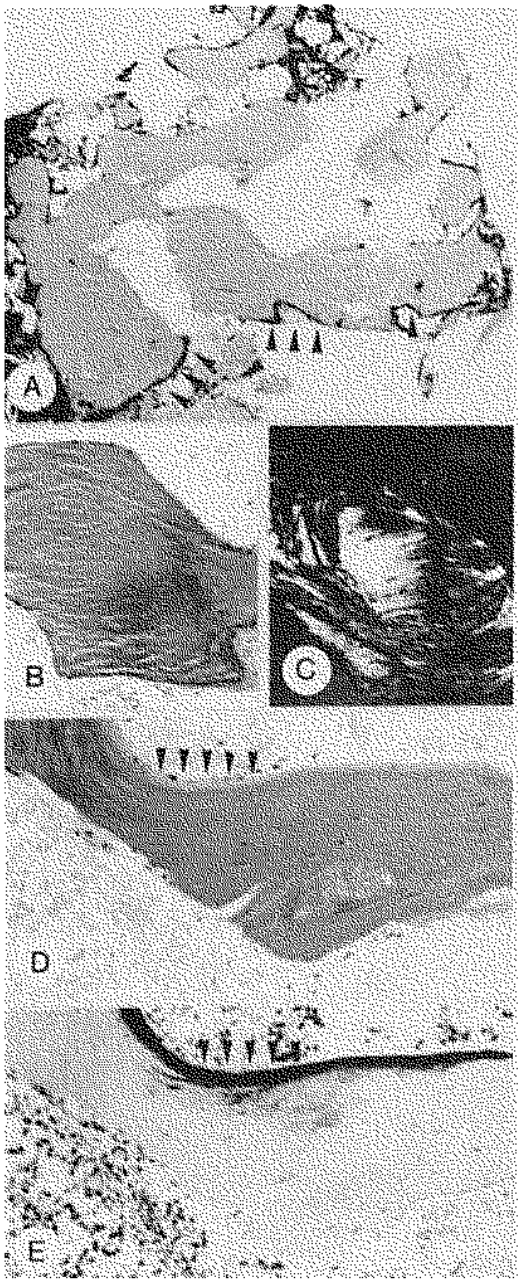

Fig. 1. — (a) Biopsy of the lateral wall of a femoral condyle, 34 months after reconstruction with morsellized bone grafts. Masson trichrome staining showing trabecular structure of the incorporated morsellized graft with local sites of osteoid indicating bone remodeling (arrow heads, × 35). (b, c) Part of fig. a, showing vital bone (b) and multiple remodeling events, investigated with polarized light (c, × 70). (d, e) Thin trabeculae located behind the cortical wall with vital osteocytes and active bone remodeling (arrow heads). (d) Hematoxylin eosin. (e) Masson trichrome staining (× 125).

The authors changed from solid bone grafting to impacted morsellized trabecular bone grafting when favorable results in revision THA at their institution became apparent (22). Morsellized bone grafts have the theoretical advantage of rapid revascularization and incorporation (2). Practically, these grafts can easily be molded to fit irregular femoral bone defects. Adequate initial support is achieved by impacting the morsellized bone graft, even in small-to-medium uncontained defects. A containing metal mesh, as used in revision THA, is less applicable at the distal femur because the obligatory soft tissue coverage is often not feasible. There were no homogenous series of patients treated with femoral morsellized bone allografting found in the literature. In combined series overall good results were reported (20, 23, 24, 25, 26).

In our patients, the Knee Society knee scores increased significantly after surgery with bone grafting. The improvement of the functional score was less impressive due to multiple joint restrictions in patients with rheumatoid arthritis. Five patients with medium and small uncontained femoral bone loss in the present study were successfully treated with impacted morsellized bone grafts (table I). There were no infectious complications, but reoperations were necessary, mostly for patellofemoral problems.

Assessment of radiographic incorporation of distal femoral bone grafting is difficult owing to metal superimposition of the prosthesis, especially when an intramedullary femoral stem is used for fixation. Osteopenia behind the anterior flange of the femoral component was observed in 52% of our patients at follow-up. Mintzer *et al.* (15) observed osteopenia at the same site in 68% of 147 primary TKA's up to 1 year after implantation. It was postulated that this phenomenon was the result of stress shielding, independent of the mode of prosthesis fixation or design. However, determination of bone mineral density on plain radiographs is unreliable (7). Petersen *et al.* (18, 19) and Liu *et al.* (13) measured bone mineral density with dual energy xray absorptiometry (DEXA) around the femoral component of uncemented TKA's and found a decrease in bone mineral density of 7 to 44% at the distal femur. Van Lenthe

et al. (12) performed an analysis with a finite-element computer model and predicted extensive distal femoral bone loss after cemented TKA due to stress shielding. Osteolysis of the distal femur as a result of histiocytic granuloma as seen by Cadambi *et al.* (3) in uncemented TKA was not observed in our study of cemented TKA's. A circumferential radiolucency around a stemmed femoral component, as seen in 2 of our patients, could mean loosening, although one of them was asymptomatic with a knee score of 99 points after 27 months.

Histologic evaluation of 2 of our patients with impacted morsellized bone grafts revealed incorporation of the graft. However, the bone was histologically osteopenic as suggested by radiographs and DEXA-scans (15, 13, 18, 19). This observation could mean that the grafts incorporate, but slowly resorbe thereafter, due to stress shielding.

CONCLUSION

Our short-to-medium term results indicate that femoral bone grafting is a succesful treatment for femoral bone loss in primary and revision TKA. The authors advocate impacted morsellized bone grafting for contained and small-to-medium uncontained femoral bone defects in combination with cemented TKA. Further evaluation is required to determine its value in the long term.

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SAMENVATTING

C. J. M. VAN LOON, M. M. J. W. WIJERS, M. C. DE WAAL MALEFIJT, P. BUMA, R. P. H. VETH. Femorale botplastiek bij primaire en revisie totale knie prothese.

De klinische en radiologische resultaten van 6 primaire en 18 revisie totale knieprothesen, waarbij een versnipperde of solide femorale botplastiek was toegepast, werden geevalueerd na gemiddeld 38 maanden. De gemiddelde leeftijd van de 22 patiënten was 62 jaar. Elf knieën waren geplaatst bij patiënten met rheumatoide arthritis, 10 bij gonarthrosis, 2 bij osteonecrose en één bij haemofilie. De femorale botdefecten waren groot (12 maal), medium (9 maal) of klein (3 maal) en werden geclassificeerd als „contained" in 10 gevallen en „uncontained" in 14 gevallen. De reconstructie van de defecten was in 13 gevallen uitgevoerd met een versnipperde botplastiek, in 7 gevallen met een solide botplastiek en in 4 gevallen met een gecombineerde botplastiek. De gemiddelde kniescore steeg met 39 punten naar 85 punten bij follow-up onderzoek. De gemiddelde functiescore steeg met 22 punten naar 48 punten. Infecties werden niet gevonden, maar 2 gevallen van reconstructie met solide botplastiek faalden door loslating. Bij 10 knieën werd osteopenie rond de femurcomponent gezien, bij 5 knieën werd een radiolucente zone rond de steel gezien en bij 5 knieën werd een kleine radiolucentie aan de voorkant van de femurcomponent gezien. Radiologische incorporatie van de botplastiek werd vastgesteld in 5 van de 6 gevallen die beoordeeld konden worden. Histologische incorporatie van een versnipperde botplastiek werd middels 2 biopsieën aangetoond. De auteurs adviseren een versnipperde femorale botplastiek bij „contained" en kleine tot medium „uncontained" femorale botdefecten in combinatie met een gecementeerde totale knieprothese.

RÉSUMÉ

C. J. M. van LOON, M. M. J. W. WIJERS, M. C. de WAAL MALEFIJT, P. BUMA, R. P. H. YETH. L'utilisation des greffes osseuses dans l'arthroplastie primaire et de revision du genou.

Ce travail avait pour but d'évaluer les résultats cliniques et radiologiques de l'arthroplastie du genou avec utilisation de greffes osseuses fragmentées ou massives. Entre avril 1989 et février 1996, les auteurs ont réalisé 6 arthroplasties primaires et 18 arthroplasties de révision du genou en utilisant des greffes osseuses, chez 22 patients dont l'âge moyen était de 62 ans. L'indication était une arthrite rhumatoïde pour 11 genoux, une arthrose pour 10 autres, une ostéonécrose pour 2 autres et une arthropathie hémophilique pour le dernier. Les pertes de substance fémorale était 12 fois de grande dimension, 9 fois de taille moyenne, 3 fois de petite taille ; il s'agissait 10 fois de défects fermés et 14 fois de défects ouverts. Dans 13 cas, la reconstruction s'est faite au moyen de greffons spongieux cryoconservés fragmentés et impactés, dans 7 cas avec des greffes massives et dans 4 cas en combinant ces deux techniques. Vingt et un cas ont été évalués cliniquement après un suivi moyen de 38 mois (9 à 89 mois). La valeur moyenne du score genou de la Knee Society était de 39 points, elle est passée à 85 points au moment de la révision. La valeur moyenne du score fonctionnel est passée de 22 points à 48 points. Deux échecs ont été notés avec les greffes fémorales massives, en rapport avec un descellement aseptique. Il n'y a pas eu d'infection. Le suivi radiologique a montré une ostéopénie périprothétique au niveau du fémur dans 10 genoux. Deux genoux présentaient une zone radiotransparente circonférentielle autour de la tige fémorale ; 5 autres présentaient une zone radiotransparente peu étendue en regard du versant antérieur de la prothèse. La radiographie a montré une incorporation des greffons dans 5 des 6 cas qui ont pu être évalués. L'étude histologique de 2 biopsies a montré une incorporation des greffes osseuses fragmentées. Les auteurs recommandent l'utilisation de greffes osseuses fragmentées et impactées pour les défects fermés et pour les défects ouverts de taille moyenne ou petite.