

# The Significance of Rectus Femoris for the Favorable Functional Outcome After Total Femur Replacement

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**Background:** In treatment of tumors, we usually reconstruct after resection of the entire femur using only metallic modular endoprostheses among many procedures and defined it as a total femur replacement. We studied the interrelation between the preservation of rectus femoris and the functional outcome after total femur replacement.

**Methods:** We rated the functional outcomes of 21 patients who underwent total femur replacement. We categorized the subjects into 2 groups: group A (rectus femoris preserved) and group B (rectus femoris unpreserved). We examined them based on the Mann-Whitney *U* test between the 2 groups in average through the Musculoskeletal Tumor Society functional scores.

**Results:** The average score of group A was 20 of 25 (11–25; 80%), whereas the average score of group B was 10 of 25 (4–13; 40%). There was significant difference between the groups ( $P = 0.00168877$ ).

**Conclusion:** We found that the preservation of rectus femoris is imperative for achieving the favorable functional outcome in total femur replacement. (*Plast Reconstr Surg Glob Open* 2016;4:e630; doi: 10.1097/GOX.0000000000000610; Published online 2 March 2016.)

Femur reconstruction options after tumor resection include the use of autografts, allografts, rotationplasty, and custom-made or modular endoprosthesis.<sup>1–10</sup> Reconstruction using only metallic modular endoprosthesis is the standard procedure we perform after entire femur resection, and we define it as a total femur replacement (TFR). In 1965, the first TFR case was reported

by Buchman<sup>11</sup> for a patient whose femur had been largely distorted because of Paget's disease. In 1977, Marcove et al<sup>12</sup> reported 19 immediate clinical outcomes of TFR targeting malignant neoplasm, and this article was the first to discuss multiple cases of TFR. In 1988, Nerubay et al<sup>13</sup> reported clinical features of 19 TFR cases whose follow-up evaluation ranged from 2.5 to 8 years. In 1994, Morris et al<sup>14</sup> reported on the functional outcomes of 7 cases after TFR and emphasized the importance of maintaining the proximal and distal muscles if favorable or excellent results are to be achieved. In 2005, Mankin et al<sup>15</sup> reported 15 cases on TFR, which included the cases using composite graft where a total hip replacement and a total knee replacement were implanted with cement into the allograft. Recently, Sewell et al<sup>10</sup> reported on the functional outcomes and the survival rate of the implant and the limb with 33 post-

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TFR cases. Ruggieri et al<sup>16</sup> reported the usefulness of TFR to achieve local control and good function in surviving patients with 23 cases of TFR. Kalra et al<sup>17</sup> reported on the treatment outcomes including the long-term prosthetic survival and limb survival and the functional outcomes with 26 cases. Sevelde et al<sup>18</sup> in their largest single-institute study stated that on evaluation of 50 tumor resection cases with TFR, the overall implant survival rate was 97%.

In reviewing these articles, patients' survival rate is found to be poor because TFR is indicated to an advanced case with massive tumor. However, the rate of complications such as infection, disarticulation of hip joint, and implant failure was also high when some of the articles included cases with a favorable long-term limb survival. This suggested that TFR ensured the operated limb salvage for a long period of time if a patient could avoid death by disease or postoperative complications. There are several remarkable case reports that support this where the operated limb was salvaged for a length of time after TFR. In 1995, Present and Kuschner<sup>19</sup> reported the case of the limb salvage with an ability to walk for 32 years after TFR operated by Buchman. Nakamura et al<sup>20</sup> has also reported 2 cases with favorable follow-up continuing over 10 years after TFR with limb salvaged.

Some authors have written significant facts to maintain limb function after TFR. They wrote that the good functional outcome deeply depends on preserved muscles such as gluteus medius and quadriceps.<sup>14,17</sup> However, there was no statistical analysis on the interrelation between the muscle preservation state and the functional outcome after TFR. Retro-

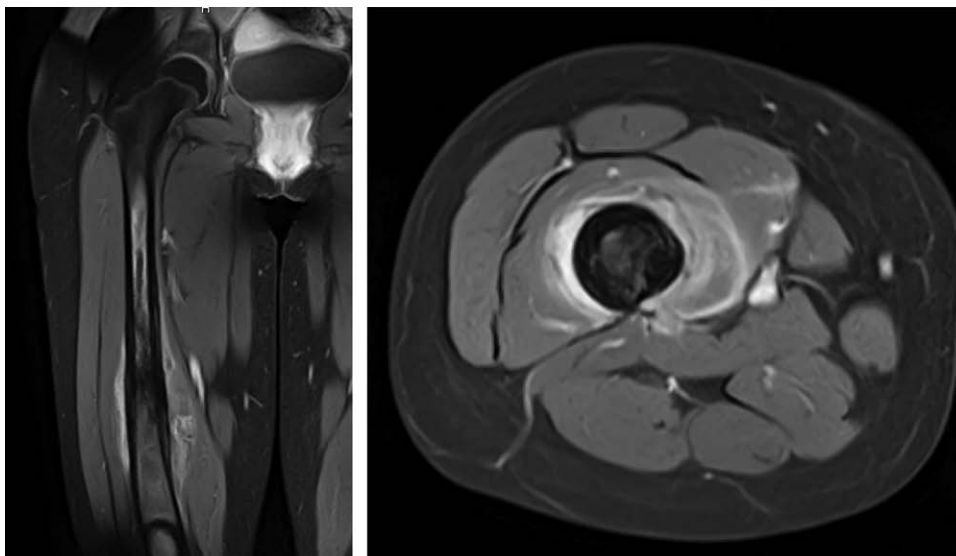
spective examination of our experimental examples suggested that the most influential factor in the favorable functional outcome after TFR was whether quadriceps, especially rectus femoris, was preserved or not. Therefore, we studied the interrelation between the preservation of rectus femoris and the functional outcome after TFR.

### PATIENTS AND METHODS

This study was approved by the Institutional Review Board of Cancer Institute Hospital and was supported by a Grant-in-Aid for Cancer Research from the Ministry of Health Labor and Welfare of Japan.

There are 3 indications for the total femur resection in the treatment of musculoskeletal tumors. The first is when the bone tumor is spread to the entire femur either by natural progression or by tumor cell contamination as a result of an inappropriate surgery (Figs. 1–3). The second is the soft tissue tumor excision that requires entire femur excision, such as where a tumor generated in vastus intermedius widely encompasses the femur. The third is the revision surgery after total knee replacement that requires the excision of the rest of the femur because of loosening or recurrence.

Twenty-two cases of TFR were performed from July 1985 to April 2012 in our department. Twenty-one cases excluding 1 case that underwent TFR after amputation of another lower limb were examined. Patients were 10 males and 11 females with a mean age of 45 years (age range, 10–79 years). Mean period of follow-up was 61 months (range, 5–336 months), and mean period between TFR and rating the functional outcome was 48 months (range, 1–305 months). Of



**Fig. 1.** Case 3, a 12-year-old girl with osteosarcoma of the whole femur. Preoperative magnetic resonance imaging shows that the tumor spread into and around the femur.



**Fig. 2.** Case 3, a 12-year-old girl with osteosarcoma of the whole femur. An excised specimen after wide resection is displayed.

the 21 cases, 14 had bone tumor, 4 had soft tissue tumor, and 3 had revision surgery. Pathological diagnosis of the bone tumor cases found 10 patients with primary bone sarcoma (6 osteosarcoma, 3 chondrosarcoma, and 1 Ewing sarcoma) and 4 patients with metastatic tumor (1 renal cancer, 1 gastric cancer,

1 breast cancer, and 1 malignant peripheral nerve sheath tumor). The soft tissue tumor cases found 4 patients with primary soft tissue sarcoma (1 malignant fibrous histiocytoma, 1 fibrosarcoma, 1 with malignant granular cell tumor, and 1 with solitary fibrous tumor). Primary disease of all revision patients was osteosarcoma.

For the purpose of examining the interrelation between preserved rectus femoris and the functional outcome, we divided the cases into 2 groups: group A (rectus femoris preserved) and group B (rectus femoris unpreserved). For the revision cases, we defined the preservation of rectus femoris as those salvaged in both the primary surgery and TFR. We rated the function of the limb based on the Musculoskeletal Tumor Society (MSTS) rating system developed by Enneking et al.<sup>21</sup> MSTS rating system is the method that rates the functional outcomes after the limb salvage surgery of musculoskeletal tumor, which arises from extremities. According to the medical records and clinical findings, the lower limbs are rated by the following 6 factors; pain, function, emotional acceptance, supports, walking ability, and gait. Referees rate at 0 to 5 points based on the rating criteria. MSTS functional score is rated either by points or percentages. In our study, we excluded the emotional acceptance and rated the MSTS functional score in 25 full points because death of some patients had not enabled such assessment. Pain score was rated by the presence or absence of pain and the necessity of analgesics. Function score was rated by the presence or absence of prohibitions or limitations in daily activities, and supports score by the necessity of walking cane, crutches or braces, or its frequency of use. Walking ability score was rated based on a stage of walking limitations: limited to indoor walking and able to walk both indoors and the outdoors. Gait score was specifically rated by a gait alteration, or no presence of, or by point of imbalance. As for the point in time of rating, the most recent MSTS functional outcomes were



**Fig. 3.** Case 3, a 12-year-old girl with osteosarcoma of the whole femur. A postoperative X-ray is presented.

**Table 1. Clinical Information of Subjects**

Indication	BMI	Follow-Up Period (mo)	Rating Period (mo)	Pain	Function	Supports	Walking Ability	Gait	Overall	Overall %	Adjuvant Therapy Before TFR	Adjuvant Therapy After TFR
Soft tissue tumor	28.3	336	305	5	5	2	5	3	20	80	CT	None
Soft tissue tumor	23	159	126	5	5	2	5	5	22	88	None	None
Bone tumor	15.8	22	17	5	5	2	5	5	22	88	CT	CT
Revision	28.7	17	11	5	5	5	5	5	25	100	×	×
Revision	19.5	42	42	5	5	5	5	5	25	100	×	×
Bone tumor	20.5	17	1	5	5	3	4	5	22	88	×	×
Bone tumor	23.2	40	2	3	3	1	1	3	11	44	RT	none
Bone tumor	17.6	205	202	5	5	5	5	5	25	100	CT	CT
Bone tumor	16	24	4	5	5	2	5	3	20	80	CT	CT
Bone tumor	21.8	157	157	5	5	5	5	5	25	100	CT	CT
Bone tumor	21.7	8	2	5	5	1	1	3	15	60	None	None
Bone tumor	17.1	6	5	5	5	2	5	3	20	80	×	×
Bone tumor	22.2	8	8	5	5	2	5	3	20	80	×	×
Bone tumor	25.8	18	5	5	3	1	1	3	13	52	none	CT
Revision	16	24	16	5	5	2	5	5	22	88	×	×
Bone tumor	23.7	101	94	5	5	1	5	3	19	76	CT	CT
Bone tumor	19.6	5	1	5	3	1	4	3	16	64	CT	CT
Bone tumor	15.6	7	1	3	3	3	4	3	16	64	×	×
Soft tissue tumor	27.5	23	7	5	3	1	1	3	13	52	CT	CT
Soft tissue tumor	20.9	18	2	3	1	0	0	0	4	16	None	None
Bone tumor	27.1	43	1	3	3	1	3	3	13	52	RT	None

rated for cases with preserved limbs and implants. In cases of death by disease, amputation, or the removal of implants caused by surgical complications, the MSTS functional outcomes in the period of the most favorable condition were rated.

**Surgical Technique**

With the patient in the lateral position, skin incision is to be curved from the hip across the anterior part of the knee joint on the lateral side of the femur including the resection of biopsy scar. In the proximal, gluteus maximus incision is made, and gluteus medius is resected or disconnected from femur by osteotomy of the greater trochanter to reach the hip joint. Although the extent of tumor spread will determine the amount of muscle preservation, preservation of rectus femoris is the most important. For this, considerable care is given from the time of biopsy. The hip joint capsule should be preserved, but where it is not possible, reconstruction of this region is done by applying mesh. If contamination of tumor is suspected in the knee joint, extraarticular knee joint resection is essential, followed by knee extensor mechanism reconstruction. In pediatric cases, TFR including extendable endoprostheses is performed.<sup>22</sup> This enables leg lengthening as the child grows, thus eliminating discrepancies. In revision cases, if no tibia component loosening is present, extra parts are added to the artificial knee joint in TFR. In our cases, case 6 was a reconstruction of hip joint capsule by mesh application. In case 16, we performed extraarticular knee joint resection followed

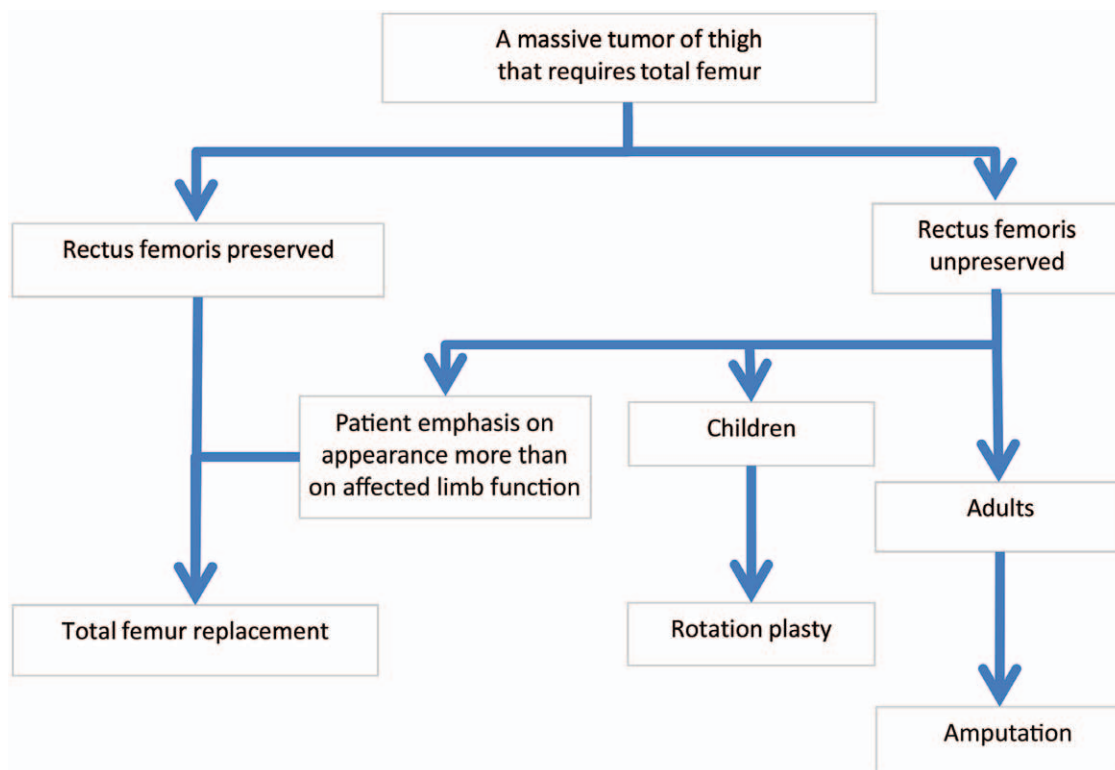
by reconstruction of the knee extensor mechanism. In 2 cases (case 8 and case 9), the extendable total knee joint replacements were applied.

**Statistical Analysis**

We examined the averaged MSTS functional scores of the subjects based on the Mann-Whitney *U* test. We used StatMate (version 3.19) software for this statistic analysis.

**RESULTS**

The overall average MSTS functional score for all patients was 18.5 of 25 (4–25; 74%; Table 1). The average MSTS functional score of group A was 20 of 25 (11–25; 80%), whereas group B was 10 of 25 (4–13; 40%). Mann-Whitney *U* test showed significant difference between the 2 groups ( $P = 0.0168877$ ). The score results of the 5 factors are as follows: Pain: overall average rate, 4.6 (3–5); group A average rate, 4.8 (3–5); group B average rate, 3.7 (3–5), difference ( $P = 0.0323357$ ); significant. Function: overall average rate, 4.3 (1–5); group A average rate, 4.6 (3–5); group B average rate, 2.3 (1–3); difference ( $P = 0.0061699$ ); significant. Supports: overall average rate, 2.3 (0–5); group A average rate, 2.5 (1–5); group B average rate, 0.7 (0–1); difference ( $P = 0.0242804$ ); significant. Walking ability: overall average rate, 3.8 (0–5); group A average rate, 4.2 (1–5); group B average rate, 1.3 (0–3); difference ( $P = 0.0137366$ ); significant. Gait: overall average rate, 3.6 (0–5); group A average rate, 3.9 (3–5); group B average rate, 2 (0–3); no significant difference found between groups.



**Fig. 4.** The flow chart of the strategy for a massive tumor of thigh.

## DISCUSSION

Many TFR articles described that the essential factor for the favorable functional outcome after surgery was the preservation of muscles around the femur. For example, Morris et al proposed that the lack of hip abductors or knee extensors procedures resulted in a poor functional outcome as the patient cannot control the limb. They argued the importance of maintaining the proximal and distal muscles to achieve favorable or even excellent results.<sup>14</sup> Kalra et al<sup>17</sup> also cited the study by Morris et al and proposed that the rectus femoris should be saved as much as possible. However, no statistical examination of the interrelation between the muscles preservation states and the functional outcome had been conducted in these articles. On retrospective examination of our experimental examples, we found that the most influential factor on the functional outcome after TFR was whether or not the quadriceps, especially rectus femoris, was preserved. We conducted a statistical study over the interrelation between the preserved muscles of rectus femoris and the functional outcome. We rated 21 cases of 22 cases in our department by MSTTS rating system. The overall average rate was 18.5 of 25 (74%). Three articles focused on the favorable post-TFR functional outcomes rated by MSTTS functional system as same as ours. Sewell et al reported that the average MSTTS functional score was 20 of 30 (67%)

in 11 cases. Ruggieri et al reported that the average MSTTS functional score of 15 cases was 66%, and Kalra et al. reported that the average MSTTS score of 9 cases was 21.8 of 30 (72.6%).<sup>10,16,17</sup> Furthermore, Renard et al<sup>23</sup> reported that the medium value of MSTTS functional score was 77% in the salvaged limb cases in various surgeries and 60% in amputation cases. In comparing these with our results, we concluded that TFR provides better prognosis than amputation and is the surgical procedure by which similar satisfactory functional outcome is anticipated as in other limbs salvage surgery. Between group A (rectus femoris preserved) and group B (rectus femoris not preserved), group A showed significantly higher average of MSTTS score than group B. This showed that the favorable functional outcome can be better attained if the rectus femoris was preserved. Significant difference was also found in the MSTTS functional scores, specifically in scores for pain, function, supports, and walking ability.

We acknowledge several limitations in this study. First, although we had performed TFR from 1985, our subjects were few because of the rarity of indications. Second, although we rated the MSTTS functional score excluding emotional acceptance because of the occurrence of patient death within our study, comparisons were made with other studies that had included this factor because no others were avail-

able. Third, our attempts to consider factors other than the rectus femoris were not successful because of a limited amount of information available. For instance, we separated the subjects into 3 groups by their body mass index: (a) less than 18.5 kg/m<sup>2</sup>, (b) 18.5 to 25 kg/m<sup>2</sup>, and (c) more than 25 kg/m<sup>2</sup>, but Kruskal-Wallis test found no significant difference. Also, analysis was not conducted on the interrelation of the MSTs functional score and other muscles such as gluteus medius, adductors and hamstrings. More definitive conclusion would require assessments of the findings from multivariate analysis with the data of other muscles preservation states.

On the discussion of the reasoning for not preserving the rectus femoris, we focused on the determining factor of rectus femoris resection at surgery. Discussions found that in all cases, massive soft tissue tumors had invaded into the rectus femoris. In cases like these, tumor development frequently progresses locally. However, even if a tumor does not invade rectus femoris, preservation difficulty still remains because of contamination made by an inappropriate biopsy or surgery. Therefore, extensive care should be given at the time of biopsy to achieve favorable functional outcome after surgery. Furthermore, in cases where rectus femoris preservation is not possible, rotationplasty is the recommended procedure in pediatric patients and the use of prosthetics above-knee amputation in adult patients. TFR performed on cases of nonpreservable rectus femoris are indicative of patients who are more concerned with their appearance rather than limb function because there is no significant difference in gait scores (Fig. 2). In the case of musculoskeletal tumor in the thigh (Fig. 4), we conclude that the favorable functional outcome after TFR is especially dependent on the preservation of rectus femoris. In such cases, extreme caution not to contaminate rectus femoris during surgeries and biopsies is essential in achieving good outcome.

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