Int J Clin Exp Med 2016;9(7):13527-13538
www.ijcem.com /ISSN:1940-5901/IJCEM0023761

Original Article

Initial application of backbone artificial prosthesis in reconstruction for bone defects after proximal femur malignancy excision

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Received January 11, 2016; Accepted April 6, 2016; Epub July 15, 2016; Published July 30, 2016

Abstract: Objective: This study aims to discuss the feasibility of backbone artificial prosthesis in the structural reconstruction for bone defects after excising backbone malignancy in the proximal femur. Methods: Seven patients with bone malignancy in the proximal femur underwent backbone artificial prosthesis replacement. Backbone artificial prosthesis accessories were selected by X-ray, CT and MR examination before the operation. Skin and subcutaneous tissues were incised layer by layer in a straight incision outside the proximal femur. Then, bones with tumors and soft connective tissue tumors were detected by MRI before the operation, which was fully exposed in the principle of tumor incision; and osteotomy was performed. After expanding the marrow, the backbone artificial prosthesis was installed and tissues were sutured layer by layer. Results: After 6-24 months of follow-up, hip joint function was not limited in the seven patients after the operation. Conclusions: Structural back defects were reconstructed after incising backbone malignancy in the proximal femur with backbone artificial prosthesis, and the adjacent hip joint and attachment point at the tendon were preserved. Hospital time was short, but with early loading. Therefore, this is an ideal limb-saving surgical treatment.

Keywords: Femur, tumor, prosthesis, implantation materials

Introduction

Morbidity in femoral stem tumors is low [1]. However, this tumor has drawn great attention due to the large bodily harm it causes after tumor segment incision and difficulties in reconstructing structural bone defects in the big segment of the loading bone. Anatomically, the femur is the longest tubular bone in human body, and the femoral stem refers to the part that starts from the lower lesser trochanter to the femoral condyle, which has a length of approximately 33 ± 2 cm. For backbone tumors in different areas in the hip and knee joints, or between both, reconstruction methods are different after incision due to differences between the neighboring anatomical structure and backbone morphology. In order to develop the research on bone defect reconstruction after incising femur stem tumors, we divided the femur into three areas (areas A, B and C) during the early fundamental research. Area A is from the lower limb of the lesser trochanter to a level 10 cm away from the lesser trochanter; area B is the backbone part between areas A and C; area C is from a level 10 cm away from the proximal femur condyle to the femur condyle (**Figure 1**). In femoral stem tumors, the ratio of a tumor appearing in area A is significantly higher than that in areas B and C. Moreover, the canal geometry of area A has a large difference with that in areas B and C, while this position is much closer to the hip joint. Therefore, research on structural bone defect reconstruction in the big segment of area A after malignancy incision has more urgency and clinical significance.

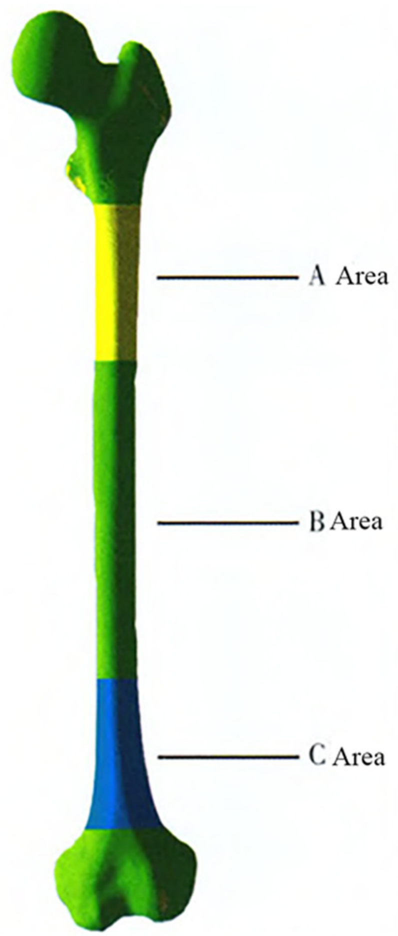

Figure 1. Schematic diagram of divisions in femur stem area A (yellow): From the lower level of lesser trochanter to 10 cm away from lesser trochanter; area B (green): Backbone area between area A and area C; area C (blue): from 10 cm level of proximal femoral condyle to that of femoral condyle.

In the past, the replacement of tumor-type artificial joint prosthesis has always been taken for the reconstruction of malignancy in area A. This method can be employed to reconstruct bone defects and realize early recovery of joint function, but sacrifices the hip joint not affected by tumor. Moreover, unnecessary osteotomy length increases and affects the stability of the prosthesis. Therefore, the probability of long-term loosening and renovation would be larger [2]. In addition, there are some other reconstruction methods such as massive allograft transplantation, inactivation and replantation of autologous tumor bones *in vitro*, autogenous bone graft and bone transportation all aim at preserving normal hip joints. However, all these methods have a high occurrence rate of complications [3-22] with poor curative effects. Therefore, the application of these methods is limited to the limb-saving treatment of tumors in area A. We designed a backbone artificial prosthesis for area A to reconstruct structural bone defects in a big segment after incising malignancy in area A of the femoral stem. This novel method for bone defect reconstruction can preserve the neighboring hip joint and required attachment point at the tendon in the reconstruction of soft tissues, and avoid or reduce complications including postoperative bone nonunion, delayed union, immunological rejection and infection; improving the effect of limb-saving treatment in area A of the femur stem. This retrospective study analyzed data of patients with malignancy in area A of the femur stem, who underwent a limb-saving operation with artificial prosthesis. This analysis attempted to realize the following research objectives: (1) to discuss the indications in the reconstruction of backbone artificial prosthesis in area A; (2) to evaluate the advantages of reconstruction for backbone artificial prosthesis in area A; (3) to conclude technical points on the reconstruction for backbone artificial prosthesis in area A.

Data and methods

Clinical data

Inclusion and exclusion criteria: Inclusion criteria: (1) primary malignant neoplasm in area A of the femur stem; (2) metastatic cancer in area A of the femur stem with life expectancy l >6 months; (3) primary malignant neoplasm or metastatic cancer in area A of the femur stem for existing pathological fractures or close pathological fractures (Mirels fracture risk assessment criteria >9 points). Exclusion criteria: (1) distance between the proximal boundary of the tumor and greater trochanter of the femur is less than 5 cm; (2) acute or active infection at any part has not been controlled.

General data: Seven patients with malignancy in area A of the femur stem from June 2011 to July 2014 received backbone artificial prosthesis replacement, including three male patients and four female patients; and age of patients were within 28-76 years old, with an average age of 61.8 years old. Four patients had primary malignant tumors, in which one patient had osteosarcoma, one patient had parosteal osteosarcoma accompanied by pathological fractures, one patient had malignant lymphoma accompanied by pathological fractures, and one patient had soft tissue malignant fibrous histiocytoma accompanied by pathological fractures. Patients with primary tumors were divided into two stages, according to Enneking's staging: stage II A tumors (two patients) and stage II B tumors (two patients). Furthermore, three patients had metastatic carcinoma, which were all breast metastatic carcinomas; including two patients with single osseous metastasis and one patient with multi-bone metastases in the whole body. All three patients have pathological fractures. According to the Tomita body evaluating system, two patients had a score of six and one patient had a score of eight; while according to Mirels scores, two patients had a score of 10 and one patient had a score of 11.

Clinical situation: Six patients presented with pain in the lesion area mainly at night, and oral analgesic intake could not relieve the pain. Visual Analogue Scale (VAS) scores were within 5-9 before the operation, with an average score of seven. Moreover, one patient had no obvious pain in the lesion area. During the physical examination, different sizes of lumps could be felt in the affected limb, which had a tough nature, poor activity and unclear boundaries. For the other four patients, no obvious lumps were felt on the surface. One patient with malignant fibrous histiocytoma in the left femur soft tissue underwent soft connective tissue tumorectomy in a local hospital two years ago. Due to the local large-dose radiotherapy received after the operation, local skin significantly changed. The patient had a pathological fracture 11 months after radiation when walking; thus, internal fixation with a steel plate was received by the patient after undergoing open reduction for the fracture in a local hospital. However, the fracture did not heal six months after the operation, and the steel plate broke after a sprain in the 8th month. One patient with parosteal osteosarcoma in the right femur underwent microwave hyperthermia for excision of parosteal osteosarcoma in the right femur three years ago in our hospital. One and half a years after the operation, a pathological fracture occurred in the right proximal femur after taking an aggravating activity. Imageological examination revealed that the patient had a relapse of parosteal osteosarcoma in the right femur accompanied by a pathological fracture. Then, tumor resection and open reduction by internal fixation with a steel plate were taken. Imageological examination revealed that a relapse of parosteal osteosarcoma in the right femur and an unhealed fracture that occurred eight months after the operation. One patient with proximal femur malignant lymphoma and three patients with proximal femur metastatic cancer of the breast had a pathological fracture in the tumor segment before the operation. All the above six patients had pain in the affected limb with limited activity.

Imageological examination: Seven patients had routine X-ray, CT and MR examinations. Tumors in these seven patients were located in area A of the femur, in which the proximal tumor segment was 9.5-11.0 cm away from the top of the greater trochanter and the distal tumor segment was 12.3-19.2 cm away from the distal articular surface of the femur. Imageological examination revealed primary malignancies in four patients. X-ray and CT images of osteocarcoma in one case revealed a cotton-fiber osteoclasia of bone tissue with a periosteal reaction around it. MRI revealed that the bone cortex with a low signal in T1WI included tumor tissues with a high signal, while T2WI had middle and high signals. The lump in the soft tissue revealed a shadow of mixed signals with unclear boundaries. X-ray and CT images of parosteal osteosarcoma in one case revealed an oval ossified lump outside of proximal femur cortex, the connection between base and bone cortex, and a transmittance between the lump and cortex, which was accompanied with a proximal femur bone fracture with an irregular edge and a broken end. MRI revealed tumor tissues in T1WI with a low-signal area and a clear boundary, and tumor tissues in T2WI had a middle-signal area. X-ray and CT images of malignant lymphoma in one case revealed a mapping osteolytic destruction in the lesion area with a blur edge accompanied with bone fracture and an irregular edge with a broken end. MRI revealed that the tumor tissues in T1WI had a middle signal, while tumor tissues in T2WI had a high signal. With the broken sclerotin, a flake shadow with a high signal appeared in the cavum medullare. X-ray and CT images in the malignant fibrous histiocytoma of soft tissues in one case revealed an osteolytic destruction in the irregular form accompanied by a bone fracture and unclear boundaries of the lump in

Figure 2. Backbone artificial prosthesis is composed of distal handle and proximal handle of cavum medullare, connecting bolt and proximal fixed titanium plate.

soft tissue. MRI revealed a flake shadow with a high signal in T1WI and T2WI, with bone fracture and unclear boundaries.

MRI of three patients with breast femur metastatic tumors accompanied by a pathological fracture revealed a proximal bone fracture in the right femur and an irregular edge at the broken end. A flake shadow with a high signal appeared in the cavum medullare, and a long shadow with T1 and T2 signals can be seen in the surrounding soft tissues.

Preoperative preparation and operation plan

Preoperative radiotherapy and chemotherapy: Among the four patients with primary bone tumors in this group, one patient had osteosarcoma, one patient had parosteal osteosarcoma and one patient had malignant fibrous histiocytoma in soft tissues; and all these patients received the AP plan with doxorubicin and cisplatin for neoadjuvant chemotherapy [23]. Before the operation, 2-3 chemotherapeutic courses were taken. One patient with malignant lymphoma underwent preoperative radiotherapy with a dose of 35 Gy. In addition, CHOP plans with cyclophosphamide, vincristine and prednisone were used for radiotherapy. Three patients with metastatic carcinoma did not take preoperative radiotherapy and chemotherapy.

Determination of osteotomy length and plane: The operation was designed by taking X-ray, CT and MR examinations before the operation to determine the osteotomy length and plane. (1) Osteotomy length: bone length in the tumor segment and the invasive range of soft tissues were determined by MRI for primary malignant bone tumors, and bone length in the tumor segment was determined as the osteotomy length. The objective of the operation for metastatic cancer is to recover the anatomical structure, improve living quality and avoid extensive excision. Therefore, the length of the tumor segment with obvious cortical destruction revealed in X-ray and CT images was taken as the osteotomy length. The marrow was affected, but the structure and tumor segment with cortical structure and good intensity was preserved. During the operation, residual tumor tissues were removed with a curette, and tumor cells were further inactivated by the heat release of bone cement. (2) Osteotomy plane: The lowest point at greater trochanter of the femur (the intersection between the greater trochanter and femur stem) was selected as a marked point. The location of the distal and proximal osteotomy planes were determined by measuring the invasive length of the tumor and the length from the proximal plane of the lesion to the marked point with preoperative MRI.

Parameters of backbone artificial prosthesis: The backbone artificial prosthesis used in this work (Beijing Weigao Yahua Joint Prosthesis Development Co., Ltd., China) is composed of a distal cavum handle, a proximal cavum medullare, two connecting bolts and proximal fixation titanium plates made of titanium alloy (Ti6A14V, **Figure 2**). The reconstruction of the distal and proximal components of the prosthesis was designed as a taper fitting connection; that is, the connection of the prosthesis is in the con-

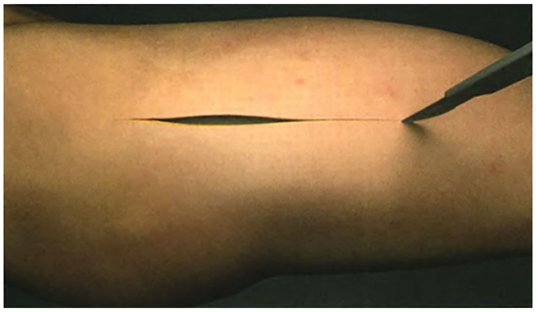

Figure 3. Schematic diagram of operation incision. Straight incision was taken outside of proximal femur, and subcutaneous tissue was cut layer by layer.

cave-convex slot structure in a taper, which has a taper ratio of 1:20 (radius: height). A slot design was used in the distal and proximal cavum medullare stem of the backbone artificial prosthesis to improve rotation resilience. When the diameter of the prosthesis handle was >12 mm, the slot depth was 2 mm; when the diameter of the prosthesis handle was <10 mm, the slot depth was 1.5 mm; and when the diameter is between 12 mm and 2 mm, the slot depth is 1.5-2.0 mm. The connection between the prosthesis handle and reconstruction should take the arc processing to a substitute right angle. The diameter of the handle root should be larger than 1 mm of the distal diameter.

Operation method

Operative route: Three patients received general anesthesia, while four patients received epidural anesthesia. All patients were placed in supine position with the buttock raised at the affected side. A straight incision was made at the outside of the proximal femur (**Figure 3**). The skin, subcutaneous tissues and femoral fascia were incised layer by layer; and the vastus lateralis muscle was split to separate the muscle by blunt dissection and expose the distal part in greater trochanter of the femur, bone in the tumor segment, and tumor in the soft tissue.

Tumor incision: The soft tissue was pulled around to separate the tumor in principle of the tumor incision. With the lowest point at greater trochanter of the femur (the intersection between the greater trochanter and femur stem) as a marked point, the bone length in the tumor segment and osteotomy plane detected by preoperative MRI were measured with calipers; and proximal and distal osteotomy planes were marked. In the osteotomy plane, the periosteum was stripped and the periosteal detacher was replaced at both sides of the backbone to protect the surrounding soft tissue. After the backbone was cut with a sewing machine, the bone in the tumor segment was raised. One layer of normal muscle tissue was preserved on the surface of the malignant primary tumor, and the tumor segment was incised. Then, the tumor tissue was removed at the stub end of the host bone with a curette for patients with metastatic cancer.

Prosthesis installation: Before installing the prosthesis, the normal force line of the backbone was marked, or the primary anatomic landmark of the backbone was used as reference in the restoration to avoid rotation, displacement and malformation after restoration. The marrow was expanded with an intramedullary broacher, and the marrow cavity at the distal and proximal ends were washed with a flushing gun, respectively. An approximate prosthesis trial mold was selected to check the force line, activity and length of the limbs; and the cavum medullare was washed again. Bone cement was injected into the distal and proximal cavum medullare, respectively; and the proximal and distal handles in the prosthesis were inserted into the proximal and distal cavum medullare, respectively. The prosthesis was adjusted internally and externally by restoration after rotation, and two bolts were used to fix the prosthesis. After the bone cement was fixed, the distal end at the outer titanium plate for supplement was fixed at the proximal end in the reconstructed prosthesis with two screws, and the proximal end was fixed in the outside of the greater trochanter through the collum femoris with two screws. The part in the titanium plate should be fixed with another two cortical bone screws (**Figure 4**). After full hemostasis and washing of the surgery field, negative pressure drainage was replaced to suture every layer of tissues in order. Tissues were incised after the operation and sent for pathological examination.

Postoperative processing: Among the four patients with primary bone tumor in this group, one patient had osteosarcoma, one patient had parosteal osteosarcoma and one patient

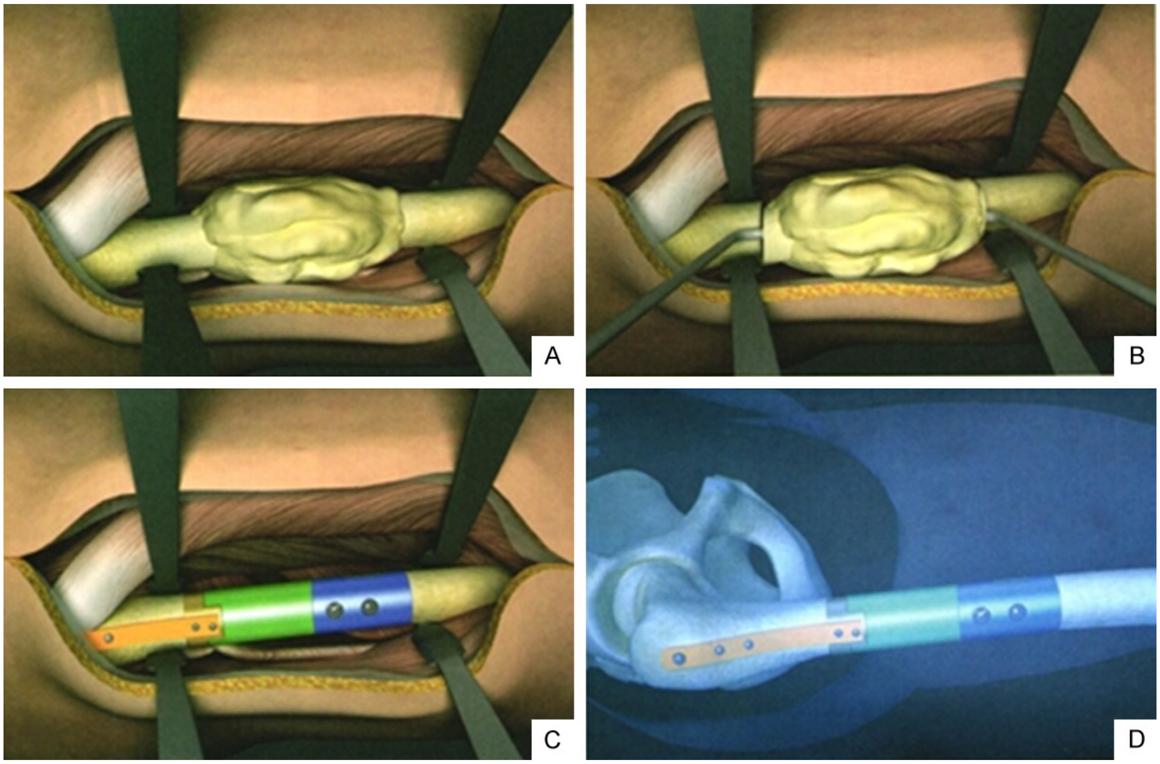

Figure 4. Schematic Diagram of Backbone Artificial Prosthesis Replacement: A. Bone and soft tissue of tumor measured by MRI before operation were fully exposed in principle of tumor excision; B. Osteotomy was conducted by designed length and plane before operation and taken out; C. Backbone artificial prosthesis was installed; D. Effects of installing backbone artificial prosthesis.

had malignant fibrous histiocytoma. All patients underwent four courses of chemotherapy after the operation according to the preoperative chemotherapy plan. One patient with malignant lymphoma received postoperative radiotherapy with a dose of 40 Gy, and the four courses of chemotherapy were conducted according to the preoperative plan. Three patients with metastatic cancer did not receive postoperative chemoradiotherapy. After the operation, routine administration of antibiotics was given, and negative pressure drainage was conducted. Patients without infection but with good neighboring joint function could stand without leaning on the bed on the 3rd day after the operation. In the early stage, patients conducted a static contraction exercise of leg muscle and started walking with a stick after getting up. One week after the operation, patients were able to walk normally.

Follow-up visit and therapeutic evaluation index: Outpatient visits or telephone follow-ups were conducted after three and six months, and annually thereafter, post-operation. Prosthesis stability, loosening and complications including fractures around the prosthesis were evaluated by X-ray examination. If the patient was found having a relapse in the operation area by X-ray examination, CT or MR examination should be conducted. During follow-up, joint functions of patients were evaluated with an evaluation system for the limb-saving operation of bone tumors formulated by the International Society of Limb Salvage (ISOLS).

Results

General condition

Operation time was within 45-120 minutes in this group, with an average time of 90 minutes. Bleeding amount during the operation was within 200-800 ml, with an average volume of 400 ml. Bone length in the excised tumor segment was 6-17 cm, with an average length of 12.1 cm. The proximal handle length was 6-10 cm, with an average length of 7.7 cm; and the distal handle length was 9-16 cm, with an aver-

Table 1. 7 cases of femoral stem in patients with bone tumor resection of tumor segment bone length and prosthesis handle distance segment (CM)

case	Tumor types	Osteotomy length	Proximal shank length	Proximal shank diameter	Distal shank length	Distal shank diameter
1	Osteosarcoma	11	8	17	14	11
2	Osteosarcoma of bone	6	10	15	9	9
3	malignant lymphoma	15	8	17	16	11
4	Malignant fibrous histiocytoma	7	7	17	11	11
5	Metastatic breast cancer	16	6	16	15	10
6	Metastatic breast cancer	17	7	15	14	9
7	Metastatic breast cancer	13	8	15	15	9

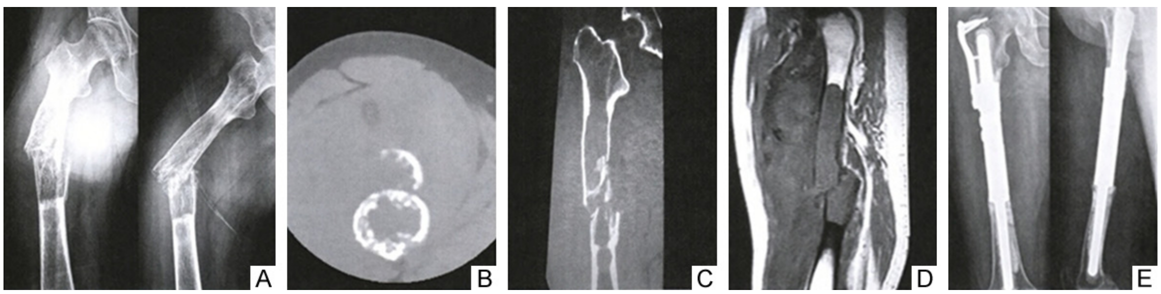

Figure 5. Female, 57 years old with proximal metastatic cancer in the right femur accompanying with pathological fracture. A: X-ray photo in adem position before operation shows bone dissolubility and bone destruction in the middle and upper section of right femur accompanying with cortex fracture, outward angulation and insertion, and upward displacement of distal broken end and edge which is not sharp. B and C: CT scanning and three dimensional reconstruction before operation show that the bone dissolubility in the middle and upper section of right femur stem accompanying with cortex fracture, overlapping distal and proximal ends in fracture and edge which is not sharp. D: Vertical plane T1W1 in preoperative MRI shows sclerotin fracture, separation, displacement and insertion in the middle and upper segment of right femur, and the flake shadow of low signal in marrow. E: X-ray photo in adem position after operation shows that the place of backbone artificial prosthesis is good without instability, loose and fracture around prosthesis.

age length of 13.4 cm. The proximal handle diameter is 15-17 mm, with an average diameter of 16.0 mm; while the distal handle diameter was 9-11 mm, with an average diameter of 10.0 mm (**Table 1**).

Tumor prognosis

Follow-up visit lasted for 6-24 months in this group, with an average period of 14 months. Pulmonary metastasis occurred one year after the operation in one patient with osteosarcoma. During the operation, local bone tissue revealed an "ivory white" sclerosis in a patient with malignant fibrous histiocytoma in the soft tissue of the left femur, but no symptom of blood supply occurred. During the operation, 7 cm of the bone was cut. The patient had discomfort of local pain in the operation area, but no relapse and further transfer occurred during the follow-up visit. During follow-up visits, one patient with parosteal osteosarcoma in the right femur and one patient with malignant lymphoma had no lapse and further transfer. Furthermore, one patient with breast metastatic cancer had multiple metastases. Thus, comprehensive treatment was given in another hospital after the operation. The patient survived with the tumor. The other two patients with breast metastatic cancer had no relapse *in situ* or transfer during the follow-up visit.

Imageology and function evaluation

Imageological evaluation of prosthesis location: The long-axis counterpoint and rotation counterpoints of the femur recovered in all patients. Five patients had a reconstruction segment of prosthesis 2 cm away from the proximal lesser trochanter, two patients had a reconstruction segment 3 cm away from the lesser trochanter, one patient had a recon-

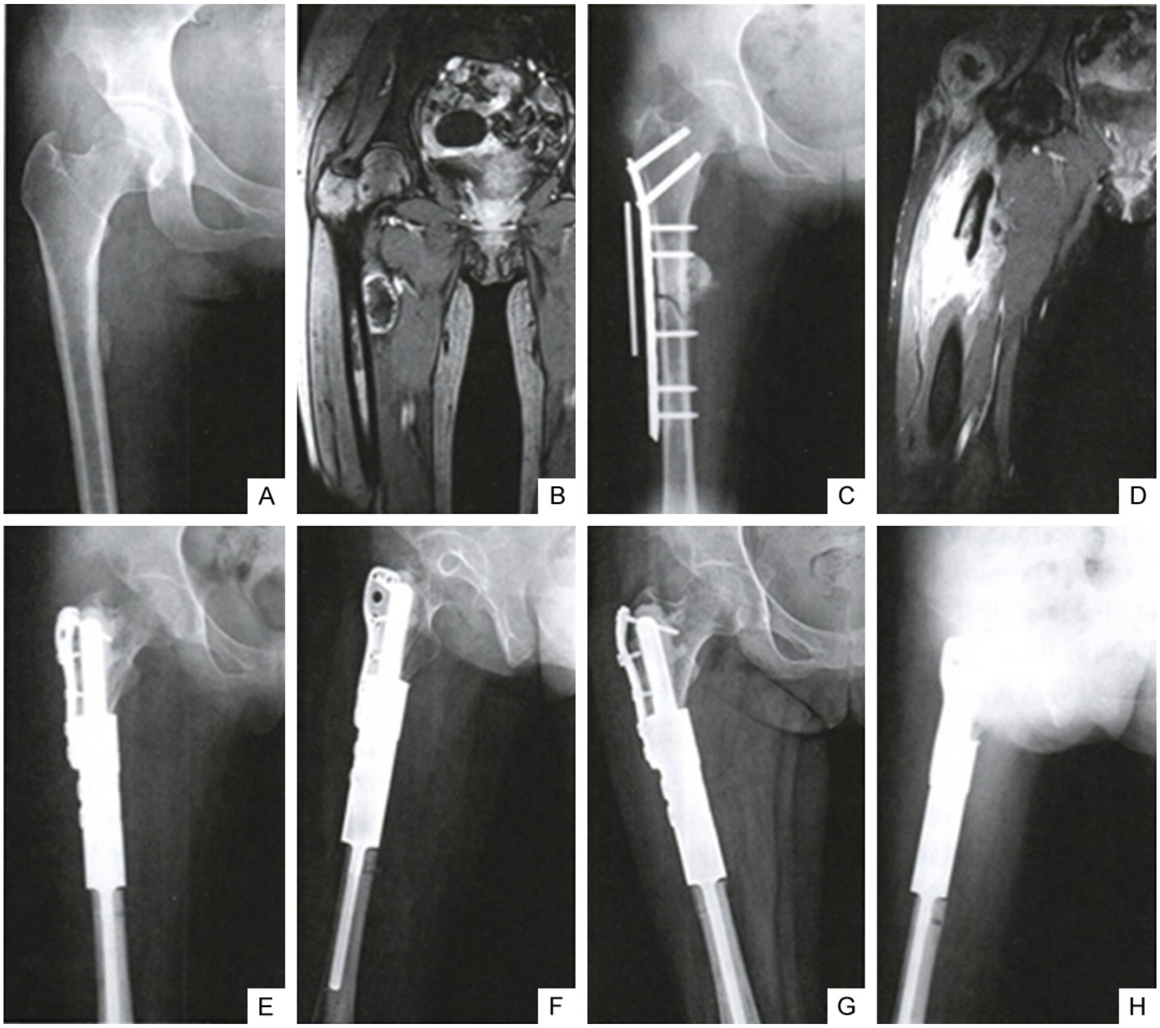

Figure 6. Female, 28 years old with parosteal osteosarcoma of right femur. A: X-ray photo in normotopia before operation shows oval ossification lump outside of proximal cortex of right femur; B: Coronal plane T2W1 in preoperative MRI shows that the tumor tissue outside of right proximal femur is the low signal area in clear boundary; C: X-ray photo in normotopia one and half a year after microwave hyperthermia shows fracture in proximal femur. Fixation with steel plate in proximal right femur was conducted with good apposition. The tumor outside of proximal internal cortex in right femur reoccurred. D: Coronal plane T2 fat-suppression image shows sclerotin fracture of right proximal femur stem with separation, displacement and flake shadow with high signal. E and F: Tumor excision and backbone artificial prosthesis replacement were conducted. X-ray photo in adem position after operation shows that the location of backbone artificial prosthesis is good. G and H: X-ray photo in adem position 3 months after operation shows that the location of backbone artificial prosthesis is good without instability, loose and fracture around prosthesis.

struction segment 1/3 lower than the distal femur, one patient had a reconstruction segment 1/3 higher than the femur stem, and five patients had a reconstruction segment in the middle section of the femur stem. Proximal prosthesis handles were all between the greater trochanter and lesser trochanter, including two patients with a handle 4 cm away from proximal lesser trochanter, three patients with a handle 3 cm away from proximal lesser trochanter, and two patients with a handle 1 cm away from proximal lesser trochanter. The prosthesis handle was 1-2 cm away from the top of the greater trochanter. One patient with breast metastatic carcinoma lacked of centralization with a little leakage of bone cement from the top of the larger trochanter. The other six patients had good centralization in the proximal handle. The centralization of the distal prosthesis handle was good and well matched with the cavum medullare. The titanium plate outside of prosthesis was stably fixed (**Figures 5** and **6**).

Function evaluation: Functions of the hip joint of the affected limb and knee joints were not limited after the operation. One month after the operation, one patient had a score of 24, one patient had a score of 26 and five patients had score of 28 based on the ISLOS functional evaluation system. Three months after operation, one patient had a score of 26 and six patients had a score of 28. Six months after the operation, one patient had a score of 26, three patients had a score of 28, and three patients had a score of 29. One year after the operation, six patients had a follow-up visit including one patient with a score of 26, two patients with a score of 28 and three patients with a score of 29.

Complications: One patient with right breast metastatic cancer had a superficial layer in the wound after the operation, which healed two weeks after sensitive antibiotic treatment and dressing change. The other six patients had no infection. During the operation, no neutral and vascular injury occurred. During the follow-up visit after the operation, prosthesis instability, loosening and fracture around the prosthesis and other complications did not occur.

Discussions

Indication selection for reconstruction of the backbone artificial prosthesis

The following three factors should be considered when selecting backbone artificial prosthesis under any condition for reconstruction.

Tumor type: The reconstruction of the backbone artificial prosthesis is a method to reconstruct the structural bone defect after tumor excision. If the primary malignant tumor and metastatic tumor in the proximal femur stem (area A) can be excised safely in principle of tumor excision, the bone defect caused by the operation can be reconstructed with the backbone artificial prosthesis. Among patients in this group, four patients had primary malignant tumors and three patients had metastatic tumor. During the follow-up visit after the operation, no tumor reoccurred; indicating that the tumor excision obtained good boundary control.

Tumor location: The measurement index to evaluate the tumor location is the distance from the proximal tumor boundary to the top of the greater trochanter of the femur when reconstructing with this method. According to the preoperative plan, the top of the greater trochanter of the femur should be used as an important anatomical indicator for method selection. Relevant finite element analysis on backbone artificial prosthesis in the early stage revealed that if the length of the handle of the stem prosthesis in the proximal cavum medullare is larger than 5 cm, the maximum stress peak of the bone cement, cortical bone of the femur stem and the proximal cavum medullare of the backbone artificial prosthesis is within the acceptable limit. Therefore, the distance between the proximal tumor boundary and the greater trochanter of the femur measured by MRI when selecting the backbone artificial prosthesis for reconstruction should be larger than 5 cm. For the seven patients in this group, the length of the proximal cavum medullare handle is 6-10 cm, with an average length of 7.7 cm, which are all longer than the standard for cavum medullare handle length (5 cm).

Excision length: The mechanical strength and stability of the backbone artificial prosthesis are mainly determined by two factors: the diameter and length of the distal and proximal cavum medullare handle, and the length of the reconstruction segment of the backbone prosthesis. As mentioned above, if the length of the proximal handle is longer than 5 cm and the length of the distal handle is longer than 10 cm, the ideal initial stability of prosthesis can be realized. This prosthesis is made of titanium alloy, and the reconstruction segment is composed of distal and proximal sections that are overlapped and connected with two sets of screws with a diameter of 5 cm. Therefore, its mechanical strength can completely satisfy with requirements in normal human activities. The influence of osteotomy length on the mechanical strength of the prosthesis could not be considered excessively. The average osteotomy length in this group is 12.1 cm, with the longest length up to 17 cm. The osteotomy can be reconstructed with the backbone artificial prosthesis to provide premise and guarantee the safe excision of the tumor. The anatomical structure of the proximal femur is complex with the arteria cruralis and femoral nerve in front, and the femoral profound artery in the internal and ischiadic nerve at the rear. Therefore, for patients with huge tumors or oncothlipsis in the front arteria cruralis and internal femoral profound artery, vessels cannot be seen when separating the exposed tumor mass in operation. This may damage the vessel and cause massive hemorrhage to affect the completeness of tumor excision. It is better to do a CTA examination in the operation area before operation to determine the vessel location and the relationship between tumor and vessel. If it is possible to temporarily interdict the abdominal aorta when giving the aorta abdominalis in operation, the separation of the blood vessel and tumor excision can be conducted in a clear operation view. Once the vessel becomes damaged or ruptures, it can be impaired in time.

Advantages of backbone artificial prosthesis

Simple operation and short hospitalization: There is no need to expose the hip joint in operation and reconstruct the joint and soft tissue. Therefore, the operation is simplified. Matched with the proximal and distal handle with different diameters, reconstruction only requires the insertion of the distal and proximal handles into the cavum medullare. The reconstruction segment in the prosthesis is connected by overlapping with two screws under direct vision. Without the guidance of imageology, operation time is saved. Moreover, a smaller operation wound would make recovery more rapid, lower the occurrence rate of postoperative complications, and shorten postoperative hospitalization time. The average operation time in this group is 90 minutes, and average hospitalization time after the operation is seven days.

Good biomechanical intensity and full weight bearing in the early stage after the operation: Henry *et al.* [24] adopted allogeneic bones to reconstruct a 5-cm bone defect model in 1/3 of the middle section of the humerus. Then, bone cement with intramedullary nail, backbone artificial prosthesis and intramedullary nail with allogeneic bone were applied in the reconstruction to analyze torque peak, rigidity and other indices of the three models. These results show that backbone artificial prosthesis is better than allogeneic bone or bone cement + intramedullary nail for fixation in both torsion rigidity and maximum torque. Abudu *et al.* [25] thought that functional excise can be conducted 48 hours after artificial prosthesis reconstruction, and full bearing can be realized 10 days after the operation. In this group, six patients could stand off the bed three days after the operation to do static contraction excises of leg muscles. One week after the operation, they could walk normally. One patient refused to get off the bed for superficial infection of the wound, but the patient was able to take full bearing one week after anti-infection and dressing change.

Long service life of prosthesis and low occurrence rate of complications: The backbone artificial prosthesis was placed in the backbone, which is a non-joint reconstruction area with less circular stress than joint prosthesis. Therefore, the occurrence rate of prosthesis fatigue or loosening is low. Alklyami *et al.* [26] adopted the backbone artificial prosthesis reconstruction of bone defect for 35 patients with backbone tumors. After an average of 107 months of follow-up visits, only one patient with osteosarcoma had prosthesis fracture for trauma, which occurred seven years after the operation. During the follow-up visit after the operation, seven patients in this group had no prosthesis loosening or fracture according to X-ray examination.

Attentions for backbone artificial prosthesis reconstruction

Selection of the proximal handle with a large diameter: The form of the cavum medullare from the lower femoral lesser trochanter to the narrow part of the femur stem is a near to far "funnel shape". According to the new-type of digital technology and finite element analysis applied in the early stage, we found that the level of the inner diameter of the cavum medullare in the lesser trochanter is 25 cm, and the narrow part of the femur is 13 mm. The inner diameter of the cavum medullare would be reduced by 1-2 mm with every 1 cm increase in backbone length. Due to the installation direction of the proximal handle, the backbone artificial prosthesis is from far to near when being inserted into the cavum medullare. Furthermore, the prosthesis handle should enter the narrowest part of cavum medullare, and finally reach the area with an expansive diameter. This direction is completely opposite to that of the cavum medullare of the prosthesis handle in the artificial hip joint. Therefore, the backbone artificial prosthesis handle can only be designed as a rod-shaped structure with an equivalent diameter. However, the terminal diameter is much less than the expansive diameter of the cavum medullare. The prosthesis handle can only be fixed by filling with bone cement, but the real cavum medullare matching cannot be realized. The cavum medullare handle with a small diameter prevents the residual cavum medullare from holding the prosthesis closely with bad centralization. Therefore, it is easy to make the prosthesis loose in the early stage.

For the metastatic tumor of the lower limb bone, 80% occurred in the trochanter area: If the prosthesis in area A can be applied in the interval near the trochanter, its application ranges would increase by geometrical times. Therefore, one of aim of this study is to make the application part of the backbone artificial prosthesis in area A close to or near the trochanter interval as much as possible. Thus, the length of the proximal handle of the cavum medullare would decrease and affect the stability of the prosthesis. According to the finite element analysis in early stage, the model fixed with a titanium plate outside of the prosthesis was added (fixing the collum femoris with two long and cancellous bone screws and other two cortical bone screws for half cortex fixation). In the stress analysis with pressure stress, pulling stress and shear stress, the stress peak of the femoral stem was reduced by 62.93 MPa, while the stress peak of the bone cement was reduced by 19 MPa. This greatly decreased the probability of bone cement fragmentation for long-term stimulation by high stress circulation. In addition, a screw is placed after filling bone cement in cavum medullare. Thus, the screw is embedded in the bone cement, rather than in the bad sclerotin. The combination of screw thread and bone cement provides a large contact surface to reduce the risk of pulling the screw out from femoral head and improve prosthesis stability. In this study, all patients received an auxiliary titanic plate outside of the femur for fixation in the operation. It is noteworthy to mention that since the proximal auxiliary titanic plate outside is fixed in the middle and lower parts of the greater trochanter, there is no need to expose 1/3 of the proximal end of the greater trochanter. The stability of the hip joint can be maintained by preserving the attachment points at the gluteus medium, gluteus minimus and iliopsoas to avoid "gluteus medius gait Trendelenburg gait" after the operation.

Bad length of the corrected limb and rotation displacement: Different from artificial joint replacement, the area of the backbone artificial prosthesis reconstruction is below the lesser trochanter; and no obvious anatomic landmarks indicate the prosthesis installation. Therefore, it is easy to cause a bad length and rotation displacement of the limb. During the operation, medial femoral condyle or malleolus medialis at both sides should be taken as an anatomic landmark after trial of the prosthesis installation, and the limb difference of both sides should be corrected by adjusting the length of the prosthesis reconstruction segment. For patients without pathological fractures, a straight line parallel to the long axis of the femur should be picked at the distal and proximal ends of the normal backbone in the osteotomy plane before osteotomy as a rotation reset mark. However, for patients with pathological fractures, the connecting line between the anterior superior spine and the second and third articulations metatarsophalangeae should be drawn as a corrected rotation reset for reference after prosthesis installation and before bone cement solidification to restore the force line.

Disclosure of conflict of interest

None.

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