

# Utilization of Modified Rhomboid Flap to Reconstruct Limb Defect after Wide Resection of Large Soft-tissue Sarcoma: Novel Application of an Old Technique

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## Research

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## Abstract

**Background:** Reconstruction of limb defects following wide resection of large soft-tissue sarcomas (STS) is challenging. Effectiveness of rhomboid flaps in covering these wounds remains to be addressed.

**Methods:** From March 2018 through February 2019, we utilized modified rhomboid flaps to reconstruct limb defects following wide resection of the large STS ( $\geq 5$  cm in diameter) in 6 patients. There were 3 males and 3 females. The average age was 65 years (47-77 years). Diagnoses included leiomyosarcoma in 3 patients, synovial sarcoma, undifferentiated pleomorphic sarcoma, and myxoid liposarcoma in 1 respectively. The anatomic locations included the anterior knee in 3 cases, upper arm in 2, and thigh in 1. The mean diameter of the tumor measured 10 cm (5-17 cm). The mean defect size was 113 cm<sup>2</sup>(38-270 cm<sup>2</sup>).

**Results:** The mean follow-up duration was 10 months (range, 6-12 months), no patients were lost to follow-up. Skin grafts were utilized in 2 cases. The mean time to heal was 7 weeks (range, 3-13 weeks). At final follow-up, there were no recurrence and metastasis. One case had cerebral hemorrhage and 1 had wound dehiscence, whereas no reoperation was performed. The range of motion of the joints adjacent to the flap reconstructions were comparable to preoperative status. The mean Musculoskeletal Tumor Society score was 27 (range, 24-30).

**Conclusions:** The modified rhomboid flap affords great versatility and is easy to design. This technique yields satisfactory effectiveness in reconstructing limb defects after resection of large STS. Long-term studies of large sample size are warranted.

## Background

Soft-tissue sarcomas (STS) comprise heterogeneous malignancies originating from the muscle, fat, blood vessel, nerve, and connective tissue with an incidence of 5 cases per 100,000 inhabitants [1]. The most frequent tumor locations are extremities, and mainstay treatment modality is wide surgical resection with or without medical therapy [2]. Wide resection of large tumors ( $\geq 5$  cm in diameter) in the extremities often leads to exposure of underlying tendons and bones [3–5]. Flap reconstructive procedures are typically warranted for limb-salvage surgery [6].

Various flaps have been advocated to cover the limb defect after wide resection of STS. Free vascularized flaps are frequently utilized, including the latissimus dorsi flap, anterolateral thigh flap, rectus abdominis flap, etc [6, 7]. The limb-salvage rate was as high as 90% [6, 7]. However, microvascular procedures usually require a plastic surgeon, and can be hardly performed by orthopedic oncologists. Although local flaps and pedicled musculocutaneous flaps are technically easier, these procedures are still restricted for coverage of large limb defects due to significant local tension [8]. Some flap designs are difficult to learn [8]. Because limb STS dictates multidisciplinary management and are primarily treated by orthopedic oncologists, flap reconstructive procedures that yield favorable efficiency and moderate difficulty are warranted to simplify the surgical procedures.

The rhomboid flap (RF) was initially introduced by Limberg, and modified by Dufourmentel [9, 10]. The traditional RF is a local flap designed in compliance with the parallelogram principle (Fig. 1). It proved to be an effective procedure for wound closure in the torso [11]. Although the RF and its variations are popularized, its effectiveness in reconstructing the limb defect has been rarely addressed. The traditional procedure tailors a circular defect into a rhomboid wound which necessitate sacrifice of circumferential tissue, this may increase the local tension and entail higher difficulty for reconstruction of the limb wound. Thus, we designed a modified RF to facilitate this procedure and conducted preliminary evaluation of its effectiveness in reconstructing the limb defect after wide resection of large STS. The relevant technical points were also summarized.

## Methods

### General data of the patients

From March 2018 through February 2019, we utilized modified RF to reconstruct limb defects following wide resection of the large STS ( $\geq 5$  cm in diameter) in 6 patients (Table 1). There were 3 male cases and 3 female cases. The average age was 65 years (47–77 years). Diagnoses included leiomyosarcoma in 3 patients, synovial sarcoma, undifferentiated pleomorphic sarcoma, and myxoid liposarcoma in 1 respectively. The anatomic locations included the anterior knee in 3 cases, upper arm in 2, and thigh in 1. The mean diameter of the tumor measured 10 cm (5–17 cm). The mean defect size was 113 cm<sup>2</sup> (38–270 cm<sup>2</sup>). In accordance with the American Joint Committee on Cancer (AJCC) staging system, 5 cases had stage IIB tumor, whereas 1 had IIA [12]. Limb functions were assessed by range of motion (ROM) of the joints and the Musculoskeletal Tumor Society (MSTS) score [6]. One patient had undergone a previous surgery, whereas no case had received neoadjuvant radiotherapy and chemotherapy.

Table 1  
Characteristics of the patients

No. Cases	Sex	Age (y)	Locations	Diagnosis	AJCC <sup>e</sup> Stage	Tumor Diameter (cm)	Defect Size (cm <sup>2</sup> )	Previous surgery	Full thickness skin graft	Time to heal (week)	Follow-up (month)	Complication	Survival
1	M	77	Upper arm	LS <sup>a</sup>	IIB	8	71	--	--	3	7	Cerebral Hemorrhage	Disease free
2	F	63	Thigh	SS <sup>b</sup>	IIB	7	64	--	--	5	13	--	Disease free
3	M	68	Upper Arm	UPS <sup>c</sup>	IIA	5	38	--	--	3	12	--	Disease free
4	F	72	Anterior Knee	LS	IIB	9	130	--	--	13	12	Wound dehiscence	Disease free
5	M	47	Anterior Knee	LS	IIB	12	102	--	Yes	8	8	--	Disease free
6	F	63	Anterior Knee	MLS <sup>d</sup>	IIB	17	270	Yes	Yes	9	6	--	Disease free

a: LS denotes leiomyosarcoma; b: SS denotes synovial sarcoma; c: UPS denotes undifferentiated pleomorphic sarcoma; d: MLS denotes myxoid liposarcoma; e: AJCC denotes American Joint Committee on Cancer

Table 2  
Functional outcome

No. Cases	Preop ROM <sup>a</sup>	Postop ROM	Postop MSTSc <sup>c</sup>
1	N/A <sup>b</sup>	N/A	N/A
2	Hip: flexion 110°; abduction 35°; adduction 30°	Hip: flexion 100°; abduction 35°; adduction 30°	30
3	Elbow: 0°-135°	Elbow: 0°-130°	30
4	Knee: Knee: 0°-120°	Knee: 0°-115°	25
5	Knee: 0°-125°	Knee: 0°-120°	27
6	Knee: 0°-90°	0°-70°	24

a: ROM range of motion of the joints adjacent to the flap reconstructions; b: N/A denotes not available; c: MSTSc denotes Musculoskeletal Tumor Society score

#### Wide resection of the tumor

The tumor size, depth, and magnitude of resection were determined in compliance with contrast-enhanced magnetic resonance images (MRI). Intraoperatively, the tumor was resected in combination with a 2–3 cm cuff of normal tissue. Intraoperative frozen section examination verified negative margins. The procedure resulted in exposure of underlying tendons and bones in 3 cases with anterior knee lesions. In these cases, after resecting the periosteum and partial retinaculum, 95% ethanol was applied to the wound for 30 minutes for further devitalization, so as to reduce the risk of recurrence.

#### Modifications to the classical RF

All cases had primary wound closure with use of the modified RF. Preoperative hand-held Doppler examination localized perforators, which were included in the flap design. We modified the classical RF (Fig. 1) by using the curved defect border as a side of the flap (Fig. 2-A). The diameter of the circular defect and the shorter axis of the elliptical defect are extended to the neighboring tissue, and equates the length of the extended line (Fig. 2-A, line AB = line BC). An angle of approximately 60° (or slightly less than 60°) is drawn at the end of the extended line (Fig. 2-A, ∠BCD), with the other side of the angle going in parallel with the defect border (Fig. 2-A, curved line CD). The length of both sides of the angle are (or approximately) equal. Wound closure results in a zigzag incision similar to the traditional RF (Fig. 1-C, Fig. 2-C).

#### Use of the modified RF for coverage of the limb defect

In the extremities, the direction of the vector of tension in the flap and location of the incisions must be properly designed. There are two vectors of tension in our flap. One vector runs horizontal to the imaginary line A'B of the defect (Fig. 2-B, V1), the other lies at approximately a 60° angle to the line BC (Fig. 2-B, V2). Therefore, the sum of the vector of stress runs at about a 30° angle to the line BC (Fig. 2-B, Vt). The vector of tension in the flap is designed approximately in parallel with the long axis of the extremity. At least two of the incisions are placed in the relaxed skin tension lines (RSTL), and vertical crossing of the joint line is avoided. These principles entail minimum tension of the flap and preservation of the limb function (Fig. 3).

#### Postoperative management

Intravenous antibiotics (cefazolin, 3 g, 1/8 h) were applied for 7 days. Drain was removed when the output was less than 20 ml/d. Active joint exercise was allowed at 6 weeks postoperatively. Follow-up was every 3 months for the first 2 years, 4 months the third year, 6 months the fourth and fifth year, and annually thereafter. All cases received physical examination, lung computerized tomography (CT) and MRI assessment of the operated locations. In this case series, no patients received postoperative radiotherapy and chemotherapy.

## Results

The mean follow-up length was 10 months (range, 6–12 months) (Table 1). No patients were lost to follow-up. The mean time to heal was 7 weeks (range, 3–13 weeks). Full-thickness skin grafts were utilized in 2 cases. At final follow-up, there were no recurrence and metastasis. All patients were satisfied with the appearance of the operated locations. There were no flap failure, infection, and seroma. One case had cerebral hemorrhage and 1 had wound dehiscence, whereas no case needed reoperation. The patient who had the cerebral vascular accident was not included in the functional evaluation. The ROM of the joints adjacent to the flap reconstructions were comparable to preoperative status (Table 2). The mean MSTS was 27 (range, 24–30) (Table 2).

## Discussion

Wide resection of the large STS in the extremities usually leads to exposure of underlying tendons, bones, and neurovascular bundles. To achieve limb salvage, flap reconstructions are typically warranted. The RF was firstly described by Limberg and has been popularized for wound closure [13–16]. This technique proved to be effective for coverage of torso defects, such as pilonidal sinus disease and facial wounds [13–16]. However, studies focusing on the use of RF for reconstruction of limb defects are sparse. The traditional RF necessitated further resection of the circumferential tissue to create a rhomboid wound, which allowed the flap to fit the defect snugly [17–19]. However, this procedure entails higher skin tension in the extremities. Although its variations allowed for easier closure of the wound, the geometric design was difficult to learn [20, 21].

We propose a modification to the classical RF. Regardless of the defect shape (circular or elliptical), we design a rhomboid-like flap sharing the curved border with the defect, hence it's unnecessary to tailor the wound further. In the classical flap, there are two points that are in strongest tension (Fig. 1-B, points a and D), and the flap fits the defect snugly, this increases the difficulty of wound closure since the versatility of the flap is restricted [22, 23]. In our flaps, one of the points under greatest tension (Fig. 2-B, point a) can be matched to any points on a length of the defect border (Fig. 2-B, dotted line A'), hence the flap affords more versatility. Additionally, due to preservation of the circumferential tissue, the advancing distance of the flap is reduced (Fig. 2-B, imaginray line A'B). All these factors allow easier closure of the wound. For large defects, we also slightly reduced the 60° flap angle, so as to further reduce the skin tension [24–26].

The design of RF is critical. We took into account of the tumor size, the perforator, limb axis, RSTL, local tension, and joint motion before flap design. The vector of stress in the flap is placed in parallel with the limb axis. At least two of the incisions are placed in the RSTL, and no incisions cross the joint line vertically. After dissection of the flap, the two points under strongest tension should be sutured firstly, so as to avoid repeated traction of the flap [27, 28]. Our flaps are easier to draw compared with the classical RF and its variations. The round and oval defects slightly decrease the advancing distance of the flap and adds its versatility. The procedure is easy to learn and viable for orthopedic oncologists.

The importance of functional outcome after limb-salvage surgery for STS has been increasingly recognized [1, 4]. The postoperative limb function is associated with various factors, such as the magnitude of resection, tumor location, and reconstructive procedures [18]. A systematic review analyzed the outcomes after functioning reconstructions in the treatment of limb STS, the results indicated most patients achieved favorable functional outcomes [18]. A case-control propensity score analysis suggested flap reconstruction tended to secure a wider surgical margin, whereas the MSTS score was lower than those having primary closure [3]. In this case series, the modified RF resulted in favorable functionality. However, it's noteworthy we did not perform muscle transfer and reconstruction of the tendons and the nerves, these procedures may affect the functional outcome.

Our research is subject to the limitations of the single-center retrospective study. Due to the limited sample size, a control group in comparison with our flaps was impossible. Prospective case-control studies are warranted to demonstrate the effectiveness of the modified RF in treatment of limb defects following wide resection of the large STS.

## Conclusions

The modified RF is versatile, easy to design and yields satisfactory effectiveness in treatment of limb defects after resection of large STS. In the extremities, flap designing is dependent upon the limb axis, perforator, RSTL, skin tension, and joint motion. Yet to be evaluated in long-term studies of larger sample size, we believe our flap provides a valuable option for reconstruction of large limb defects after resection of the STS.

## List Of Abbreviations

STS: soft tissue sarcoma; AJCC: American Joint Committee on Cancer; MRI: magnetic resonance images; RSTL: relaxed skin tension lines; RF: rhomboid flap; MSTS: Musculoskeletal Tumor Society

## Declarations

Ethics approval and consent to participate: This study was approved by the Ethics Committee of First Hospital of China Medical University (Number AF-OG-03-1) and informed consent was waived due to the retrospective nature of this study.

Consent for publication: All the images used in this article were completed following obtaining a written consent for publication from each patient.

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare they have no competing interests.

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Authors' contributions: YC accountable for design of the study and writing of the manuscript. MML accountable for the collection and analysis of the data. All authors read and approved the final manuscript.

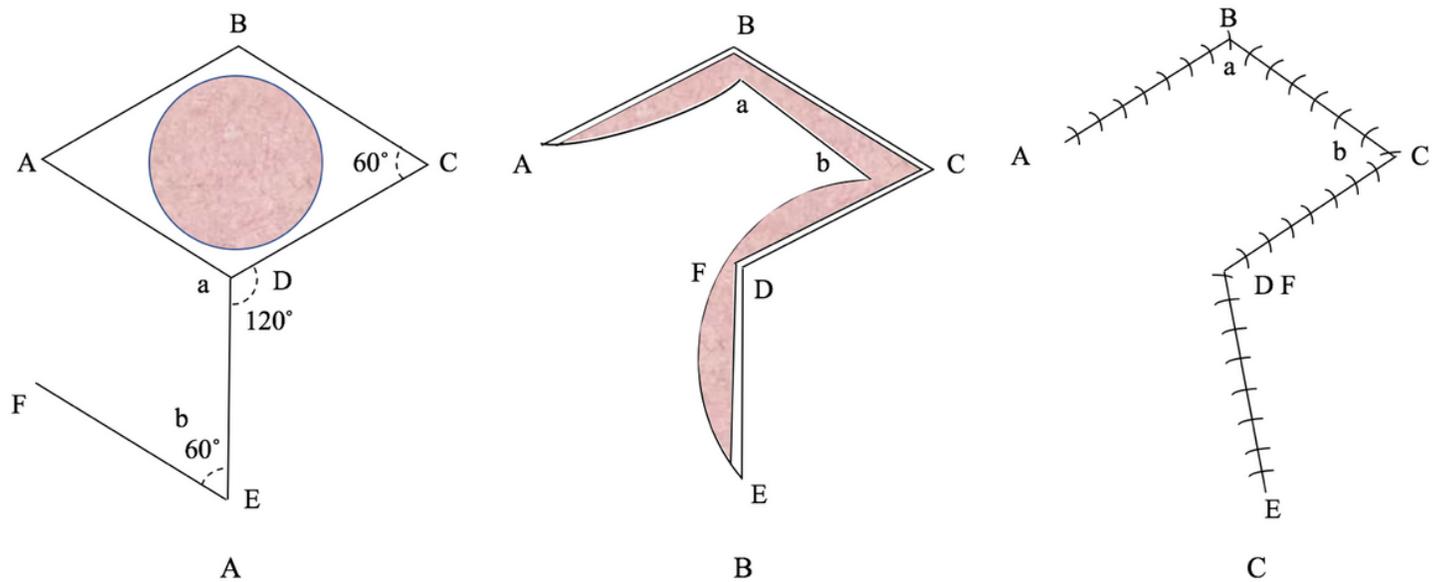
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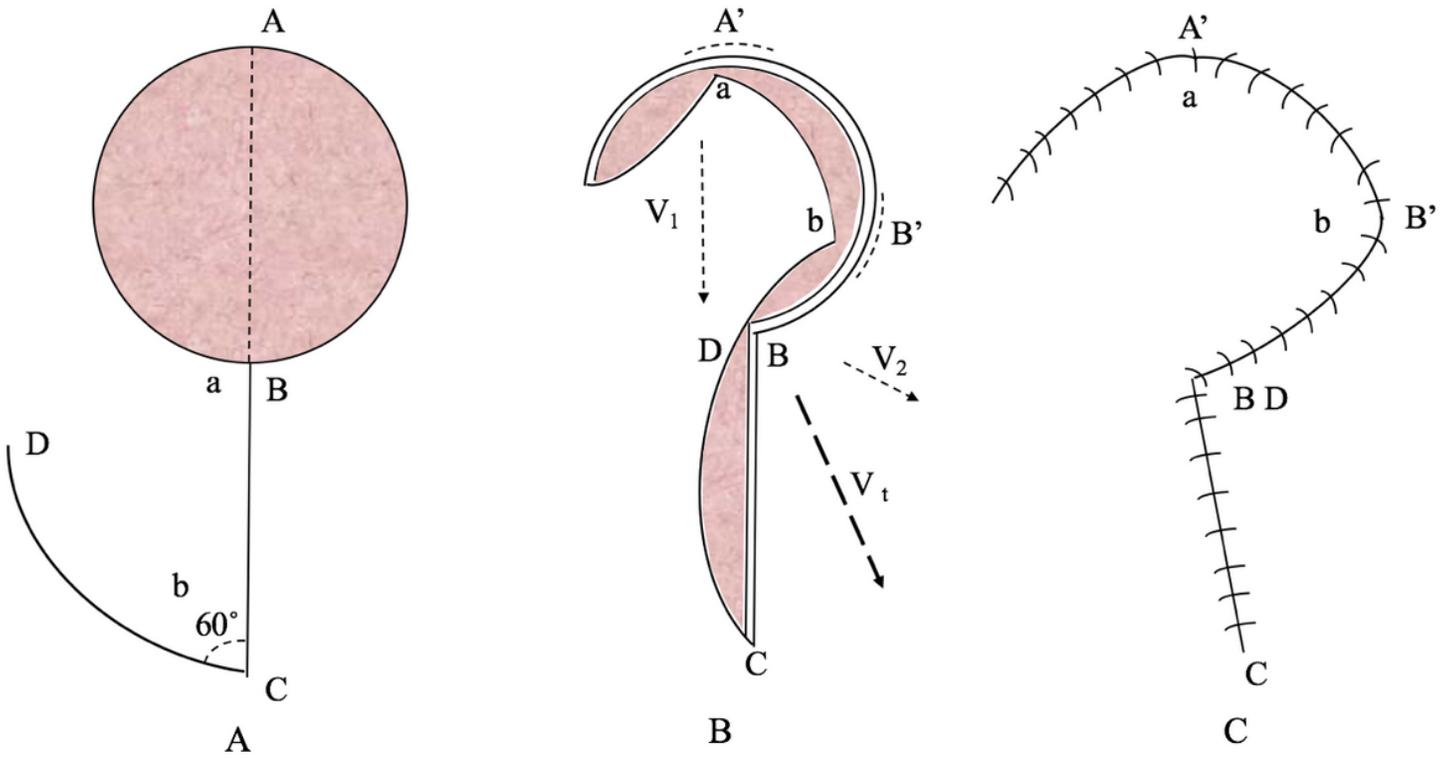
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## Figures



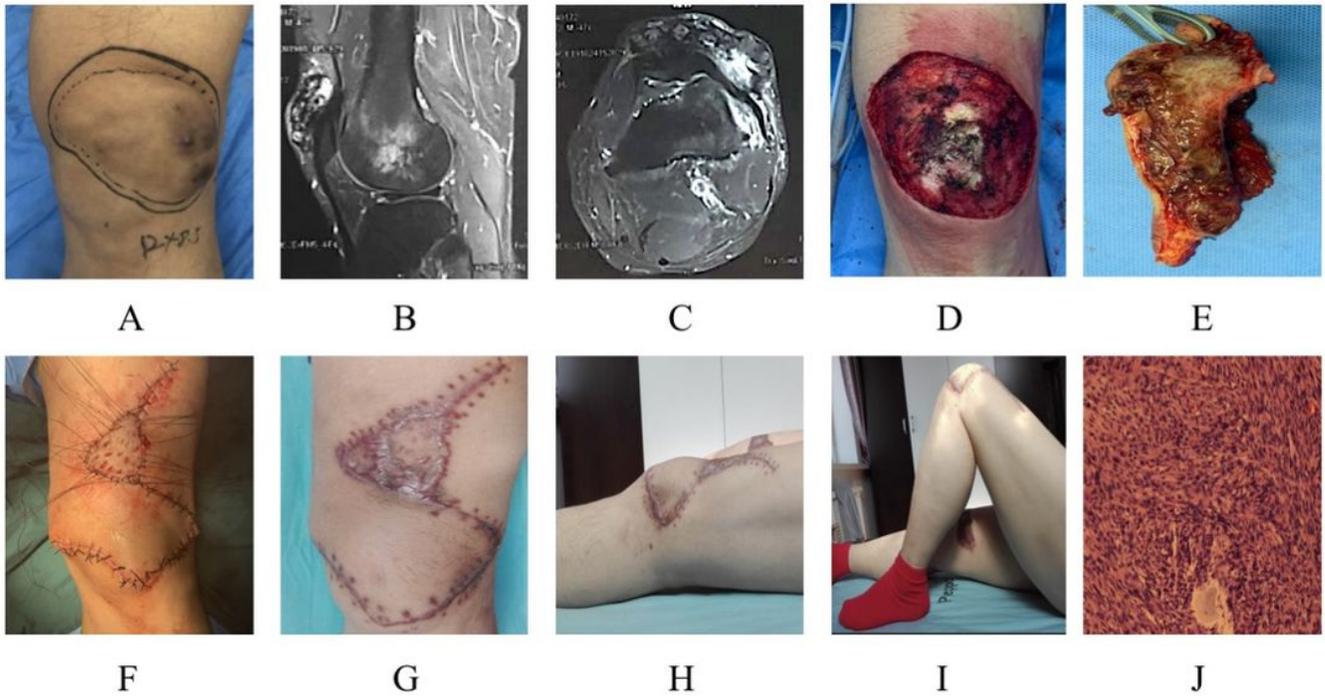
**Figure 1**

Traditional rhomboid flap. Demonstration of the traditional rhomboid flap. Figure 1-A shows the geometric design of the flap, the circular defect is tailored into a parallelogram with  $\angle BCD = \angle DEF = 60^\circ$ , line AD=line AB, line DE=line BC, and line EF=line CD; Figure 1-B demonstrates intraoperative transfer of the flap, and 1-C shows the zigzag-shaped incision.



**Figure 2**

Modified rhomboid flap. Demonstration of the modified rhomboid flap. Figure 1-A shows the geometric design of the flap, the dotted line  $AB$  is the diameter (or the shorter axis) of the defect after resection of the superficial soft tissue sarcoma, line  $AB$  is extended to  $C$  with line  $AB = \text{line } BC$ ,  $\angle BCD = 60^\circ$  (or slightly  $< 60^\circ$ ), line  $CD$  runs in parallel with the contralateral border of the flap; Figure 1-B shows intraoperative transfer of the flap, the points  $a$  and  $B$  are in strongest tension, there're two vectors of tension, one runs horizontal to the imaginary line  $A'B$  ( $V_1$ ), and the other lies at approximately a  $60^\circ$  angle to the line  $BC$  ( $V_2$ ), hence the sum of the vector of tension runs at about a  $30^\circ$  angle to the line  $BC$  ( $V_t$ ), points  $a$  and  $b$  of the flap are matched to any point in the curved line  $A'$  and  $B'$ ; Figure 1-C shows the incisions of the flap.



**Figure 3**

Reconstruction of the defect following resection of the leiomyosarcoma in the anterior knee. Figure 3-A shows the appearance of the tumor located at the left anterior knee of a 47-year old male patient; Figure 3-B and C: T2 weighted MRI demonstrates the size and the depth of the tumor; Figure 3-D shows the wound following wide resection that resulted in exposure of the underlying bone and tendons, whereas E demonstrates the gross specimen; Figure 3-F and G demonstrate the modified rhomboid flap and full-thickness skin graft. Figure 3-H and I show the range of motion of the knee was favorable. Figure 3-J shows the histologic finding indicative of leiomyosarcoma (HE,  $\times 100$ ).