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ORIGINAL PAPER

Onlay fibula autografting technique and its comparison with cortical allograft for the reconstruction of periprosthetic bone defects around the femur

İbrahim Tuncay[1] · Remzi Tözün[2] · Orkhan Aliyev[1] · Göksel Dikmen[2] · Gökçer Uzer[1] · Vahit Emre Özden[2] · Fatih Yıldız[1]

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Abstract

Background Bone defect around the femur related to revisions or periprosthetic fractures (PFF) is an issue. We present a bone defect reconstruction technique in femoral revisions and/or PFF using fibula autograft and compared our radiological and clinical results to that of allograft.

Methods A total of 53 patients who underwent revision hip arthroplasty and/or PFF fixation with the use of cortical fibula autograft (FG group) or cortical allograft (CG group) were evaluated. After exclusions, 20 patients who had minimum two years of follow-up were investigated for each group, for their radiological and clinical outcomes.

Results In FG and CG groups, the median ages were 69.5(44–90) and 62(38–88) years, follow-ups were 59(28–72) and 120(48–216) months, defect lengths were seven (1–10) and ten (1–17) cm, and grafts lengths were 16.5(10–30) and 20(12–37) cm, respectively. The rate of graft incorporation was 90% in each group and median time to incorporations were seven (4–12) and 12(6–24) months ($p < 0.001$), and graft resorption (moderate and severe) rates were 10% and 25% ($p = 0.41$), respectively. Median Harris Hip (77.6 vs 78.0), WOMAC (23.2 vs 22), SF-12 physical (50.0 vs 46.1), and SF-12 mental (53.8 vs 52.5) scores were similar between the groups, respectively. Kaplan–Meier survivorship analyses revealed an estimated mean survival of 100% at six years in FG group and 90% at 14 years in CG group.

Conclusion In the reconstruction of periprosthetic bone defects after femoral revision or PFF, onlay cortical fibula autografts provide comparable clinical and radiological outcomes to allografts. Its incorporation is faster, it is cost-effective and easy to obtain without apparent morbidity.

Keywords Fibula · Autograft · Allograft · Hip · Arthroplasty · Periprosthetic fracture · Revision

Introduction

Total hip arthroplasty (THA) is known to be one of the most successful orthopaedic procedures in terms of high patient satisfaction and low complications rates by means of improvements in the surgical techniques and implant technologies. However, as the number of hip replacements and life expectancies increase around the globe, the numbers of revisions or re-

✉ Fatih Yıldız
yildizfatih@hotmail.com

İbrahim Tuncay
ituncay@bezmialem.edu.tr

Remzi Tözün
rtozun@acibadem.com

Orkhan Aliyev
orkhanaliyev@outlook.com.tr

Göksel Dikmen
goksel.dikmen@acibadem.com

Gökçer Uzer
gokceruzer@yahoo.com

Vahit Emre Özden
emre.ozden@acibadem.com

1 Department of Orthopedics and Traumatology, School of Medicine, Bezmialem Vakif University, Adnan Menderes Blv., Fatih, Istanbul 34093, Turkey

2 Department of Orthopedics and Traumatology, School of Medicine, Mehmet Ali Aydınlar University, Acibadem Maslak Hospital, Darüşşafaka Büyükdere Caddesi No No:40, Sarıyer, Istanbul 34457, Turkey

operations increase [1, 2]. There are several reasons for femoral component revisions after hip arthroplasty such as septic revisions, aseptic loosening, component malpositioning-related complications, bearing wear, and trunniosis [3–8]. Moreover, sometimes re-revisions are required, even in the relatively younger patients [9, 10]. Regardless of the etiologies, all those revisions on the femoral side have potential to create severe metaphyseal or diaphyseal bone defects.

Another concern associated with the hip arthroplasty is periprosthetic femoral fracture (PFF). We have done more THA to elderly patients in recent years because of longer life and their improved health status. On the other hand, this may result in increased number of PFF, and these fractures sometimes create bone defects around the femoral component or distal to it, especially in the osteoporotic elderly patients.

When the revision of the femoral component and/or fixation of a PFF is planned in patients with bone defects on the femur, the surgeons should consider that poor bone stock can cause low functional outcomes [11], femoral stem subsidence [12], PFF [13], sometimes implant fracture [14], malunion or nonunion [15], and re-fractures [16, 17]. In order to decrease those complications and provide bone stock for the possible re-revisions, use of cortical onlay strut allografts has been recommended to reinforce the deficient femurs during the revisions and/or the fixation of PFF [18–23].

Even though cortical strut allografts are useful and inevitable for some specific cases, they come with some problems: Their costs are high and there are difficulties in obtaining, especially in some regions, and they create risks for infection transmission [24–26]. Thus, we searched for an alternative method.

Non-vascularized autogenous cortical bone grafts have been used for the reconstruction of bone defects in different fields of orthopaedics for the past 100 years. The first description of their use was in 1911 [27]. Successful results of fibular autograft in different orthopaedic procedures have since been reported [28, 29]. Among them, the use of non-vascularized fibular autografts has been reported to be simple and shorter procedures with strong [30], but less expensive constructs [28].

The literature regarding the use of onlay cortical fibula autografts instead of cortical allografts for the reconstruction of femoral defects in femoral component revisions and/or PFF fixations is lacking. We do not know whether it is useless or not according to evidence based medicine. Moreover, to our knowledge, this technique has not been described before in the literature for femoral defect revision. We hypothesized that use of onlay fibula autografts in the reconstruction of periprosthetic bone defects can provide comparable results to cortical allografts. The purpose of the present study was to describe surgical technique of using fibula strut autograft and compare its outcomes to cortical allografts in the reconstruction of bone defects.

Materials and methods

This retrospective study was approved by our Institutional Review Board (45446446-020-5169) and conducted according to Declaration of Helsinki for Human Studies. Using the hospital databases, we searched for all femoral component revisions and PFF surgery that was operated on between December 1999 and April 2018. A total of 53 patients were evaluated who underwent revision hip arthroplasty and/or PFF fixation with the use of onlay cortical fibula autograft (FG group) or cortical allograft (CG group). We included patients who had enough documentation and at least 24 months of follow-up. In the FG group, three patients were excluded due to early mortality not related to the technique and two patients were excluded because of shorter follow-up period. In the CG group, five patients were excluded because their femoral defect sizes (Paprosky type 4) were not comparable to the FG group, two patients were excluded because of early post-operative death, and a patient was excluded due to use of tumour prosthesis. Finally, 20 patients were remained in each group.

All patients in the FG group were operated by one of the senior authors (IT) in one centre and patients from the CG group were operated by the senior author (IRT) from another centre. Both are high-volume arthroplasty surgeons.

All data were gathered from the hospital databases, patient charts, digital files. and digital or conventional radiographs. We noted the reasons for the index surgery and the final surgery at which the grafts were used. All patients with the diagnosis of PFF were classified according to the Vancouver classification [31], and patients who had bone defects during revision surgery were classified according to Paprosky types [32]. Because four patients from each group had intra-operative femur fracture during revision of the femoral stems, they were classified with both systems. Lengths of the bone defects, which were measured intra-operatively and recorded to operation notes, were obtained from the documents. Lengths of the grafts were defined as total lengths of the grafts used side-by-side or end-to-end for allografts and harvested length for fibula.

Surgical technique of fibula autografting

We used autogenous fibula grafting mainly for two conditions: first, in cases of the remaining diaphyseal cortical bone defects after stable fixation of the revision femoral components and, second, after plate fixations of the periprosthetic femoral fractures, especially in comminuted Vancouver type B or C fractures with bone defects. For both conditions, graft harvesting and its application methods were similar.

For the revision cases, after checking final positions of the implants and stability of the joint using the trial implants, the prostheses are inserted and remaining bone defect is evaluated. For the periprosthetic fracture cases, a direct lateral approach is used, the fracture is reduced and fixed preferentially using limited contact, locking compression plates (LCP), or distal femur locking compression plates (LISS) according to the level of the fracture. Stable fixation is achieved using locking screws for the distal part and unicortical locking screws and cables for the proximal part. Then the bone defect around the fracture site is evaluated for the decision of grafting.

A straight, lateral incision over the fibula starting at 5-cm distal from tip of the fibular head to 7 cm proximal from distal fibular tip is made. After incising the fascia, peroneal muscles retracted and the periosteum over the lateral fibula is incised. All muscles around the fibula were dissected off subperiosteally, between the levels of bone cuts. For the proximal fibula, careful dissection is necessary not to damage the peroneal nerve and for the distal fibula, cut level of osteotomy should be decided carefully in order to protect the syndesmosis. The fibula graft is bisected and divided longitudinally using a narrow oscillating saw to obtain four cortices with fresh bone marrow and spongiosa inside (Fig. 1). The fibula grafts are put to the defect area side-to-side, so that the inner sides of the grafts are placed over the defect and intact cortices of the femur. The grafts are then fixed to the host bone with surgical cables or cerclage wires and the wound is closed (Figs. 2 and 3).

Surgical technique of cortical strut allografting

In our series, the decision to use a CG was made by the senior surgeon (IRT) if axial and/or rotational stability of the trial revision femoral component was not satisfactory or if the remaining bony defect was large, after cemented or cementless acceptable distal fixation of the stem was achieved. It was also applied to support a large bone defect during fixation of PFF. The grafts are placed and fixed over the defect area with careful dissection of the soft tissues to maintain femoral blood supply, especially at the linea aspera. After checking final implant positions and stability of the hip, the wound is closed.

Post-operative follow-up

As standard rehabilitation protocols in both centres, all patients were allowed partial weight-bearing on the first or second day after the surgery. Full weight-bearing was allowed at the sixth or eight week post-operatively. Our weight-bearing

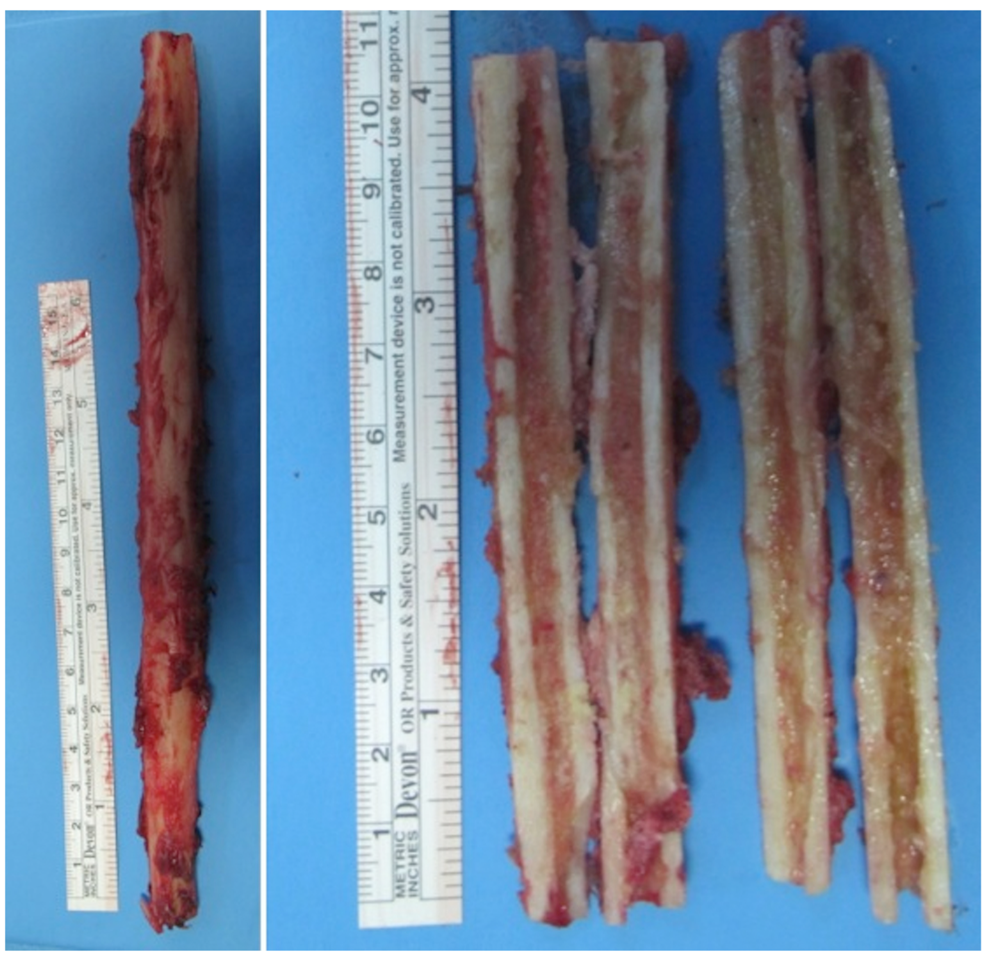

Fig. 1 After harvesting 20 cm of non-vascularized autogenous fibula, it is bisected and each part was divided longitudinally; therefore, four pieces of the fibula with 10 cm each were obtained

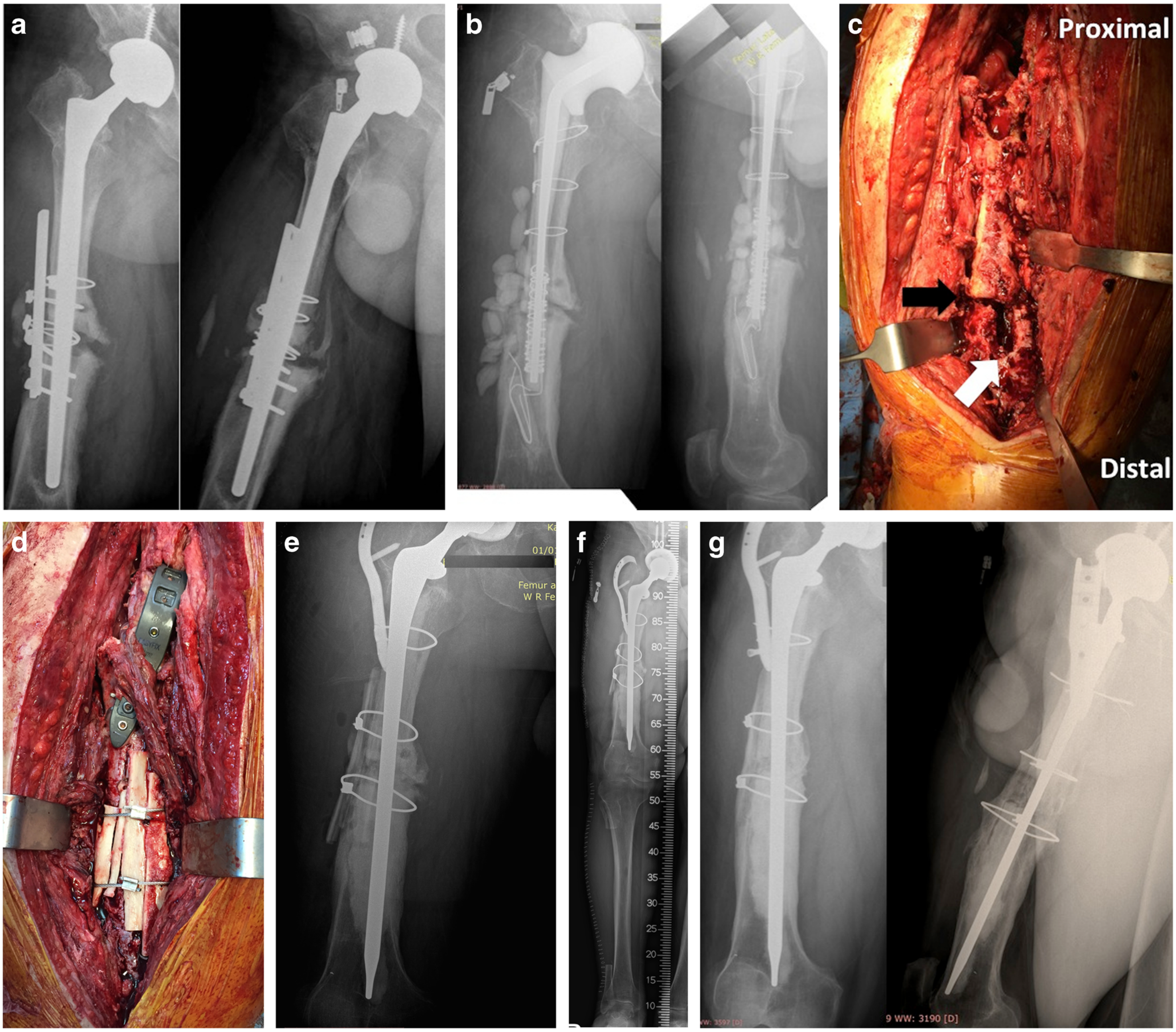

Fig. 2 **a** Anteroposterior and lateral radiographs of a 60-year-old male who presented with septic loosening and nonunion of the index diaphyseal fracture. **b** Femoral stem was loose distally but well-fixed proximally; therefore, we made extended trochanteric osteotomy for stem removal, debridement, and antibiotic loaded spacer and **c** showing Paprosky type 3B bone defect with diaphyseal nonunion (black arrow) and cortical window (white arrow) at the second stage. **d** The fibula autografts were placed over the defect and fixed with two cables after cemented fixation of the long revision stem, and greater trochanter was reattached. Early post-operative radiographs of **e** the femur and **f** full length. **g** Anteroposterior and lateral radiographs 3 years post-operatively show complete graft incorporation

protocol was not directly related to radiographic union in this series. For the clinical and radiographic follow-up, they were seen on the sixth week, third month, sixth month, first year, and annually after that.

Outcome parameters

Primary outcome of this study was to compare graft incorporation rates and times to incorporation, between FG and CG groups. We evaluated graft incorporation according to the Emerson classification and noted incorporation time by evaluating radiological bridging on the anteroposterior and lateral radiographs; however, biplanar assessment was difficult in some cases because of metallic implants. Secondary outcomes of the study were comparisons of graft resorption rates, stem subsidence and malalignment, complication rates, and the functional outcomes using Harris Hip Scores (HHS), the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and the Short Form-12 (SF-12) scores. Survival analyses were made for both group, defining femoral revision as endpoint.

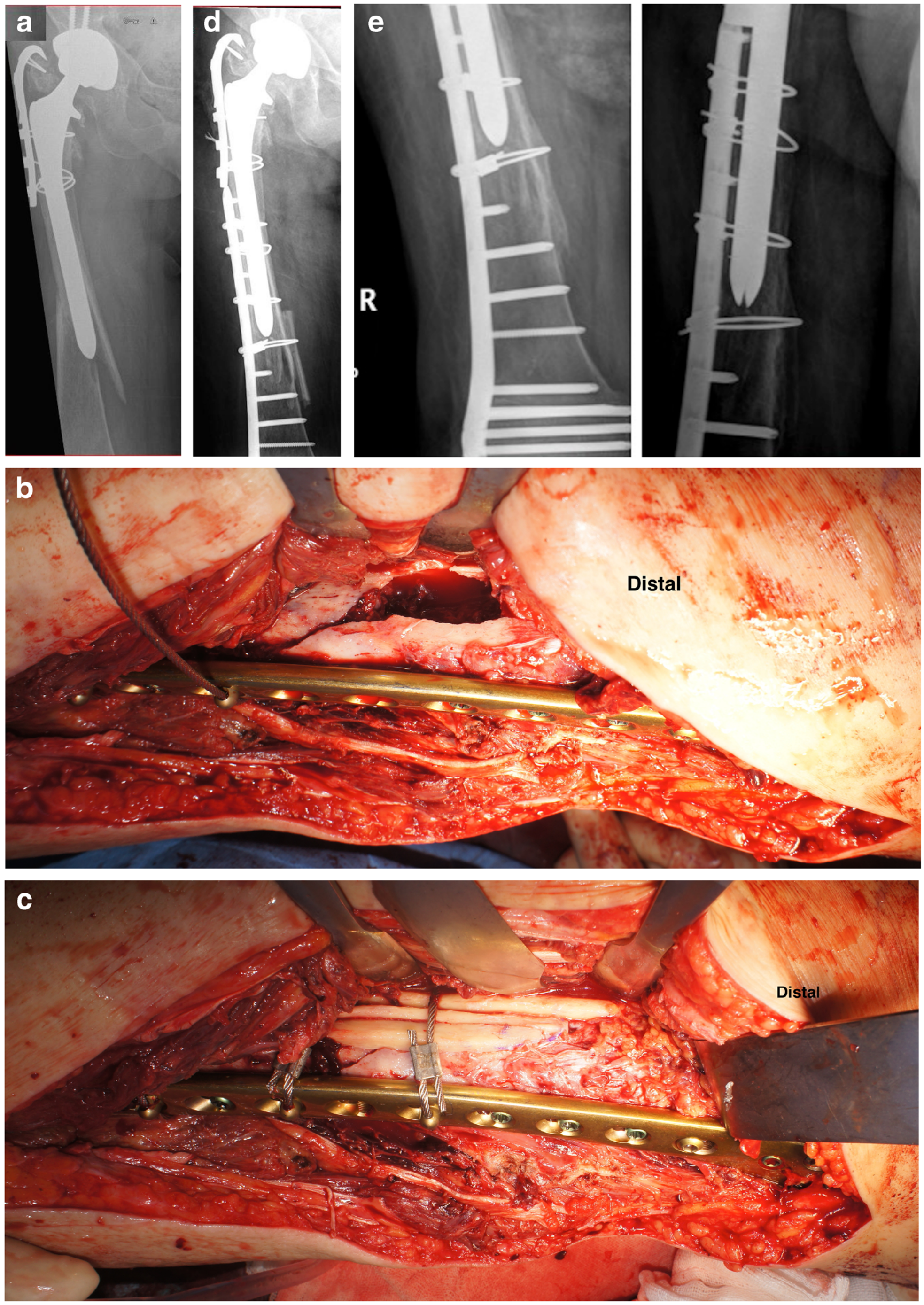

Fig. 3 **a** Vancouver type B1 periprosthetic fracture in an 82-year-old female. **b** Anteromedial defect after anatomical reduction of the fracture. **c** 15 cm fibula harvested, bisected and divided into four, and placed anteriorly and medially over the defect. **d** Early post-operative radiograph. **e** Anteroposterior and lateral radiographs taken at the first year post-operatively show complete union and graft incorporation

Resorption of cortical strut onlay allograft was evaluated comparing the initial and final radiographs of a patient and graded as follows [33]: none; mild, less than 50% of allograft thickness in one or two zones; moderate, less than 50% of thickness of allograft in more than two zones or greater than 50% of thickness but not fully thickness in one or two zones; or severe, full thickness in any zone or greater than 50% of thickness in more than two zones. The same method was applied to the FG group.

Statistical analyses

Kolmogorov–Smirnov and Shapiro–Wilk tests showed that the data were not normally distributed ($p < 0.001$). Categorical variables were analyzed using the chi-square test or Fisher's exact test and continuous variables were tested using the Mann–Whitney *U* test. Spearman correlation coefficients were used to evaluate the relationship between the graft lengths and the graft incorporation time. The estimated survivorship of the femoral stem was calculated using the Kaplan–Meier method. We have considered any revision of the femoral stem as an endpoint. The statistical analyses were performed using IBM SPSS Statistics for Windows, ver. 22.0. (IBM, Armonk, NY). Significance was set at $\alpha < 0.05$.

Results

Forty patients (37 female, 92.5%) with a minimum follow-up of 2 years (mean 7.1 years, ranging from 2.3 to 18 years) and with the mean age of 65.3 ± 13.5 years (range, 38 to 90 years) were evaluated (Table 1). The mean BMI was 28.6 kg/m^2 ± 4.4 kg/m^2 and the median ASA score was 2 (range, 1 to 3). The median number of previous revisions was three (range, 0 to 6). The median follow-up was significantly higher in the CG group than in the FG group ($p < 0.001$).

The reasons for the surgeries in FG group were PFF ($n = 8$), second stage of two-stage revision due to prosthetic joint infection ($n = 6$), aseptic loosening of the femoral component ($n = 3$), and nonunion of the previously fixed PFF ($n = 1$), subtrochanteric fracture ($n = 1$), and subtrochanteric osteotomy ($n = 1$). Four patients had intra-operative PFF during the revision. Types of PFF and femoral bone defects are given in Table 2. Seven patients were treated with open reduction and internal fixation (ORIF), one patient treated with only grafting and the remaining 12 patients were treated with revision of the femoral components using long, extensively coated modular femoral stems (Arcos Revision Stem, Zimmer Biomet, Warsaw, USA) in six patients, monoblock stem (Wagner SL, Zimmer Biomet, Warsaw, USA) in four patients, and long cemented stems in two patients (CRC cemented revision, Zimmer Biomet, Warsaw, USA). In 12 patients, plates were used for fixation of PFF ($n = 9$) or trochanteric fracture ($n = 3$). They were LISS ($n = 5$), grip-plate ($n = 4$), Dall-Miles plate ($n = 2$), and LCP ($n = 1$). The median numbers of proximal and distal screws were two (1 to 7) and 6 (2 to 9), and cables were three (1 to 5) and one (1 to 3), respectively. The mean defect length was 6.1 cm and the mean graft length was 17 cm (Table 3).

In the CG group, the reasons for the surgery were aseptic loosening ($n = 12$), PFF ($n = 5$), and nonunion of the subtrochanteric osteotomy ($n = 2$) and previously fixed PFF ($n = 1$). Four patients had intra-operative PFF in this group during the femoral component revisions and all were treated with long revision stems. One patient with pre-operative PFF was treated with ORIF using DCS plate screw and cables, and the remaining 19 patients underwent femoral component revisions using long, extensively coated distal fluted cementless femoral stems in 18 hips (Echelon Porous Plus HA, Smith&Nephew in 20 hips and Solution System; DePuy in 2 hips), and a tapered rectangular stem in one hip (SLR-Plus; Smith&Nephew). No screw was used in this group, and the median number of proximal and distal cables were two (1 to 3) for each side. One CG was used in 13 hips (65%), and two were used in seven hips (35%). Seventeen grafts were freeze-dried and irradiated, and the remaining grafts were fresh-frozen. The mean defect length was 8 cm and the mean total graft length was 20.5 cm.

Table 2 Types of periprosthetic fractures (Vancouver classification) and bone defects (Paprosky classification) in both groups

Variables	Fibula autograft group ($n = 20$)	Cortical allograft group ($n = 20$)
Periprosthetic fracture types		
B1	6	2
B2	1	3
B3	4	4
C	0	2
Types of bone defects		
I	0	1
II	1	6
IIIA	6	5
IIIB	6	7

Table 1 Summary of demographic information of the patients from each group

Variables	Fibular autograft group ($n = 20$)	Cortical allograft group ($n = 20$)	p value
Median age (range)	69.5 (44–90)	62 (38–88)	0.15
Sex, female	18 (90%)	19 (95%)	0.50
IQR of ASA scores	2 [1–3]	2 [1–3]	0.25
Median numbers of revisions (range)	3 (0–5)	3 (1–6)	0.25
Median follow-up time (range), months	59 (28–72)	120 (48–216)	< 0.001
Smokers	3 (15%)	3 (15%)	1.00

IQR interquartile range, *ASA* American Society of Anesthesiologists Classification

Table 3 Bone defect and graft lengths and radiological results showing graft incorporation, stem stability, and complication rates

Variables	Fibular autograft group ($n = 20$, 50%)	Cortical allograft group ($n = 20$, 50%)	p
Median defect length (range), cm	7 (1–10)	10 (1–17)	0.47
Median graft length (range), cm	16.5 (10–30)	20 (12–37)	0.22
Incorporation rate	18 (90%)	18 (90%)	1.00
Median time to incorporation (range), months	7 (4–12)	12 (6–24)	*< 0.001*
Graft resorption rate (moderate and severe)	2 (10%)	5 (25%)	0.41
Complication rate	7 (35%)	7 (35%)	1.00
Stem subsidence (range), mm	0 (0–7)	1 (0–3)	0.27
Coronal malalignment, (range), degree	0 (0–10)	0 (0–8)	0.41

p <0.05 means statistically significant difference between the given parameters

The median defect and graft lengths were similar between the groups ($p = 0.47$ and $p = 0.22$, respectively). In both groups, the rate of graft incorporation was 90%. The median time to graft incorporation was significantly less in FG group than CG group ($p < 0.001$). In the FG group, 16 grafts healed completely, two grafts healed partially, and two grafts did not incorporate. In the CG group, 13 grafts were completely incorporated, five grafts were partially incorporated, and two grafts did not heal. Table 4 shows graft incorporation in both groups according to the Emerson classification. Moderate and severe graft resorption was less in the FG group (10% vs. 25%) but the difference was not statistically significant ($p = 0.41$; Table 5).

The mean amounts of stem subsidence and stem malalignment at the follow-up were also similar between the groups ($p = 0.272$ and $p = 0.408$, respectively).

At the last follow-up, the median HHS, WOMAC, SF-12 physical, and SF-12 mental scores were similar between the groups. In the FG group, 13 patients were able to walk without a support and five patients with a cane and two patients with a walker. In the AG group, 12 patients were able to walk without a support and eight patients with single cane (Table 6).

There were seven complications in each group. In the FG group, none of the femoral stems have revised during the follow-up period. Three patients had hip dislocation: One revised with constrained cup, one with dual mobility cup, and one patient who had accompanying acute prosthetic joint infection treated with DAIR procedure with removal of the grafts and open reduction. One patient underwent acetabular component revision due to early loosening. Two patients had grip-plate irritation: One removed at the eighth month and another at the third year, post-operatively. One patient had superficial surgical site infection and treated with short-term antibiotherapy. In the CG group, two patients had femoral component loosening: one of them was revised with extensively porous coated long stem and another patient revised at the fourth year post-operatively, with bone impaction, mesh, and cemented femoral component. One patient had hip dislocation twice at the third and fourth year and revised with all-poly cup and then with the constraint cup. One patient had type C periprosthetic fracture and treated with cast because of comorbidities. Grip-plate was removed in a patient at the sixth month due to irritation. Two patient were followed conservatively because of acetabular loosening and displaced trochanteric nonunion. Kaplan–Meier survivorship analyses revealed an estimated mean survival in the FG group which was 100% at two years and at the end of 72 months follow-up, and in the CG group was 100% at two years and 90% at 14 years.

None of the patients in the FG group had complaints in their ankles, knees, or donor sites. There was no clinically apparent donor site morbidity associated with fibula graft-

Table 4 Emerson classification for graft incorporations in both groups

	Fibular autograft group ($n = 20$)	Cortical allograft group ($n = 20$)
I—Rounding off		
II—Scalloping		1
III—Partial bridging	6	6
IV—Complete bridging	11	11
V—Cancellization		
VI—Resorption	3	2

Table 5 The amount of graft resorptions in both groups

	Fibular autograft group ($n = 20$)	Cortical allograft group ($n = 20$)
None	8	
Mild	10	15
Moderate	1	5
Severe	1	

Table 6 Functional outcomes at the last follow-up of the patients

Variables	Fibular autograft group ($n = 20$)	Cortical allograft group ($n = 20$)	p
HHS scores, median (range)	77.6 (70–85.3)	78.0 (35–90)	0.86
WOMAC, median (range)	23.2 (19.5–34)	22.0 (14.0–53.0)	0.36
SF12 physical score, median (range)	50.0 (43.3–57.3)	46.1 (31.8–57.6)	0.04
SF12 mental score, median (range)	53.8 (42.0–62.0)	52.5 (43.0–60.0)	0.26

harvesting procedures such as peroneal nerve palsy, incisional pain, or ankle instability during the follow-up period.

Discussion

An important strength of this comparative study is that the use of cortical fibula onlay autografting in the reconstruction of periprosthetic femoral defects, and their comparison with the cortical strut allografts in terms of graft healing rates and times, and their success rates have not been published before. The most important outcome of this study is that in the reconstruction of PFF and Paprosky type II or III bone defects, the use of autogenous fibula onlay grafts provides comparable radiological and clinical outcomes to cortical allografts. The main purpose of using a structural graft is to have graft–host bone incorporation, which provides bone stock and mechanical support. The results of the present study showed that the rate of graft incorporation was similar to allograft. More importantly, the healing was achieved earlier with the fibula autografts than the allografts. This result was not a surprise to us because autografts are fresh viable tissues with cancellous parts and the bone marrow, which means that they are not only osteoconductive but also osteoinductive and osteogenic grafts. This is the main advantage of autogenous fibula grafts compared to cortical allografts. Jeffrey et al. have compared fibular allograft with autograft in multilevel cervical spondylosis in terms of fusion rates, and they found that there is not statistical difference [34]. Faldini et al. showed that there is no difference between fibular autograft and cortical allograft in terms of surgical treatment of aseptic forearm nonunion with plate [35]. Kim et al. showed that supportive cortical strut onlay allografts provided high survivorship beyond 12 years of follow-up [23]. In their cohort, the mean Harris Hip and WOMAC scores were similar to our results. In the literature, after such revisions, the time for full weight-bearing mobilization of patients has been shown between three and seven months [23, 36]. We allowed full weight-bearing mobilization in the second month without waiting for a complete union. In our series, 13 patients in the FG group and 12 patients in the CG group were able to do full weight-bearing without any support. Similar results have been reported in the literature [23, 36]. Total complication rates are higher compared to primary total hip arthroplasties and are consistent with the literature [7, 9, 15, 37]. Dislocation rates, periprosthetic fracture rates, periprosthetic joint infection rates, and aseptic revision rates are also similar to the literature and seem to be high.

In the orthopaedic field, surgical techniques, implant technologies, and biological solutions by the industry are rapidly increasing. However, they are most of the time costly and sometimes can be difficult to obtain. The use of allografts in different fields of orthopaedics is not new but they are expensive and not always easy to obtain. In addition, there are some other concerns regarding use of allografts to reconstruct bone defects in revision hip arthroplasty. Transmission of the viral and bacterial diseases is one of them, although its reported rate is very low [24–26]. Another concern is whether using a fresh-frozen or a freeze-dried, irradiated non-viable bone tissue in the second stage of septic revision can increase recurrence of prosthetic joint infection [26]. Fibula autografts have been shown to be a successful option for the reconstruction of large bone defects due to tumour, trauma, tibial bone gaps after war injuries, and osteomyelitis in the adult or paediatric population [28, 29, 38, 39]. Contrary to disadvantageous of cortical allografts, harvesting a patient's own fibula and its application is easy, is cost-effective, and there is no risk of infection transmission, and donor site morbidity of this procedure as a disadvantage is not evident. Therefore, all those issues have encouraged us to reconsider a well-known technique and to use it with some modifications, in the reconstruction of femoral defects instead of using cortical strut allografts.

Reconstruction of the osseous defects in revision cases or in fixation of PFF is necessary and this has been achieved with the structural allografts [18]. Successful use of cortical allografts for fixation of PFF [22] and reinforcement [18–21] of the structurally compromised proximal femur at the time of revision hip arthroplasty has also been reported. Although they have some disadvantageous as mentioned above, we found similar incorporation rates in our series.

Cortical allografts have also some superiority to fibula autografts. They are larger and longer than the fibula in size and therefore can be used in larger defects. In addition, because their cortices are much thicker than the fibula, they can theoretically provide higher mechanical strengths to the constructs. However, in a biomechanical study, Sariyilmaz et al. showed that in the Vancouver type B1 PFF model, the use of structural allograft significantly increases rigidity of the fixation but not the failure load [37]. In another words, fracture fixation with LCP and bicortical and unicortical locking screws and cables without using structural graft can afford about 4 times body weight for a 90-kg patient. If there were no gaps around the fracture, it would be higher. This is an in vitro result and may not completely simulate biologic environment. Lochab et al. compared the results of LCP-allograft and LCP-locking attachment plates in a biomechanical study and they stated that these two constructs provide similar mechanical strength in different loading models [40]. Previous techniques described by Ogden et al. [41] include the use of allografts and cable or cerclage wire fixation because of the stem inside medullary of the proximal part and difficulties in placing screws [17]. However, with the advent of locking plate technologies, better fixation strength can be achieved as described by Fulkerson et al. [42–45]. We do not know whether biomechanical strength of reconstruction with fibula graft is comparable to that of allograft. But, it should not be an issue because as Zdero et al. reported, immediate postoperative stability of constructs in PFFs has moderate importance clinically because most failures occur at an average of 22 months after initial fixation [46, 47].

In our experience, fibula autografts can be used in revision cases if stable distal fixation of the prosthesis is achieved. Otherwise, fibula autografts cannot provide enough stability to the implants. However, we did not find a higher rate of mechanical failure in revision or fracture cases in the FG group compared to the allograft group. Earlier graft incorporation in this group may be a reason for prevention of the mechanical failure due to thin cortices of the fibula.

Another important point of this study is evaluation of the complications in both techniques. Although non-vascularized fibular grafting is a simple procedure and has much better patient compliance [29], fibula harvesting has potential risks for the donor site as peroneal nerve damage, wound-healing problems, pain, and functional limitations around the leg and foot. However, we did not observe any donor site morbidity in our patients during the follow-up periods. None of the patients in our series reported functional complaints or pain around their ankles or knees. The reason can be lower expectation and limited activity because of recurrent revisions and surgeries in older patients. Although most of the patients in this study had extended exposures, none of them had wound-healing problem except of one patient with the diagnosis of acute prosthetic joint infection that were treated successfully with the DAIR procedure and removal of the grafts. Although it is shown that the fibular donor site is regenerated in the paediatric age group [48], the literature reports superficial peroneal neuroma (1.2%), prolonged incisional pain (15%), tibial stress fracture (3%), ankle instability (1.2%), superficial infection that responded to short-term oral antibiotics (9%), and deep infection (0.6%) requiring debridement [49], as complications related to fibular graft harvesting. In the present study, the rates of complications were similar in both techniques and none of the complications were directly related to grafting procedure in both groups. The literature is not satisfied regarding the complications of cortical allografts but some compromises during their application including vascular injury and infection have been reported [24–26, 49]. The most obvious disadvantage for us was routine availability of sufficient quantities of suitable allografts at the time of surgeries [50].

In patients with re-revisions and severe bone defects, mega-endoprostheses can be an alternative option. Compared to other reconstruction methods, mega-endoprostheses can provide shorter surgical time, immediate full weight-bearing and mobilization, satisfactory functional results, and good overall results. On the other hand, it should be considered as the last alternative because of its some disadvantages: It has high costs compared to standard revision stems, high rate for the risk of periprosthetic joint infections (as high as 36%), and abductor insufficiency due to large resections [51, 52]. Moreover, it is not a suitable method for patients with younger age and less severe bone defects as in our series [51–53].

Limitations of the study

Because this study is the first to compare fibular strut autografts and cortical strut allografts in hip arthroplasty, we had some limitations and our findings should be interpreted accordingly. First, all surgery were performed by two senior authors in two arthroplasty centres. Therefore, there may be some variables that we could not take into account. Second, although same surgical techniques were applied within the groups in terms of grafting procedures, femoral stem selections and patient groups were not completely homogenous and included both periprosthetic femoral fracture fixation and/or femoral component revision surgeries with variable numbers of cables or plates. Third, a single independent surgeon interpreted all radiological results and we did not check inter-observer reliability regarding radiological incorporation. And evaluation of graft incorporation on the radiographs was difficult in some cases because of metallic implants. Lastly, we could evaluate patients in terms of post-operative functional results using objective measurement tools of function and pain scores because we could not reach pre-operative functional scores in some patients.

Conclusion

Our technique reveals that in the reconstruction of femoral diaphyseal bone defects, autogenous fibula strut grafting seems to be a good alternative to cortical allografting if stable fixation of the femoral prosthesis is achieved. Although both techniques have similar and high success rates, bony incorporation is faster in autogenous fibula grafting. Additionally, it is safe, cheap, and easy to obtain without apparent donor site morbidity.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical review committee statement This retrospective study was approved by the institutional review board (45446446-010.99-5866).

A statement of the location where the work was performed Patients who were reconstructed with fibular autograft were applied in Bezmialem Vakif University Hospital, and patients who were reconstructed with cortical allograft were applied in Acibadem Maslak Hospital.

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