Dissertation

Donor site morbidity after the harvesting of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial

submitted by

Dr. med. univ. **Maximilian Neuwirth**

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Division of Plastic, Aesthetic and Reconstructive Surgery;

Department of Surgery; Medical University of Graz

under the Supervision of

Prof. Dr. Lars-Peter Kamolz

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Statutory declaration

I hereby declare that this is my own original work and that I have fully acknowledged by name all of those individuals and organizations that have contributed to the research for this thesis. Due acknowledgement has been made in the text to all other material used. Throughout this thesis and in all related publications I followed the “Standards of Good Scientific Practice and Ombuds Committee at the Medical University of Graz”.

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- *Division of Plastic, Aesthetic and Reconstructive Surgery; Department of Surgery; Medical University of Graz*
    - Prof. Dr. Lars P. Kamolz
    - Prof. Dr. Michael Schintler
    - Dr. Raimund Winter
    - Dr. Stefan Benedikt

- *Department of Plastic, Aesthetic and Reconstructive Surgery; General Hospital Klagenfurt am Woerthersee*
    - Prof. Dr. Matthias Rab
    - Dr. Michel Mueller-Eggenberger
    - Dr. Madeleine Mischitz

- *Department of Trauma Surgery; Hospital Friesach*
  - Dr. Wolfgang Palle
  - Dr. Karina Hoenck

- *Division of General Radiology; Department of Radiology; Medical University of Graz*
  - Prof. Dr. Helmut Schoellnast
  - Dr. Elmar Janek

- *Institute for Medical Informatics, Statistics and Documentation; Medical University of Graz*
  - Dipl. Ing. Andrea Borencich

- *Division of Hand and Microsurgery; Private Hospital Maria Hilf*
  - Heinz Buerger

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Abbreviations and Definitions

ADL	Activities of Daily Living
BMI	Body mass index
BML	Bone marrow lesions
BS	Bone or soft tissue
CL	Cartilage loss
cm	Centimeter(s)
DGA	Descending genicular artery
DGA-CB	DGA cutaneous branch
DSM	Donor site morbidity
ES	Effusion synovitis
IKDC	International Knee Documentation Committee Subjective Knee Evaluation Form
kg	Kilogram(s)
KOOS	Knee Injury and Osteoarthritis Outcome Score
KSFS	Knee Society Function Score
KSS	Knee Society Score
LFC	Lateral femoral condyle
LKS	Larson Knee Score
MFC	Medial femoral condyle
MOAKS	MRI Osteoarthritis Knee Score
MRI	Magnet resonance imaging
O	Osteophytes
OA	Osteoarthritis
OAK	OAK Knee Score
OC	Osteocartilaginous
PAM	Potential active motion
PD	Proton density
POSAS	Patient and Observer Scar Assessment Scale
ROM	Range of motion
SA	Saphenous artery
SD	Standard deviation
SFA	Superficial femoral artery
SLGA	Superior lateral genicular artery
TSE	Turbo spin echo
VAS	Visual analogue scale

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Abstrakt

Hintergrund

Nicht zuletzt aufgrund der konstanten anatomischen Verhältnisse und dem hohen rekonstruktiven Potential entwickelte sich die Region um den medialen und lateralen Femurkondyl zu einer der vielversprechendsten Spenderregionen in der rekonstruktiven Mikrochirurgie. Verglichen mit der Vielzahl an Publikationen, die den Fokus auf die rekonstruktiven Möglichkeiten dieser Lappenplastiken richteten, existieren nur vereinzelte Arbeiten, die die Hebedefektmorbidität dieser Spenderregion evaluieren. Da der Langzeiterfolg einer mikrochirurgischen Spenderregion aber vor allem durch eine niedrige Hebedefektmorbidität bestimmt wird, setzte sich diese Arbeit eine umfassende Analyse der Hebedefektmorbidität nach objektiven und reproduzierbaren Kriterien zum Ziel.

Patienten und Methoden

Diese Studie inkludierte 156 PatientInnen denen zwischen 2005 und 2017 ein mikrovaskuläres Knorpel-, Knochen-, oder Weichteiltransplantat vom medialen oder lateralen Femurkondyl entnommen wurde. Mithilfe einer retrospektiven Datenanalyse wurden alle demographischen Daten, die Lappencharakteristiken wie auch der postoperative Verlauf evaluiert. Im weiteren standen 97 PatientInnen für eine klinische und radiologische Nachuntersuchung zur Verfügung. Bei dieser wurde die Hebedefektmorbidität nach objektiven (Knee Society Score; Larson Score; OAK Score;), subjektiven (IKDC Score; KOOS Score; Knee Society Function Score;) und radiologischen Kriterien (Kellgren and Lawrence Score; MRI Osteoarthritis Knee Score – MOAKS) erhoben.

Ergebnisse

In 82,7% (129/156) des Gesamtkollektives kamen Lappenplastiken vom medialen Femurkondyl zur Anwendung, während 17,3% (27/156) eine Entnahme vom lateralen Femurkondyl erhielten. Mikrovaskuläre Knochen- oder Weichteiltransplantate kamen in 73,7% (115/156) zur Anwendung, osteochondrale Lappenplastiken wurden in 26,3% (41/156) gehoben. In 9,6% (15/156) zeigten sich Komplikationen am Hebedefekt im postoperativen Verlauf (Interventionspflichtige Major-Komplikationen: 3%). Osteochondrale Lappenplastiken waren mit einer signifikant höheren Komplikationsrate assoziiert.

Der mediane Nachuntersuchungszeitraum betrug 1529 Tage (range: 248-4810). Die Ergebnisse im Knee Society Score (94,8 ±10,1), Larson Score (94,5 ±10,1) und OAK Score (95,5 ±6,6) zeigte eine nahezu ungestörte Kniefunktion des Nachuntersuchungskollektives. Die patienten-orientierte Evaluation der Kniefunktion zeigte sich ebenfalls unauffällig und bestätigte die Ergebnisse der objektiven Nachuntersuchung (IKDC Score: 86,7 ±17,4; KOOS Score: 89,3 ±17,1; Knee Society Function Score: 97,2 ±7,7). Im Vergleich zu mikrovaskulären

Knochen- und Weichteiltransplantaten zeigte die Entnahme von osteochondralen Transplantaten einen signifikant größeren Einfluss auf die postoperative Kniefunktion, unabhängig der Heberegion (medialer oder lateraler Femurkondyl). Die Entnahme von mikrovaskulären Knochentransplantaten hatte keinen Einfluss auf den radiologischen Kniestatus (Kellgren und Lawrence Score Grade 0 oder 1: 88,9%, 48/64). Im Vergleich zur gesunden Gegenseite, zeigten osteochondrale Transplantate im bilateralen MRT (MOAKS) keine signifikante Anhäufung an relevanten radiologischen Pathologien. Die offensichtlichen Knorpeldefekte hatten in der Mehrzahl der PatientInnen keinen Einfluss auf die Kniefunktion.

Conclusio

Die Hebedefektmorbidität nach Entnahme von mikrovaskulären Knochen- und Weichteiltransplantaten ist minimal und hat keinen wesentlichen Einfluss auf die postoperative Kniefunktion. Bei insgesamt geringer Hebedefektmorbidität kann die Hebung eines osteochondralen Lappens einen Einfluss auf die postoperative Kniefunktion haben.

Abstract in English

Background

Due to their consistent anatomy and reconstructive potential, free flaps from the medial and lateral femoral condyle region have become increasingly popular over the last decade. In contrast to the countless scientific reports that have focused on the primary reconstructive potential, there are very few that have evaluated the donor site morbidity (DSM) of these flaps. Since a low flap related morbidity at the donor site ultimately determines the long-term success of every microsurgical donor region, this study aimed to evaluate the DSM of free flaps from the distal femur according to objective and reproducible criteria.

Methods

This study included 156 patients who had a microvascular cartilage, bone or soft tissue harvest from either the medial or lateral femoral condyle region between 2005 and 2017. A retrospective chart review that focused on all flap characteristics as well as the postoperative course at the donor sites was performed for all patients. In total 97 patients were available for clinical and radiologic long-term follow-up examination. At the follow-up examination, the DSM was assessed according to objective (Knee Society Score; Larson Score; OAK Score;), patient-reported (IKDC Score; KOOS Score; Knee Society Function Score;) and radiologic criteria (Kellgren and Lawrence Score; MRI Osteoarthritis Knee Score – MOAKS).

Results

In 82.7% of patients (129/156) medial femoral condyle flaps we used, while free flaps from the lateral femoral condyle were harvested in 17.3% (27/156). The flaps included bone or soft tissue in 73.7% (115/156) while osteocartilaginous flaps were used in 26.3% (41/156). The overall complication rate at the donor sites was 9.6% (15/156; major complication rate: 3%) with a significantly higher complication rate for the osteocartilaginous flap subgroup. The median follow-up time was 1529 days (range 248-4810 days). The mean Knee Society Score (94.8 ±10.1), Larson Score (94.5 ±10.1) and OAK Score (95.5 ±6.6) showed nearly unimpaired knee function at the time of follow-up. The overall patient-reported DSM was low (IKDC Score: 86.7 ±17.4; KOOS Score: 89.3 ±17.1; Knee Society Function Score: 97.2 ±7.7). Compared to bone or soft tissue flaps, the osteocartilaginous flap subgroup presented a significantly higher DSM, regardless of the donor site (medial or lateral femoral condyle). Bone flaps did not show any relevant radiologic DSM in the Kellgren and Lawrence scoring system for knee osteoarthritis (Grade 0 or 1: 88.9%, 48/64). Osteocartilaginous flaps showed no significant occurrence of the majority of knee pathologies at the donor knee in the bilateral MRI scans (MOAKS). The obvious cartilage lesions at the donor site did not have a relevant impact on knee function in most of the patients.

Conclusion:

The DSM for bone and soft tissue flaps from the medial and lateral femoral condyle region is negligible and has no impact on the objective or patient-reported knee function. The DSM for osteocartilaginous flaps can be considered to be low. Compared to bone or soft tissue flaps, the harvesting of these flaps can have some impact on the postoperative knee function.

1. Introduction

1.1. History of vascularized bone grafts in reconstructive microsurgery

"…the ideal of the future: the insertion of a piece of living bone which will exactly fill the gap and will continue to live without absorption." (Curtis, 1893)[5,6]

With his idea that a vital, vascularized bone graft could minimize bone resorption rates, Wilhelm Wagner opened a new chapter in bone reconstruction. In 1889 he first described a pedicled, split-thickness bone flap for the closure of a defect on the neurocranium.[7]

Driven by the first promising results of Wagner and others, as well as the need for a reliable option in long bone reconstruction to reduce high amputation rates and perioperative mortality, Nichols reported the first successful use of pedicled fibula flaps in ipsilateral lower leg reconstruction in 1904.[6,8] Despite the obvious advantages of these grafts compared to the popular non-vascularized bone grafts, the technically demanding flap harvest and the local restriction of these flaps limited their use and acceptance in routine reconstructive bone surgery at the time.[6]

Based on the clinical observation that vital bone grafts are associated with faster healing and lower resorption rates, the bone blood supply and its impact on bone healing moved into the scientific focus in the early and middle 20th century. Thanks to the pioneering work of Brookes[9], Trueta[10], Crock[11] and Rhinelander[12], the general shift in understanding of the bone from an inert tissue towards a well vascularized complex organ system paved the way for future bone reconstruction.[13]

With the subsequent introduction of microsurgical techniques by Jacobson in 1962[14] – a "game-changer" in modern reconstructive surgery – the use of free microvascular bone grafts became technically possible and eliminated the major disadvantages that were associated with pedicled bone grafts. As a result of these developments, Östrup and Frederickson performed the first free vascularized bone graft in a canine model in 1974.[15] Finally, the first free vascularized bone transfer in a human was successfully performed in 1974 by Taylor, who used a free fibula flap to reconstruct a large traumatic defect of the tibia of a teenaged male patient.[16]

Based on the publication of Taylor, and with the further establishment of microsurgical techniques in daily reconstructive practice, the free fibula flap quickly became a workhorse flap and the preferred technique in the reconstruction of large bone defects.[6,17]

With the experience of the free fibula flap, in the following years the donor sites of free bone flaps were successfully expanded to the iliac crest[18], the scapula[19] and the radius.[20]

With the introduction of supermicrosurgical techniques in recent years, new donor regions for small microvascular bone and cartilage grafts moved into the scientific focus and opened innovative options in small bone and vascularized cartilage repair.[4,21-26]

1.2. Vascularized vs. non-vascularized bone grafts

Despite low union and high resorption rates, and due to the fact that feasible alternatives were missing, non-vascularized bone grafts have been the gold standard in bone reconstruction for decades.

Based on the findings of colleagues in the past who investigated the patterns of osseous vascularity and made a decisive contribution to the understanding of bone healing, a comparative study of Weiland et al. could clearly show the advantage of vascularized bone grafts compared to non-vascularized bone grafts in terms of healing, union rates and biomechanical strength.[27] Further studies supported these findings and additionally showed the higher resistance of vascularized grafts to bone resorption, which is known to be one of the major long-term problems of non-vascularized bone grafts.[28-30]

Regarding the above-mentioned advantages, vascularized bone grafts had been widely accepted and became a standard procedure in the reconstruction of so called “critical sized bone defects”. Beside the reconstruction of larger bone defects, where the advantage of vascularized bone grafts was obvious and without alternatives, there was a disagreement about their indications and advantages in the reconstruction of smaller bone defects.

With the introduction of the angiosome concept by Taylor and the subsequent invention of perforator flaps and supermicrosurgical techniques, new donor sites for smaller vascularized bone grafts came into the reconstructive focus.[21,31]

Aside from clinical innovations, further basic scientific studies that investigated the impact of vascularity on bone healing highlighted the role of angiogenesis for successful bone repair and showed that impaired blood flow of the bone is directly linked to impaired bone healing.[32]

As mentioned above, the role of small microvascular bone grafts in small bone reconstruction, as is carried out in hand and maxillofacial surgery, was unclear. For many years, there was an undisputed dogma that the reconstruction of small bone defects is the ideal domain for non-vascularized grafts, and a vascular graft in the reconstruction of “small-sized” defects would not bring an additional benefit in the clinical outcome. Interestingly many of these non-vascularized grafts were used to solve problems that were directly linked to impaired bone vascularization (i.e. avascular necrosis). Although immediate union could be achieved in some cases, due to the process of creeping substitution and graft resorption, the future outlook of non-vascular bone grafts was unpredictable.

Regarding the superior outcome of large, vascularized grafts and the growing knowledge surrounding bone healing, further research was undertaken to investigate the effects of vascularized bone grafts in small defect repair and bone revascularization. In an experimental study, Benlidayi et al. compared vascularized and non-vascularized femur grafts for the reconstruction of mandibular defects in pigs.[33] They reported a lower rate of bone resorption for vascularized grafts. Although direct biomechanical testing was not performed, the histomorphometric results of this study implied the greater strength of a vascularized graft compared to non-vascularized grafts.[33] Sunagawa et al. reported similar findings in scaphoid nonunion with avascular necrosis in an experimental canine study.[34] Besides increased fracture healing of the vascularized grafts compared to the non-vascularized graft group, a significantly higher rate of revascularization and osteogenesis at the avascular proximal bone was evident in the vascularized graft group. This observation has been described before and could imply the capacity of these grafts to restore revascularization and osteogenesis in an avascular bone segment.[35]

Subsequent clinical studies supported these experimental observations and showed the advantages of small, vascularized bone grafts in relation to healing rates, reconstructive potential and functional outcome compared to non-vascular bone grafts.[24,36-38]

Nowadays the reconstructive benefits of vascularized bone grafts are undisputed, and their use has developed from an innovative procedure for selected cases to a routine procedure in everyday reconstructive practice (Figure 1).

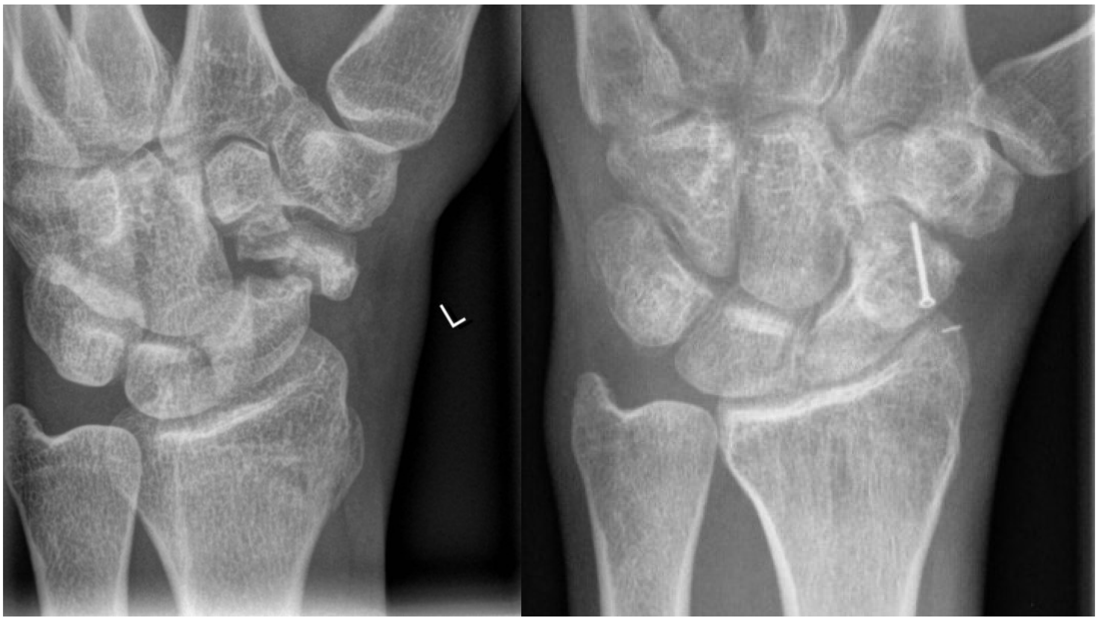

Figure 1. Treatment of a scaphoid nonunion with a corticocancellous bone flap from the medial femoral condyle; left: preoperative x-ray, right: postoperative follow-up x-ray.

1.3. The femoral condyle region as a donor source for vascularized bone grafts

In 1989 Hertel et al. first reported their experience with a pedicled reverse-flow corticoperiostal flap based on the vascular system of the medial femoral condyle.[39] Two years later, in 1991 Sakai et al. introduced a free corticoperiostal flap based on the descending genicular artery (DGA) system to resolve upper extremity non-unions.[21] Based on promising initial results along with subsequent innovations in supermicrosurgery and increased knowledge about bone healing, this flap developed from an interesting reconstructive option for selected cases to a workhorse flap in the treatment of bony non-unions (Figure 2).[3]

Today there are a number of reports that underline the reconstructive and osteogenic potential of the medial femoral condyle corticoperiostal flap in the restoration of long bone non-unions in the upper and lower extremity.[40-55] A recent meta-analysis of Weir et al. analyzed the performance of these flaps in the treatment of recalcitrant long bone non-union of the upper and lower extremity. With a combined union rate of 99%, this study demonstrated the osteogenic potential and advantages of these flaps compared to the existing non-vascularized therapeutic options.[56]

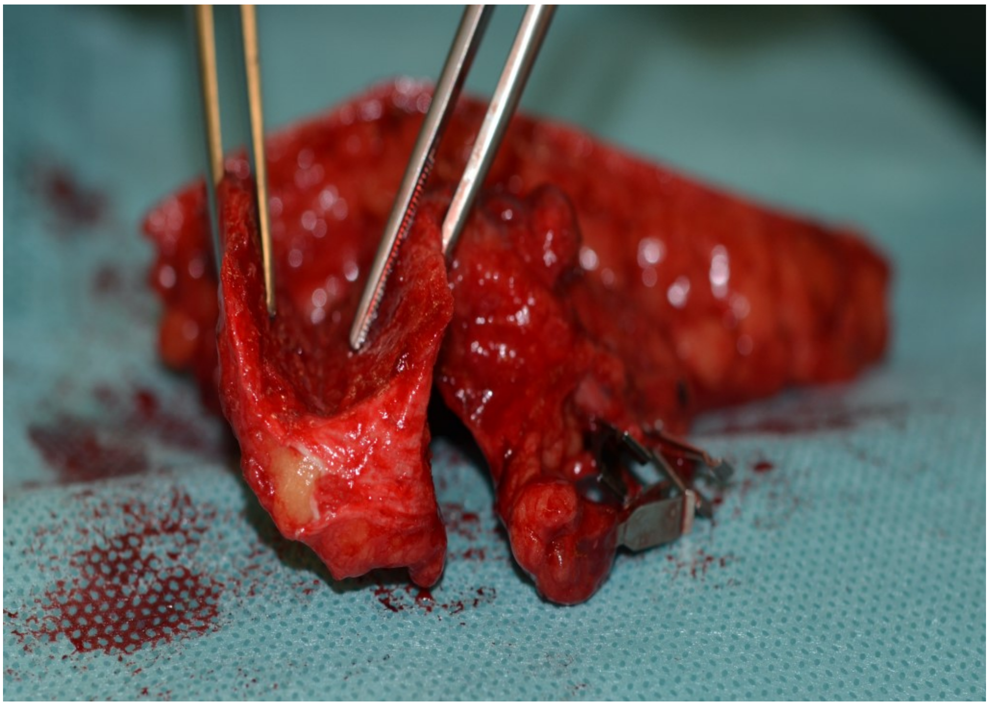

Figure 2. Intraoperative view of a corticoperiostal flap from the medial femoral condyle.
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With increasing clinical experience, the composition of these flaps was further expanded from thin corticoperiostal flaps to small semistructural corticocancellous bone flaps (Figure 3). This opened up new interesting reconstructive options, in particular in hand surgery as well as head and neck surgery.

Figure 3. Intraoperative view of a semistructural corticocancellous flap from the medial femoral condyle.

Aside from the reconstruction of small bone defects in the hand[57-62], the reconstruction of complex carpal non-unions as well as the treatment of avascular necrosis of the carpus became a main indication of these flaps.[63-67]

Due to the reconstructive potential, bone flaps from the medial femoral condyle (MFC) region have also proven to be an ideal and versatile vascularized bone graft for many reconstructive challenges in head and neck surgery.[37,38,68-72]

As a major advantage compared to other donor regions, the vascular system of the medial condyle region offers the unique opportunity to harvest a piece of the convex cartilaginous surface of the medial femoral trochlea as a vascularized osteocartilaginous (OC) flap (Figure 4).[73] The use of these flaps can be seen as a real “game-changer” in reconstructive hand surgery, since they provide a reconstructive solution for unsolved complex intra-articular pathologies where other therapeutic options did not really exist.[24,25]

Figure 4. Intraoperative view of a osteocartilaginous flap from the lateral femoral condyle.
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In addition to bone flaps and OC flaps, the angiosome of the medial femoral condyle (MFC) region offers the possibility to harvest a skin island or tendon flap (adductor magnus tendon) from the medial condyle vascular system, either isolated or as part of a chimeric flap (Figures 5-7).[69,74-79]

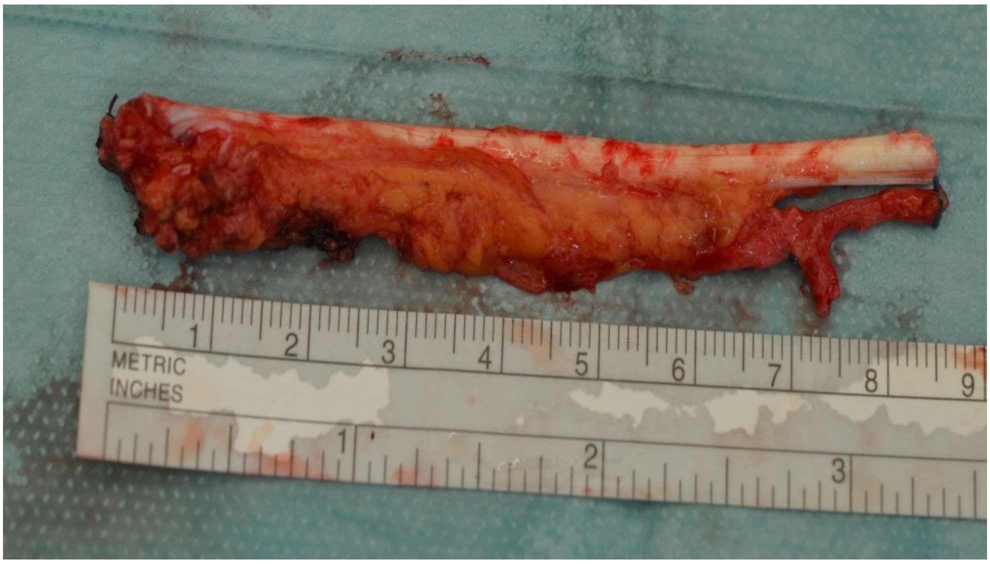

Figure 5. Intraoperative view of a microvascular adductor magnus tendon graft from the medial femoral condyle.

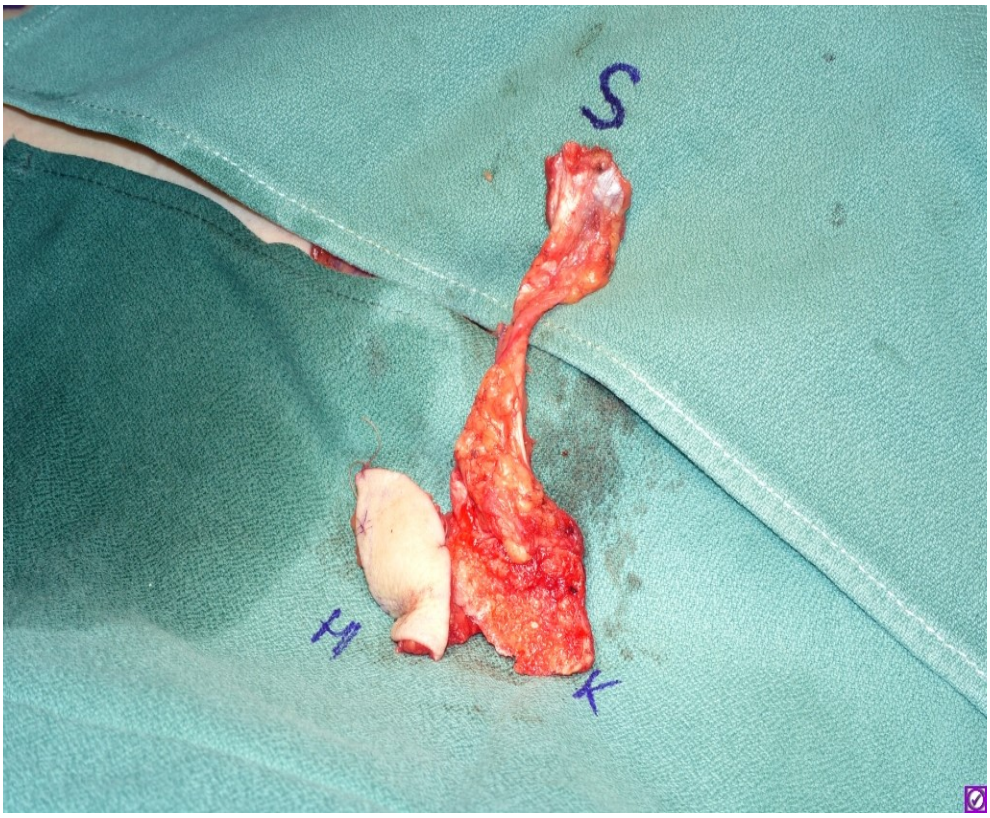

Figure 6. Intraoperative view of a chimeric flap (adductor magnus tendon and skin island) from the medial femoral condyle; S: proximal portion of the adductor magnus tendon, K: bony insertion of the adductor magnus tendon, H: skin island.

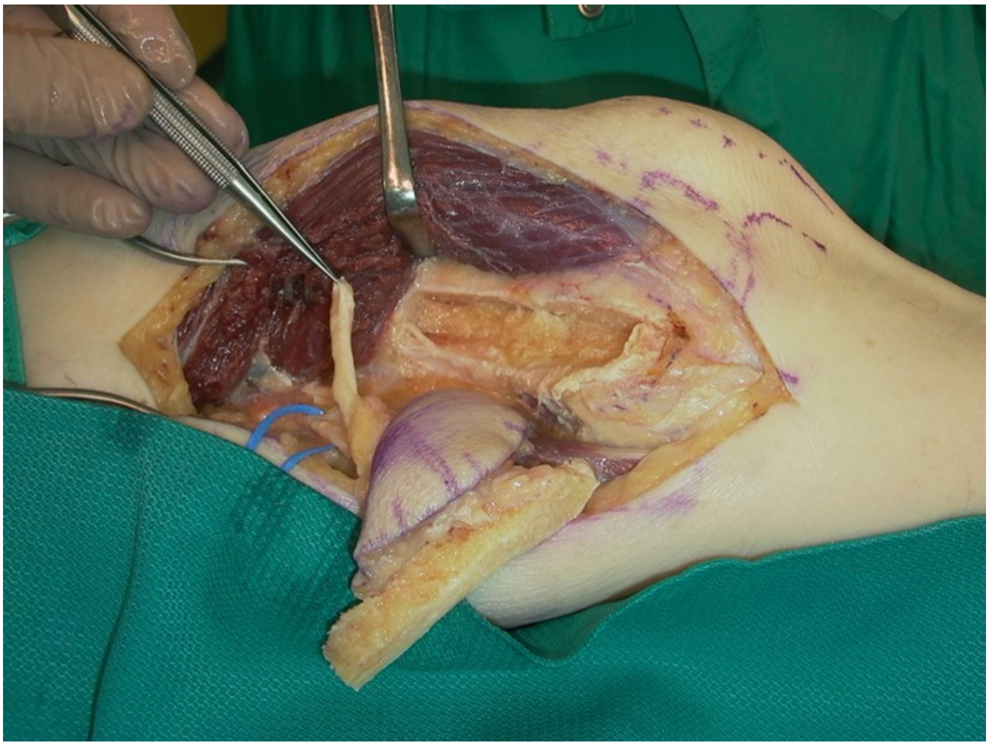

Figure 7. Intraoperative view of a chimeric flap (bone, adductor magnus tendon and skin island) from the medial femoral condyle.

In recent years, the lateral femoral condyle (LFC) region became in the reconstructive focus of interest. A fasciocutaneous flap from the vascular system of the lateral femoral condyle region was first described by Laitung in 1989.[80] A subsequent report by Hayashi et al. further investigated the vascular anatomy of these flaps and described the lateral genicular artery flap.[81] Similar to the medial condyle region, the lateral femoral condyle provides the possibility to harvest a vascularized corticoperiostal, corticocancellous or osteocartilaginous flap.[4,82] Furthermore, a skin flap as well as a soft tissue (e.g. fascia, iliotibial tract) can be included in the flap (Figure 8 and Figure 9). Compared to the medial femoral condyle region, the lateral condyle flap is characterized by a shorter vascular pedicle and a larger diameter artery. The geometric configuration of the lateral femoral trochlea clearly differs from the medial trochlea. The different shape of OC flaps from the lateral trochlea allows the reconstruction of cartilaginous defects that were not applicable to OC flaps from the medial femoral condyle region. Regarding this fact, we successfully used lateral femoral trochlea flaps to reconstruct cartilage defects on the talus shoulder.

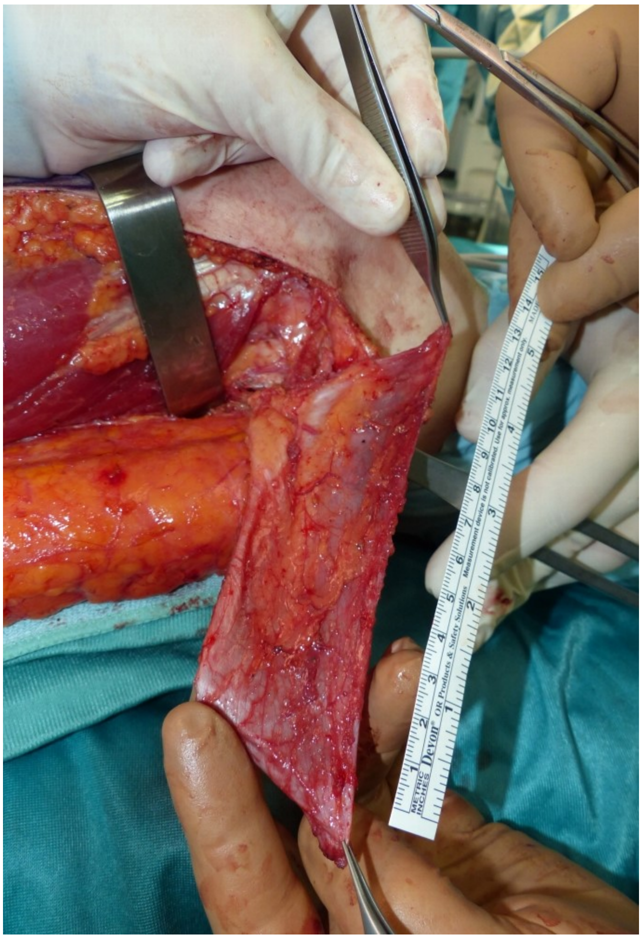

Figure 8. Intraoperative view of a microvascular fascia lata flap from the lateral femoral condyle.

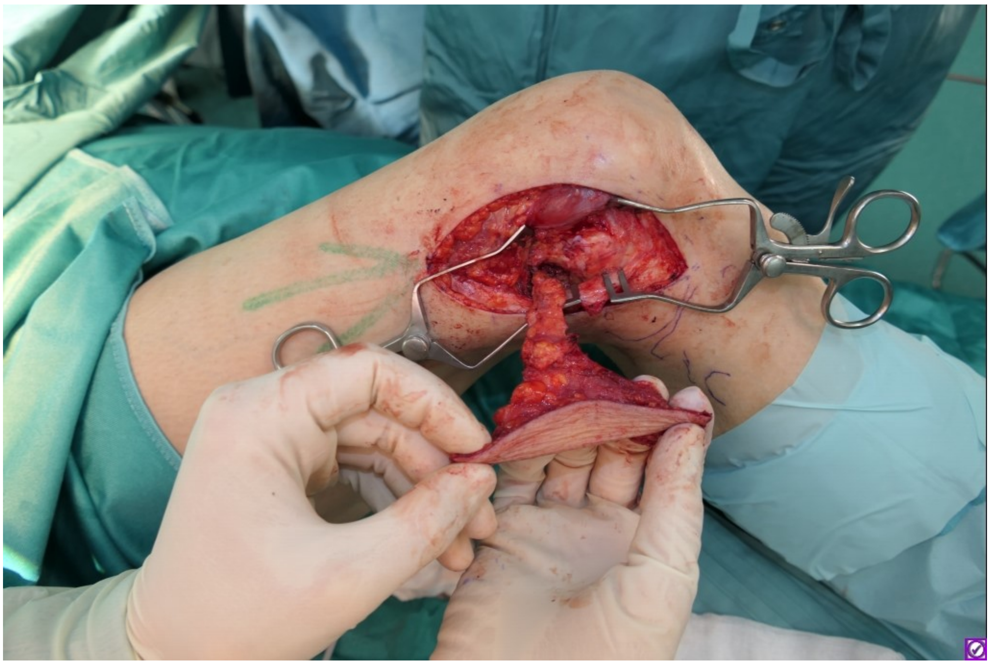

Figure 9. Intraoperative view of a microvascular fascio-cutaneous flap from the lateral femoral condyle.

As a new innovation, the lateral femoral condyle region provides the possibility to harvest a OC flap from the lateral patella based on a constant perforator of the SLGA. Compared to the classical convex-shaped osteocartilaginous grafts from the MFC and LFC, these grafts have a concave shape, which opens new possibilities in the reconstruction of concave-shaped cartilage defects, for example the lunate fossa and distal radius (Figure 10).

Figure 10. Intraoperative view of a microvascular osteocartilaginous flap from the lateral patella based on a SLGA branch; SLGA: superior lateral genicular artery.

1.4. Vascular anatomy of the medial and lateral femoral condyle flap

1.4.1. The medial femoral condyle region

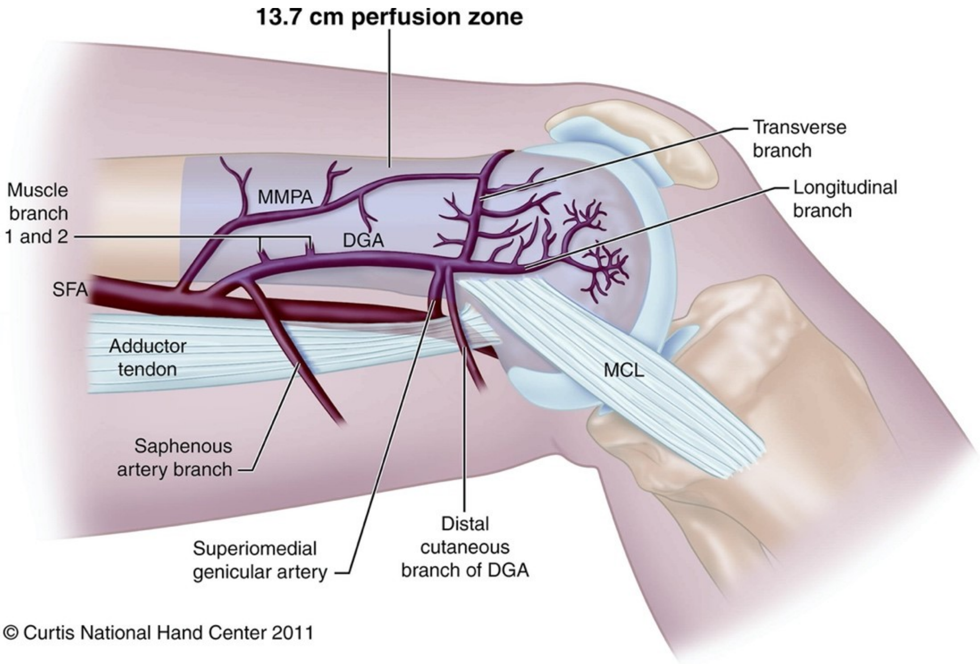

Figure 11. Anatomy of the medial femoral condyle region.
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The arterial supply of the medial femoral condyle is ensured by the descending genicular artery (DGA), the superior medial genicular artery or both (Figure 11).[83] In the majority of cases the arterial inflow of the medial femoral condyle flap is supplied by the DGA.[83,84] This artery arises from the superficial femoral artery at the proximal level of the adductor hiatus approximately 14.2cm from the knee-joint line (± 2.4cm).[3,85]

As described by Weitgasser et al. in a cadaveric study, three vascular main patterns of the medial femoral condyle region can be distinguished.[84]

Vascular pattern 1
At 80%, a Y-shaped vascular pattern has been most frequently observed in their study. In this variation the DGA originates from the superficial femoral artery (SFA) in the upper third of Hunter's canal and then divides into an articular more medially located branch and the more

laterally located saphenous artery branch (SA). For this pattern, the mean pedicle length of the DGA before splitting up into the two distal branches was 3.2cm (± 1.1cm). The mean length of the articular branch which supplies the medial femoral condyle flap from the division of the DGA to the medial femoral condyle was 6.72cm (± 2.07cm). In the majority of cases (88.5%) the DGA was accompanied by only one dominant vein, while a vascular pattern with the DGA and two accompanying veins was described in 11.5%.[84]

Vascular pattern 2

This H-shaped pattern was evident in 18% of their cases. In this pattern the SA originates separately from the SFA instead of the DGA. In this pattern a mean DGA pedicle length of 7.5cm (± 1.5cm) from its origin to the medial femoral condyle is described.[84]

Vascular pattern 3

In 2% the DGA was absent and the medial femoral condyle region was supplied by the medial superior genicular artery (branch of the popliteal artery) alone.[84]

These results are in accordance with the findings of Yamamoto et al.[83] Similar to the above-mentioned study, the DGA as a major source vessel of the medial femoral condyle region could be observed in the majority of cases (89%). In contrast to the results of Weitgasser et al. they described an absence of the descending genicular artery (vascular pattern 3) in 11%. In these cases, the medial femoral condyle region was supplied by the medial superior genicular artery alone. These anatomical findings support our clinical observation, where vascular pattern 3 can be observed in 10% to 20%.

Additional arterial branches of the DGA

Aside from the saphenous branch, which arises from the DGA in 80% of people, one to three muscular branches from the DGA to the vastus medialis muscle can be observed.[3,83,84] Further small branches from the DGA nourish the adductor magnus tendon, which allows for the harvesting of a vascularized tendon graft based on the DGA pedicle (Figure 5, Figure 6).[78]

At the condyle level, a distal cutaneous branch of the DGA (DGA-CB) can be found. The presence of this cutaneous perforator is inconsistent, but if available a skin paddle centered over the medial femoral condyle can be harvested on this perforator (Figure 7). Iorio et al. showed in their cadaveric injection study that the angiosome of this perforator measures approximately 70cm^2.[86] In case of a Y-shaped vascular pattern of the DGA, a larger skin paddle based on the SA can be harvested.[75,84]

Distally the DGA perfuses the medial femoral condyle surface with on average 30 perforators.[3] At the level of the condylar flare, the DGA divides into two major branches:[3,24] a longitudinal branch which extends to the knee-joint line and a transverse branch that passes to the proximal aspect of the patellofemoral joint.[3]

In cases in which a corticoperiostal or corticocancellous semi-structural flap is needed, these flaps are centered over the perforators of the longitudinal branch of the DGA on the medial femoral condyle. The transverse branch which passes to the cartilage-bearing area of the medial femoral trochlea is the major source vessel when harvesting an MFC OC flap.[3,24,25,75,84]

1.4.2. The lateral femoral condyle region

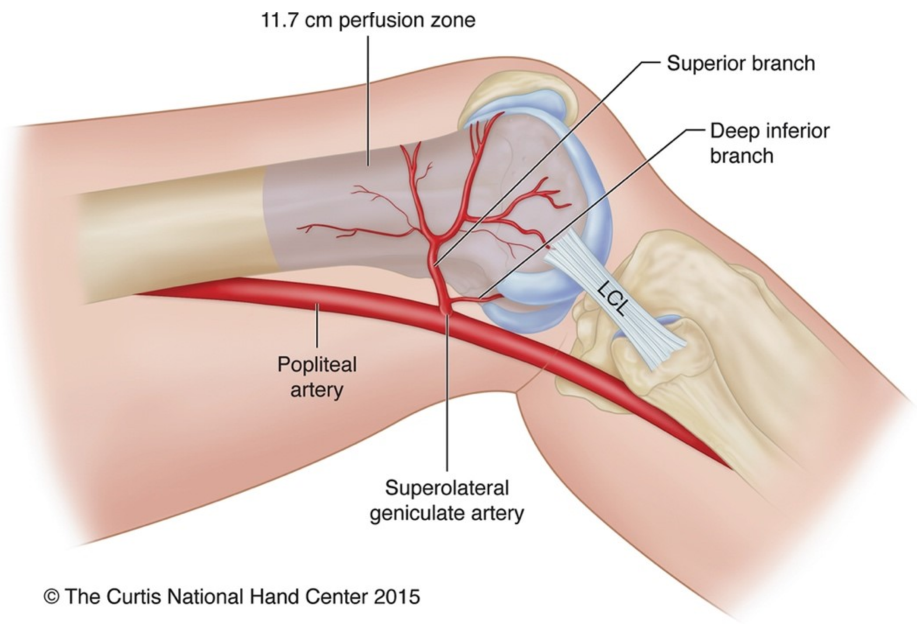

Figure 12. Anatomy of the lateral femoral condyle region.
Reproduced from Wong W, Buerger H, Iorio M, Higgins J. Lateral femoral condyle flap: An alternative source of vascularized bone from the distal femur. Journal of Hand Surgery 2015. With permission of publisher, Elsevier.[4]

The lateral femoral condyle region is consistently vascularized by the superior lateral genicular artery (SLGA). The SLGA branches from the popliteal artery approximately 4.9cm (± 1.2cm) from the knee-joint line (Figure 12).[4]

After approximately 3.8 cm (± 1cm) from the origin of the popliteal artery, the SLGA divides into a superficial patellar branch and a deep articular branch.[87] This vascular pattern can be observed in the majority of cases (96%).[87] The LFC, the patella, the distal femur shaft periosteum, the vastus lateralis and the iliotibial band is consistently vascularized through the superficial branch of the SLGA.[4,88] In the majority (86%) of their cases, Parvizi et al. observed a septocutaneous perforator from the superficial branch that vascularized the iliotibial band and the overlaying skin.[87] An average pedicle length of 4.8cm (± 0.9cm) has been reported for LFC bone flaps.[4] The SLGA is accompanied by at least one consistent vein, suitable for microvascular anastomosis.[4]

Through the superficial branch, the LFC region offers the opportunity to harvest OC flaps from the lateral femoral trochlea as well as the patella (Figure 10), corticoperiostal or corticocancellous semistructural flaps. Furthermore the distal part of the vastus lateralis muscle, the iliotibial band or a skin flap can be harvested on the SLGA pedicle as a single flap or as part of a chimeric flap (Figures 8, 9).[4,87]

1.5. Surgical technique of medial and lateral femoral condyle flap harvest

1.5.1. Medial femoral condyle flap

In a supine frog legged position, the skin incision is marked on the medial distal thigh, from the midpoint of the medial patella to the hunter canal proximally (Figure 13). After dissection through the subcutaneous plane, the fascia overlaying the vastus medialis muscle is incised. Using a sharp hook, the vastus medialis muscle is retracted anteriorly. At this point the DGA can be identified in the submuscular plane on the deep surface of the medial femur column (Figure 14). After dissection of the DGA on the proximal origin from the superficial femoral artery, the vascular pedicle is traced distally towards the medial femoral condyle. Muscular branches towards the vastus medialis muscle as well as the adductor tendon are ligated. At the level of the medial condylar flare, the two major periosteal vessels of the DGA can be visualized. For a corticocancellous or corticoperiostal bone flap, the longitudinal branch is used as the target vessel, whereas the transverse branch is used when harvesting an OC flap from the medial femoral trochlea. The flap should be centered over the chosen periosteal branch of the DGA and visible nourishing branches to the bone should be incorporated into the flap (Figure 15). After the flap dimensions have been marked on the condylar flare, the periosteum is incised a bit larger than the calculated flap size using electrical cauterization with a Colorado needle on a low energy setting. Since the periosteal branches of the DGA are firmly attached to the underlying periosteum, the distal pedicle dissection can be carried out in a subperiosteal plane to avoid any accidental pedicle injury. After the cortex of the distal femur is incised with the micro-oscillating saw, stiff small osteotomes are used to gently mobilize the flap according to the desired size (Figure 16). Finally, the pedicle is ligated proximally according to the desired length (Figure 17). A deep suction drain is placed, and a three layered (fascia, subcutis, skin) wound closure is performed. A non-adhesive wound dressing is applied. A special cast or immobilization of the knee is not required, and patients are fully mobilized on the first postoperative day.[23,26,36,75,89]

Figure 13. Surgical MFC flap harvest technique: marking of the skin incision (horizontal line); MFC: medial femoral condyle.
With permission of the copyright holder, Heinz Buerger.

Figure 14. Surgical MFC flap harvest technique: skin and underlaying fascia incised, the vastus medialis muscle is retracted anteriorly; branches of the DGA can be visualized in the submuscular plane on the surface of the medial femoral condyle; MFC: medial femoral condyle, DGA: descending genicular artery.
With permission of the copyright holder, Heinz Buerger.

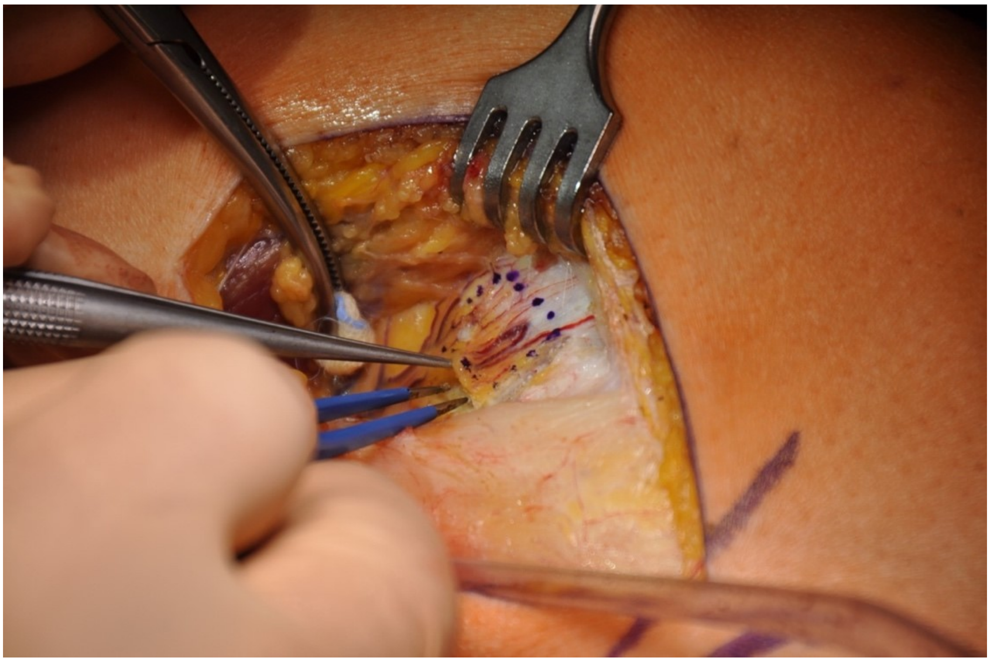

Figure 15. Surgical MFC flap harvest technique: the corticocancellous MFC flap is centered over the longitudinal branch of the DGA on the medial femoral condyle according the appropriate size; MFC: medial femoral condyle, DGA: descending genicular artery.
With permission of the copyright holder, Heinz Buerger.

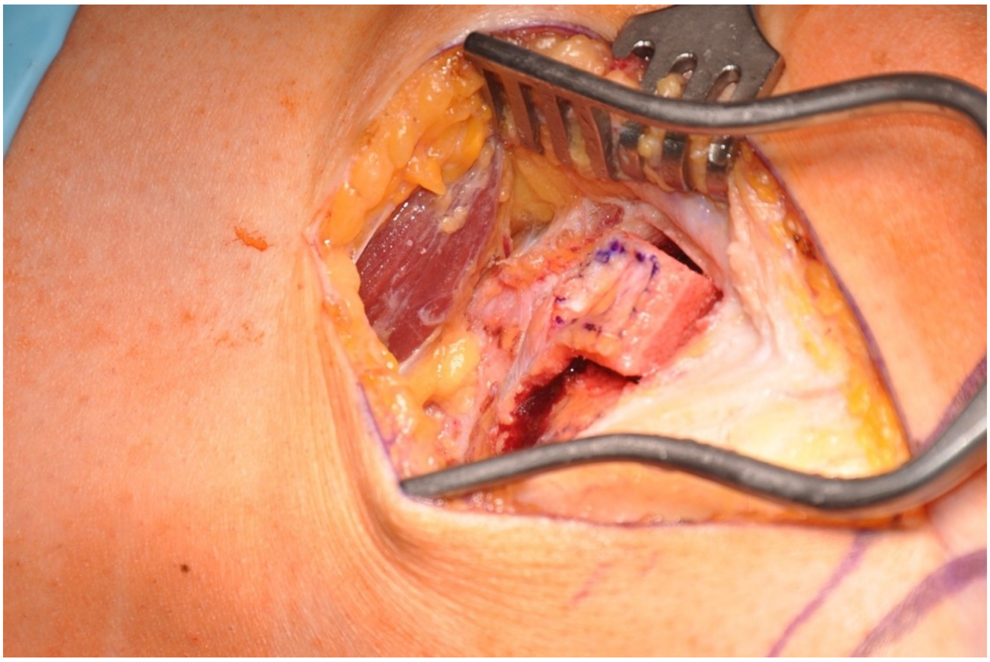

Figure 16. Surgical MFC flap harvest technique: after incision of the periosteum, the MFC flap is harvested with a micro-oscillating saw and small osteotomes; MFC: medial femoral condyle.

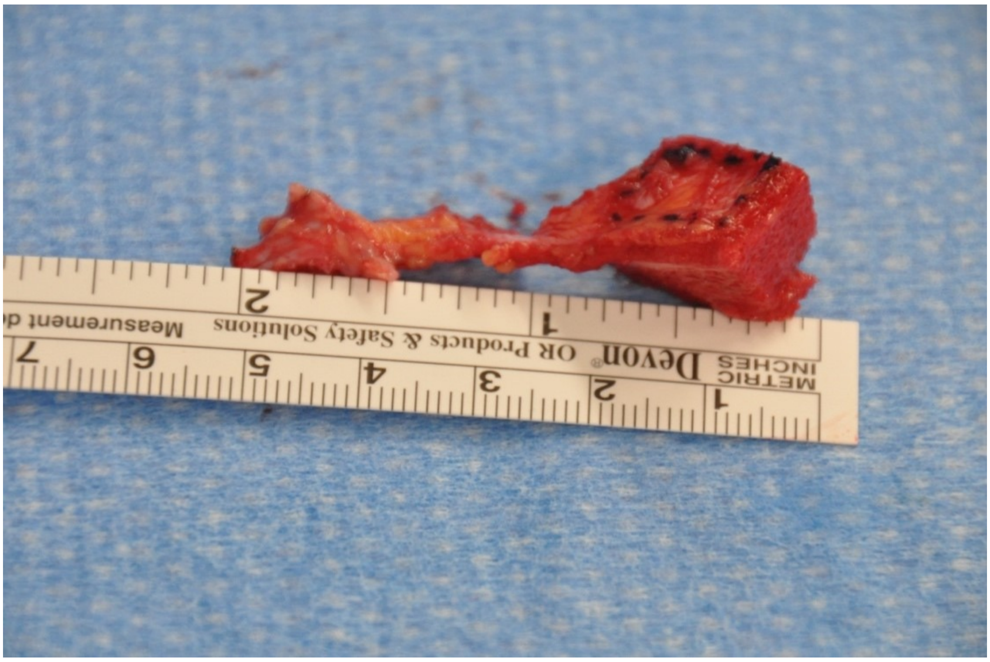

Figure 17. Surgical MFC flap harvest technique: harvested semistructural corticocancellous MFC flap with pedicle; MFC: medial femoral condyle.

1.5.2. Lateral femoral condyle flap

In a supine position with the knee slightly flexed and internally rotated, the skin incision is marked distally between the lateral margin of the patella and the prominence of the LFC. The proximal end of the incision is marked over the axis of the distal femur between the vastus lateralis muscle and the biceps femoris (Figure 18). Similar to the MFC flap, the skin incision is carried out down through the subcutaneous plane to the level of the fascia. After incision of the vastus lateralis muscle fascia, the distal portion of the muscle is retracted anteriorly using a sharp hook. At this point the superior branch of the SLGA can be identified in the submuscular plane on the deep surface of the lateral condylar flare (Figure 19). The SLGA is then traced proximally towards the origin from the popliteal vessels (Figure 20). Additional branches, like the deep branch of the SLGA as well as additional branches to the muscles and skin are ligated and the flap is harvested as described for the MFC flap. The additional figures (Figures 21 and 22) show the harvest of an OC flap from the LFC. The wound closure as well as postoperative rehabilitation process is similar to the above described MFC flap.[4,87]

Figure 18. Surgical LFC flap harvest technique: marking of the skin incision (horizontal line); LFC: lateral femoral condyle.
With permission of the copyright holder, Heinz Buerger.

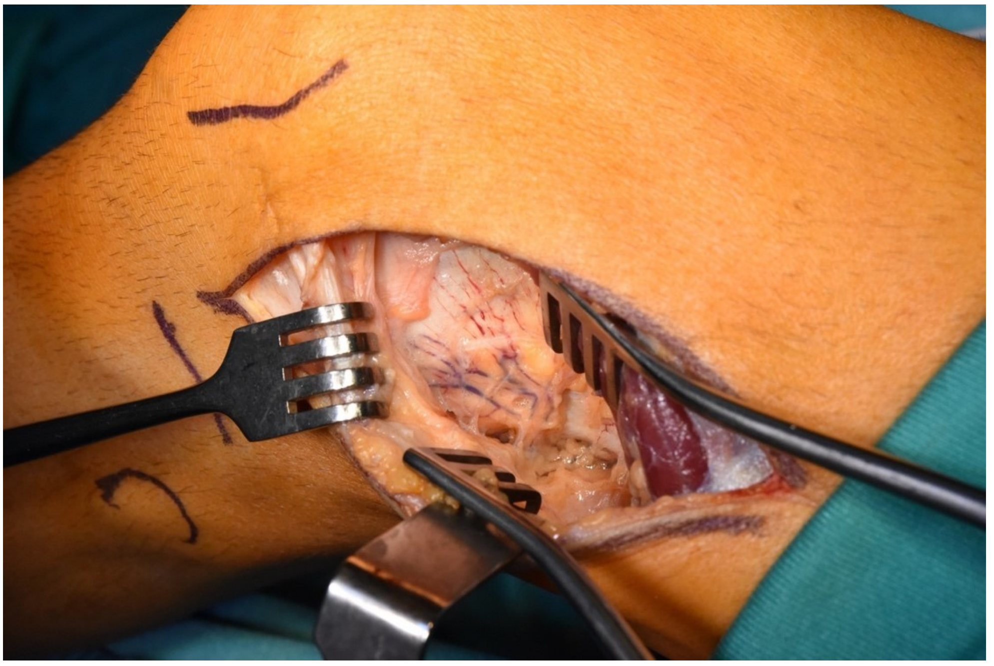

Figure 19. Surgical LFC flap harvest technique: skin and underlaying fascia incised, the vastus lateralis muscle is retracted anteriorly; the superior branch of the SLGA can be visualized in the submuscular plane on the surface of the lateral femoral condyle; LFC: lateral femoral condyle, SLGA: superior lateral genicular artery.
With permission of the copyright holder, Heinz Buerger.

Figure 20. Surgical LFC flap harvest technique: the SLGA pedicle can be traced down towards the popliteal vessels; LFC: lateral femoral condyle, SLGA: superior lateral genicular artery.
With permission of the copyright holder, Heinz Buerger.

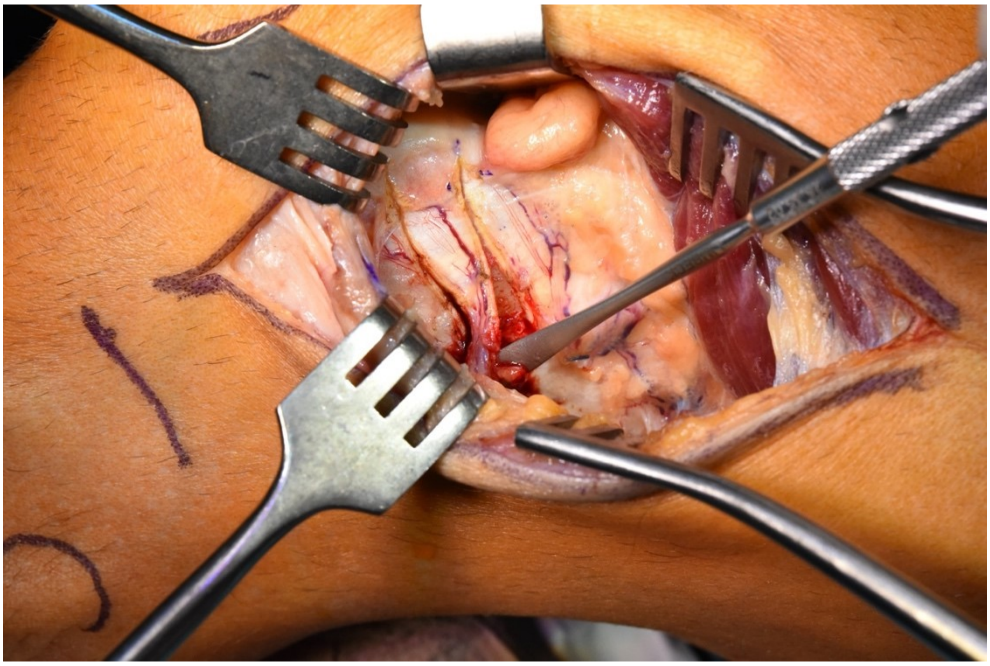

Figure 21. Surgical LFC flap harvest technique: the OC flap is centered over the superior branch of the SLGA on the lateral femoral trochlea according to the appropriate size and the pedicle is dissected towards the popliteal vessels; LFC: lateral femoral condyle, SLGA: superior lateral genicular artery.

Figure 22. Surgical LFC flap harvest technique: harvested OC-LFC flap with pedicle;
OC: osteocartilaginous, LFC: lateral femoral condyle.

1.6. Application sites of the medial and lateral femoral condyle flap

The subsequent tables list the reported indications (Table 1) and the reported application sites (Table 2) for free flaps from the distal femur and are modified from the original publication of Kazmers et al. in the Journal of Microsurgery.[2]

Small bone non-union	21,50,51,64,65,90–92
Large bone non-union	21,41,43,47,49–51,90–96
Bone defect repair	50,59,62,74,96–98
Avascular necrosis	25,90,92,99,100
Cartilage repair	25,36,82,101
Tendon reconstruction	77,102,103

Table 1. Reported indications of free flaps from the distal femur.
Reproduced with modifications from Kazmers N, Thibaudeau S, Steinberger Z, Levin S. Upper and lower extremity reconstructive applications utilizing free flaps from the medial genicular arterial system: A systematic review. Microsurgery 2016. With permission of publisher, John Wiley and Sons[2]

Head and neck	
Trachea	71,72,76
Orbit	104
Mandible and Maxilla	37,38,68,69,82
Nose	70
Skull	105,106
Upper extremity	
Phalanx	50,51,91,97,107
Thumb	50,59,60,62,97,98
Metacarpus	21,50,90
Scaphoid	64–67,73,89,101
Lunate	25
Forearm	21,43,45,49–51,90,91,93
Humerus	21,43,50,51,90,91,95,108
Clavicle	22,41,51,93,94
Lower extremity	
Foot	74,90,92,93,99
Talus	90,92,96
Achilles Tendon	77,102,103
Tibia	48,50,51,93,94,109
Femur	93,94

Table 2. Reported application sites of free flaps from the distal femur.
Reproduced with modifications from Kazmers N, Thibaudeau S, Steinberger Z, Levin S. Upper and lower extremity reconstructive applications utilizing free flaps from the medial genicular arterial system: A systematic review. Microsurgery 2016. With permission of publisher, John Wiley and Sons[2]

1.7. Donor site morbidity as a key factor in reconstructive surgery

The potential for success of every new donor area in reconstructive microsurgery is based on three key factors. The first is a consistent and reliable vascular pattern of the flap, which allows for a fast and safe flap harvest in every patient. Second, the reconstructive potential of the flap at the recipient area can be considered to be another major success factor. Finally, donor site morbidity, which summarizes the impact of the flap harvest on the function and aesthetic appearance, ultimately determines the success of every new technique in reconstructive microsurgery. Based on donor site morbidity as a major key factor, even the most reliable flap with the highest reconstructive potential will not become the “gold standard” in daily clinical practice if the donor site morbidity that is associated with the flap harvest is not acceptable. Although the invention of perforator flaps along with supermicrosurgical techniques have had positive impacts on the DSM, the decision-making process before every reconstructive procedure is always a balancing act between the best reconstructive option at the recipient site and minimal morbidity at the donor site.

In general, the DSM that is associated with every microsurgical flap harvest is composed of objective and subjective DSM. Objective DSM describes the clinical status at the donor site that can be evaluated according to clear and reproducible criteria (e.g. the range of motion of the knee joint according to the neutral zero method). Furthermore, the evaluated data can be translated to a clinical outcome score for better comparability. Aside from the objective DSM, which is basically a physician-based evaluation of the DSM, the evaluation of the subjective, patient-reported morbidity at the donor site has become more and more important in recent years. Since the objective function or aesthetic appearance of the donor site does not always coincide with the individual impression of the patients (e.g. minimal objective DSM but high patient-reported complaints at the donor site or an unsatisfying functional outcome at the donor site which does not affect a patients quality of life) the patient-reported satisfaction with the donor sites is ultimately related to the level of the flap associated morbidity.

Figure 23. Donor site after a corticocancellous MFC flap harvest; MFC: medial femoral condyle.

Figure 24. Donor site scar (same patient as in Figure 23.) after a corticocancellous MFC flap harvest in the late follow-up period; MFC: medial femoral condyle.

1.8. Aims and hypothesis

This study aimed to precisely evaluate the long-term DSM after the harvest of microvascular bone, cartilage or soft tissue flaps from femoral condyle region according to objective and reproducible as well as patient-reported criteria. Beside a comprehensive evaluation of the overall DSM, we additionally wanted to investigate the impact and variation in different flaps from this region (e.g. bone flaps vs. osteocartilaginous flaps) as well as the donor area (medial femoral condyle region vs. lateral femoral condyle region) on the long-term DSM.

The basis of this study was formed by the following hypothesis:

1. The overall long-term DSM after the harvest of microvascular flaps from the femoral condyle region according to objective and patient-reported criteria is low.
2. The harvest of osteocartilaginous femoral trochlea flaps has a significantly higher impact on the postoperative objective and patient-reported knee function compared to all other flaps from this region.
3. There is no site-specific difference in the postoperative DSM for flaps from the medial and lateral femoral condyle region.

2. Material and Methods

This multi-center study included 156 patients who underwent a harvest of bone, cartilage or soft tissue flaps from either the MFC or LFC between 2005 and 2017. Institutional review board approval was obtained for all participating centers (number: 29-053 ex. 16/17).

The detailed evaluation of donor site morbidity after the harvesting of microvascular flaps from the distal femur consisted of two main parts.

1. A retrospective chart review of all relevant demographic data, surgical details, and the postoperative course at the donor sites
2. A detailed follow-up evaluation of the DSM according to objective and reproducible criteria

2.1. Retrospective chart review

With a retrospective chart review, all relevant demographic data, medical history, surgical details, and the postoperative course of each patient was analyzed.

The following data was collected for each participating patient:

2.1.1. Demographic data

- Age at surgery
- Gender
- Age at follow-up
- Risk factors
- Smoking history

2.1.2. Surgical details

- Donor site
- Donor area
- Flap composition
- Flap indication
- Recipient site

2.1.3. Postoperative course

- Complication rates at the donor site
- Revision rates at the donor site
- Number of inpatient days

2.2. Follow-up examination

At the follow-up examination, the DSM was evaluated according to objective, patient-reported and radiologic criteria.

2.2.1. Objective follow-up examination

At the objective follow-up examination, the patient's height (cm), weight (kg) and body mass index (BMI) were evaluated. In addition, previous problems at the donor knee as well as previous surgeries at the donor knee were evaluated.

2.2.1.1. Range of motion

The active and passive range of motion (ROM) of both knees (donor knee and healthy opposite side) were measured with a standard knee goniometer according to the neutral zero method. The collected motion data was then used to calculate the potential active motion (PAM) of the donor knee (active ROM donor knee / active ROM healthy knee x 100).

2.2.1.2. Knee scores

Moreover, the Knee Society Score (KSS)[110], the Larson Knee Score (LKS)[111] and the OAK Knee Score (OAK)[112] were used to detect any functional donor site morbidity.

Each of the above-mentioned knee scores generates an objective rating of the knee function through the analysis of the following subgroups:

Knee Society Score

- Pain
- Total range of flexion
- Flexion contracture
- Extension leg
- Alignment (varus/valgus)
- Stability (anterior/posterior and mediolateral)

Larson Knee Score

- Function (gait; activities)
- Anatomy (deformity; atrophy at thigh; swelling)
- Pain
- Range of motion

OAK Knee Score

- History (pain; swelling/effusion; giving-way; ability to work, physical activity)
- Clinical examination (tenderness; swelling/effusion; thigh circumference; range of motion)
- Stability (anteroposterior; mediolateral; lachman's test; drawer test; pivot-shift test; reversed pivot-shift test)
- Function tests (single leg jump; single leg knee squat, duck walk)

Each subgroup examination of the above-mentioned scores generates a subgroup score which can be summed up to a total score that ranges from 0-100 (0: worst function, 100: unimpaired function).

2.2.1.3. Scarring

Scar assessment at the donor sites was performed with the Patient and Observer Scar Assessment Scale (POSAS).[113] This scale consists of an observer scale and a patient scale. For the objective scar assessment, the POSAS observer scale was used, and the donor site scar was evaluated according to the vascularity, pigmentation, thickness, relief, pliability and surface area. The evaluation of each feature generates a single score from 1-10 points (1: normal skin, 10: worst imaginable scar) which are summed up to a total score (6-60 points; 6: normal skin, 60: worst imaginable scar). The results of the observer scale and the patient scale can be added together to arrive at an overall Patient and Observer Scar Assessment Score (12-120 points; 12: normal skin,120: worst imaginable scar).[113]

2.2.2. Patient-reported follow-up examination

2.2.2.1. Knee questionnaires

The patient-reported donor site morbidity was evaluated with the International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC)[114], the Knee Society Function Score (KSFS)[110] and the Knee Injury and Osteoarthritis Outcome Score (KOOS).[115] Each of the above-mentioned scores generates a knee function score according to the patient-reported analysis of the following subgroups:

Knee Documentation Committee Subjective Knee Evaluation Form

- Symptoms
- Sports activities
- Function

Knee Society Function Score

- Function

Knee Injury and Osteoarthritis Outcome Score

- Pain
- Symptoms
- Function in daily living
- Function in sport and recreational activities
- Quality of life

Each patient-reported subgroup analysis generates a subgroup score according to the level of knee function. For both the Knee Documentation Committee Subjective Knee Evaluation Form and the Knee Society Function Score, the addition of the subgroup scores generates a total score from 0-100 points (0: worst knee function, 100: unimpaired knee function).[110,114]

Additionally, the knee function before and after flap harvest was rated with a visual analogue scale (0-10 point; 0: worst function, 10: best function). For the evaluation of the Knee Injury and Osteoarthritis Outcome Score, each subgroup is analyzed and interpreted independently (0-100 points; 0: worst subgroup score, 100: best subgroup score). A total score can be calculated by using a mean score of all subscale scores.[115]

2.2.2.2. Scar assessment

The patient-reported evaluation of the donor site scar (quality and sensory testing) was carried out with the patient scale of the POSAS and the Ten Test.[113,116]

The POSAS patient scale evaluates the scar quality according symptoms and quality. The evaluation of each feature generates a single score from 1-10 points (1: normal skin; 10: worst imaginable scar) which are summed up to a total score (6-60 points; 6: normal skin, 60: worst imaginable scar). The results of the observer scale and the patient scale can be added for an overall POSAS score (12-120 points; 12: normal skin, 120: worst imaginable scar).[113]

Sensory testing of the scar area was performed with the Ten Test. This test evaluates for possibly impaired sensitivity around the donor scar in direct comparison to the healthy opposite site (1-10 points; 1: maximally impaired sensibility, 10: normal sensibility).[116]

2.2.2.3. Visual analogue scales

Visual Analogue Scales (VAS) were used to evaluate pain, functional donor site morbidity, aesthetic donor site morbidity and satisfaction (0-10; 0: best result, 10: worst result).

2.2.3. Radiologic follow-up examination

The blinded radiological grading of all follow-up patients was performed by an experienced radiologist (E.J.) who was unaware of the individual clinical characteristics.

2.2.3.1. Kellgren and Lawrence grading system for knee osteoarthritis

For bone and soft tissue flaps (BS flaps), the radiologic DSM was evaluated with a conventional knee x-ray. The findings of the x-ray were then transferred to the Kellgren and Lawrence grading system for knee osteoarthritis (OA).[117] This grading system classifies the severity of the osteoarthritis by using the following five scores:

- 0 (none): no osteoarthritis
- 1 (doubtful): doubtful narrowing of joint space and possible osteophytic lipping
- 2 (minimal): definite osteophytes and possible joint space narrowing
- 3 (moderate): moderate multiple osteophytes, definite narrowing of joint space, some sclerosis and possible deformity of bone contour
- 4 (severe): large osteophytes, marked narrowing of joint space, severe sclerosis and definite deformity of bone contour

2.2.3.2. MRI Osteoarthritis Knee Score (MOAKS)

For OC flaps, knee MRI scans (3T Magnetom Prisma and 1.5T Magnetom Symphony, Siemens Healthineers, Erlangen, Germany; 3T Philips Achieva, Philips Healthcare, Eindhoven, Netherlands) of the donor knee and the healthy opposite knee were used to detect any side-specific DSM. The MRI protocol consisted of axial, coronal and sagittal PD-weighted fat-saturated TSE sequences and coronal T1-weighted TSE sequences. The results of both scans were transferred to the MRI Osteoarthritis Knee Score.[118]

As a semi-quantitative scoring system, MOAKS evaluates the knee status in different subregions in terms of all relevant structural features of knee OA (pulse sequence protocol was used as recommended by Hunter et al.).[118]

For this study, the occurrence of bone marrow lesions (BML), cartilage loss (CL), osteophytes (O) and effusion-synovitis (ES) was analyzed both in general and regionally (MFC: anterior, central and posterior medial femur; LFC: anterior, central and posterior lateral femur).

Each structural feature generates a single score (0-3; 0: no pathology; 3: highest level of pathology) for its presence and characteristics. As described by Kaukinen et al., a size score >0 indicated the presence of the above-mentioned structural pathologies.[119]

MOAKS

Feature	Scoring	Any structural change	Severe structural change
Bone marrow lesions	Size score: Grade 0: no BML Grade 1: < 33% of subregion Grade 2: 33-66% of subregion Grade 3: > 66% of subregion	Size score > 0	Size score ≥ 2
Cartilage loss	Size score: Any cartilage loss (partial/full thickness) Grade 0: no CL Grade 1: <10% of subregion Grade 2: 10-75% of subregion Grade 3: > 75% of subregion % of full-thickness cartilage loss (FTCL): Grade 0: no FTCL Grade 1: <10% FTCL of subregion Grade 2: 10-75% FTCL of subregion Grade 3: > 75% FTCL of subregion	Size score > 0	Size score ≥ 2 and score for FTCL ≥ 2
Osteophytes	Size score: Grade 0: no O Grade 1: small O in subregion Grade 2: medium O in subregion Grade 3: large O in subregion	Score > 0	Size score ≥ 2
Effusion-synovitis	Grade 0: no ES knee Grade 1: small ES knee Grade 2: medium knee Grade 3: large knee	Score > 0	Moderate to large: size score of 2-3
MRI protocol	axial, coronal and sagittal PD-weighted fat-saturated TSE sequences and coronal T1-weighted TSE sequences		

Table 3. Scoring system of the MOAKS and definitions for the presence and severity of structural change. Reproduced from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

2.3. Statistical analysis

Statistical analyses were performed using R (version 3.6.1). Differences between the flap characteristics were analyzed using the Kruskal-Wallis rank sum test. Correlations were determined using Spearman's correlation coefficient. The significance level for the analyses was set to $\alpha=0.05$.

3. Results

3.1. Retrospective chart review

The mean patients age at the time of surgery was 40.6 years (±16.4; range: 15-77 years). The mean patients age for the BS flap subgroup was 41.5 years (±17.5; range: 15-77 years) whereas the mean age of the OC flap subgroup was 38.2 (±12.7; range: 17-65 years). There were 115 (73.7%) male and 41 (26.3%) female patients.

In 82.7% (129/156) of patients, flaps from the MFC were used, compared to 17.3% (27/156) for LFC flaps. In 73.7% (115/156), BS flaps (MFC: 66%; LFC: 7.7%) were used, in contrast to 26.3% (41/156) for OC flaps (MFC: 16.7%; LFC: 9.6%) (Table 4). The composition of all flaps is listed in Table 4.

Donor site (n = 156)	
Medial femoral region	129 (82.7%)
BS flaps	103 (66%)
OC flaps	26 (16.7%)
Lateral femoral region	27 (17.3%)
BS flaps	12 (7.7%)
OC flaps	15 (9.6%)
Flap composition (n = 156)	
Corticocancellous	69 (44.2%)
Osteocartilaginous	41 (26.3%)
Corticoperiostal	25 (16%)
Chimeric (bone and skin)	8 (5.1%)
Chimeric (bone and muscle)	3 (1.9%)
Tendon	3 (1.9%)
Chimeric (bone, tendon and skin)	2 (1.3%)
Fascia	2 (1.3%)
Periosteum	1 (0.6%)
Chimeric (bone and tendon)	1 (0.6%)
Chimeric (tendon and skin)	1 (0.6%)

Table 4. Donor sites and flap composition of the study population; BS: bone and soft tissue, OC: osteocartilaginous. Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

In 69.9% (109/156) of patients, flaps were used for upper extremity reconstruction, while for 30.1% (47/156) flaps were used to reconstruct defects in the lower extremity. The flap indication details are listed in Table 5.

Flap indication (n = 156)	
Upper extremity	109 (69.9%)
Non union	66 (60.6%)
Avascular bone necrosis	27 (24.8%)
Carpal instability	4 (3.7%)
Bone cysts	2 (1.8%)
Recurrent nerve entrapment	2 (1.8%)
Other	8 (7.3%)
Lower extremity	47 (30.1%)
Non union	27 (57.4%)
Avascular bone necrosis	10 (21.3%)
Tendon defect	4 (8.5%)
Other	6 (12.8%)

Table 5. Flap indication of the study population.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

In 51% (79/156) of patients flaps were harvested from the left knee, whereas in 49% (76/156) the right knee was chosen as the donor site. An ipsilateral flap harvest (donor and recipient on the same side) was performed in 85.8% (133/156) of surgeries.

The overall complication rate at the donor sites was 9.6% (15/156) (Table 6). Major complications (defined as complication that needed further surgical intervention) occurred in 3% of patients. At 19.5%, OC flaps showed a significantly ($p = 0.012$) higher complication rate compared to the complication rate of our BS flaps (complication rate: 6.1%) (Figure 25).

Complications at the donor sites (n=156)	15 (9.6%)	0.012[2]
BS flaps	7 (6.1%)	
Wound dehiscence	2 (1.7%)	
Knee joint infection	2 (1.7%)	
Superficial wound infection	1 (0.9%)	
Supracondylar femur fracture	1 (0.9%)	
Hypertrophic scar	1 (0.9%)	
OC flaps	8 (19.5%)	
Symptomatic knee chondropathy	2 (4.9%)	
Seroma	2 (4.9%)	
Knee joint infection	1 (2.4%)	
Hematoma	1 (2.4%)	
Prolonged pain	1 (2.4%)	
Paresthesia	1 (2.4%)	

Table 6. Complications at the donor sites of the study population. BS: bone and soft tissue; OC: osteocartilaginous.

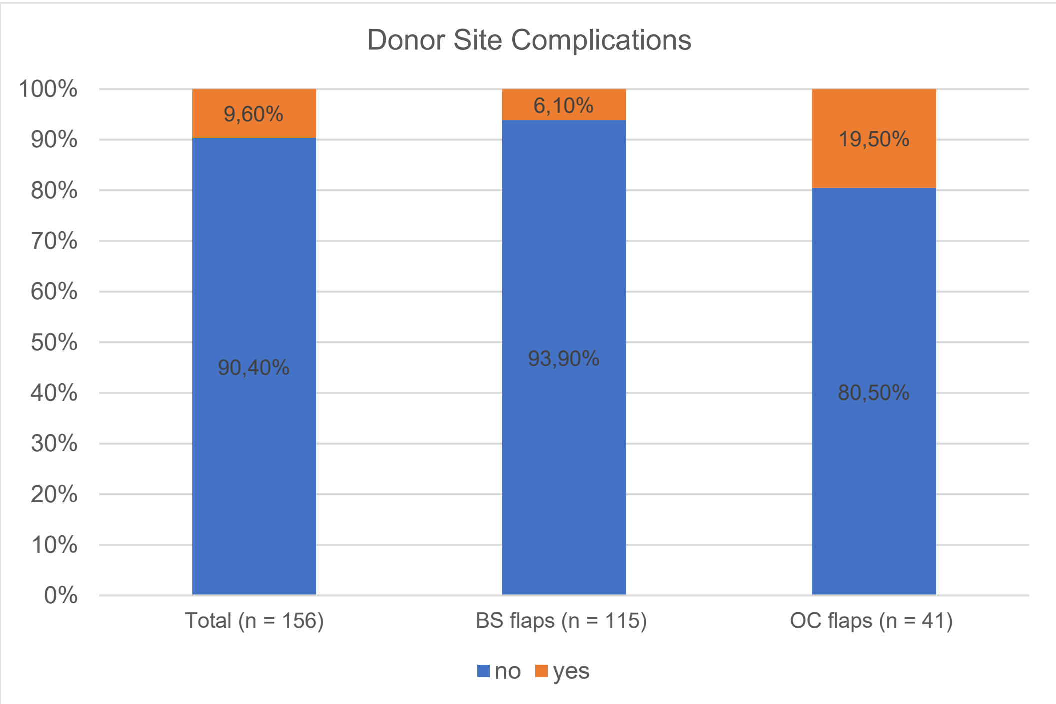

Figure 25. Complication rates at the donor sites. BS: bone and soft tissue; OC: osteocartilaginous.

The site-specific analysis of the follow-up population (n = 97) showed a complication rate of 8.7% (4/46) for our BS flaps that were used for upper extremity reconstruction, while the complication rate of the upper extremity OC flap subgroup was 22.2% (6/27). In cases of lower extremity reconstruction, the complication rates were 16.7% (3/18) for the BS flap subgroup, while none of our OC flap patients (0.0%; 0/6) showed a complication at the donor sites in the postoperative course.

The reconstruction site (upper vs. lower extremity reconstruction) of all flaps did not have a significant impact on the complication rates at the donor sites in the postoperative course (BS flaps: p = 0.358 and OC flaps: p = 0.202) (Table 7).

Complications at the donor site (n = 97)

BS flaps	Upper extremity (n = 46)	Lower extremity (n = 18)	p-value
no	91.3% (42/46)	83.3% (15/18)	0.358
yes	8.7% (4/46)	16.7% (3/18)	
OC flaps	Upper extremity (n = 27)	Lower extremity (n = 6)	
no	77.8% (21/27)	100% (6/6)	0.202
yes	22.2% (6/27)	0% (0/0)	

Table 7. Donor site complications of the follow-up population; BS: bone and soft tissue, OC: osteocartilaginous. Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

Comorbidities (p = 0.822), an increased BMI (p = 0.618) or a history of smoking (p = 0.468) did not significantly influence the complication rates at the donor sites.

Since the majority of the OC flaps were used for the same indication and had nearly the same flap size, the impact of the flap size on the complications rates in the postoperative course was evaluated exclusively for the follow-up BS flap group (n = 63). In our study, the BS flap size (small vs. long bone reconstruction) did not significantly (p = 0.130) influence the complication rates at the donor sites (complication rate small flaps: 5.1%; complication rate large flaps: 16.7%) (Table 8).

BS flap complications at the donor site (n = 63)

	Large flap (n = 24)	Small flap (n = 39)	p-value
no	83.3% (20/24)	94.9% (37/39)	0.130
yes	16.7% (4/24)	5.1% (2/39)	

Table 8. Impact of the flap size on the donor site complications of the follow-up population; BS: bone and soft tissue. Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

Revisions at the donor site (any intervention at the donor site) were needed in 7.1% (11/156) of cases. OC flaps showed higher, though not statistically significant ($p = 0.134$), revision rates at the donor sites (OC flap: 12.2% vs. BS flap: 5.2%) (Figure 26).

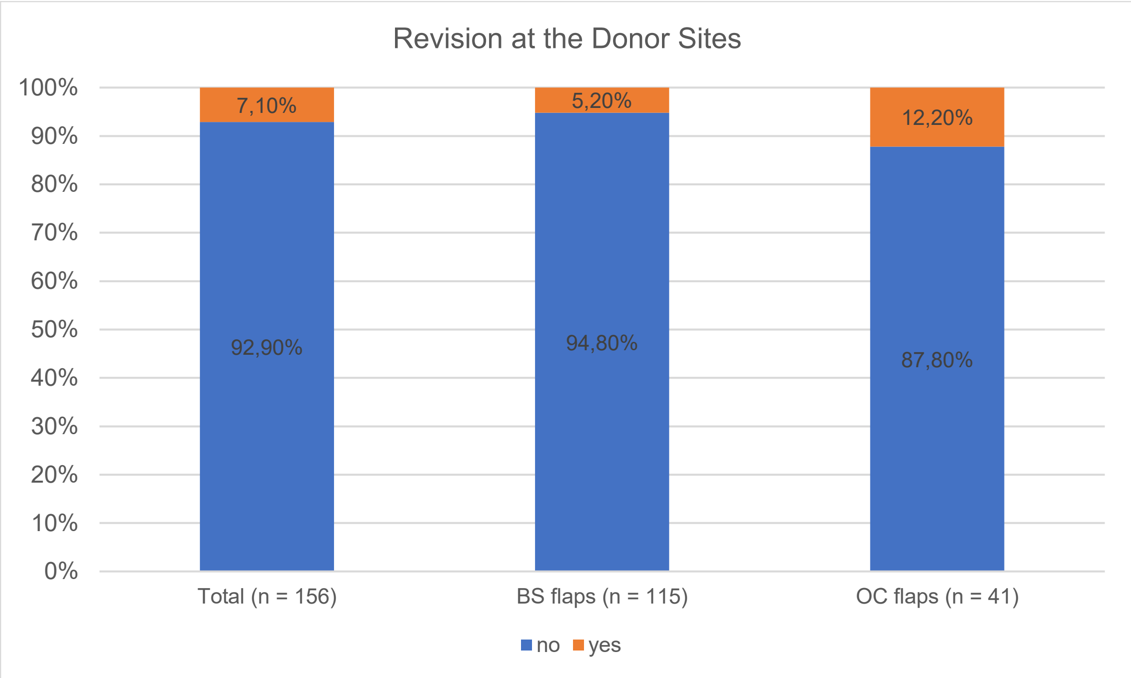

Figure 26. Revision rates at the donor sites. BS: bone and soft tissue; OC: osteocartilaginous.

Primary healing at the donor sites could be observed in 96.7% (140/156) of patients without any significant difference between BS and OC flaps. The median number of inpatient days was 8 (range: 2-112).

3.2. Follow-up examination

In total 97 patients (66 male and 31 female patients) were available for a long-term follow-up examination (62% of the study population). The median follow-up time was 1529 days (range 248 to 4810 days). The mean age at follow-up was 46.7 years (±15.3) (Table 9).

Follow-up Population	BS flaps (N=64)	OC flaps (N=33)	Total (N=97)	p-value
Days surgery and follow-up				0.031[1]
Mean (SD)	2178.4 (1451.1)	1454.1 (916.0)	1932.0 (1334.4)	
Median (range)	1731.0 (276.0-4810.0)	1133.0 (248.0-4464.0)	1529.0 (248.0-4810.0)	
Gender				
Male	48 (75.0%)	18 (54.5%)	66 (68.0%)	
Female	16 (25.0%)	15 (45.5%)	31 (32.0%)	
Age follow-up				0.092[1]
Mean (SD)	48.6 (16.4)	43.0 (12.2)	46.7 (15.3)	
Median (range)	52.0 (20.0-83.0)	47.0 (20.0-69.0)	49.0 (20.0-83.0)	
Body mass index				0.334[1]
Mean (SD)	26.1 (3.7)	25.5 (4.6)	25.9 (4.0)	
Median (range)	26.4 (17.7-33.6)	24.4 (17.0-37.7)	25.8 (17.0-37.7)	

Table 9. General data of the follow-up population; BS: bone and soft tissue, OC: osteocartilaginous.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

Each flap subgroup of the follow-up population showed no significant difference regarding age distribution (Figure 27) or BMI (Figure 28). The median follow-up time was 1529 days (range: 248-4810).

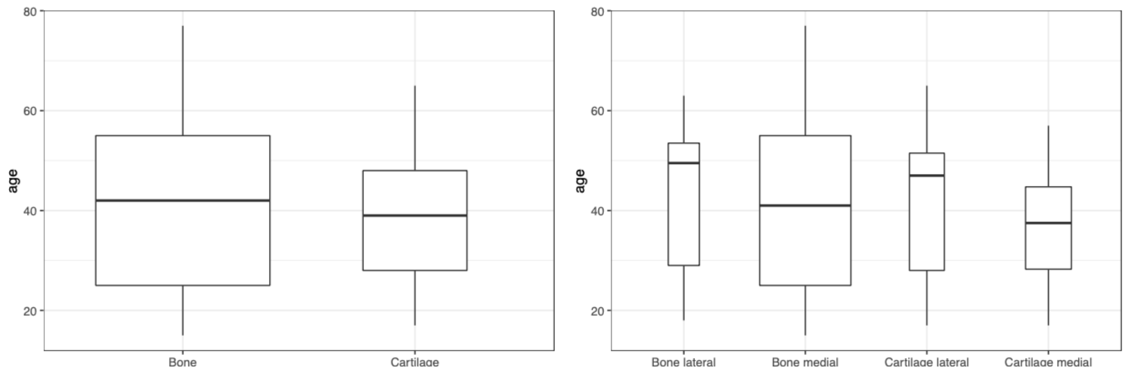

Figure 27. Age distribution among all flap subgroups.

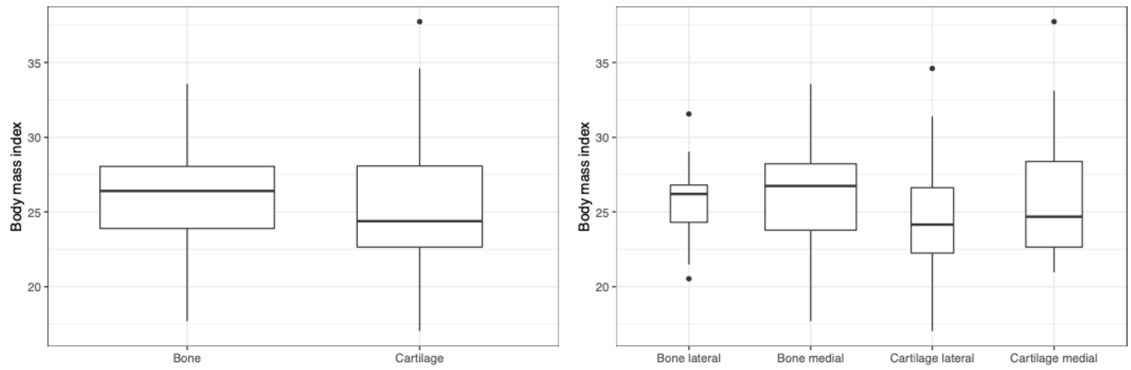

Figure 28. BMI distribution among all flap subgroups.

In the follow-up population 78.4% (76/97) underwent a MFC flap harvest, whereas 21.6% (21/97) underwent a harvest from the LFC. Of the follow-up patients, 66% (64/97) had a BS flap harvest whereas an OC flap was harvested in 34% (33/97). In the BS group, 14.1% (9/64) reported knee problems in the medical history before the flap harvest compared to 18.2% (6/33) in the OC flap group. Surgical procedures were at the donor knee before the flap harvest were performed in 7.8% (5/64) of the BS flaps and 12.1% (4/33) of the OC flaps (Table 10).

Follow-up Population	BS flaps (N=64)	OC flaps (N=33)	Total (N=97)	p-value
Donor knee				
Left	30 (46.9%)	18 (54.5%)	48 (49.5%)	
Right	34 (53.1%)	15 (45.5%)	49 (50.5%)	
Donor region				
Lateral	9 (14.1%)	12 (36.4%)	21 (21.6%)	
Medial	55 (85.9%)	21 (63.6%)	76 (78.4%)	
Flap utilization				
Upper extremity	46 (71.9%)	27 (81.8%)	73 (75.3%)	
Lower extremity	18 (28.1%)	6 (18.2%)	24 (24.7%)	
Previous problem donor knee				0.595
No	55 (85.9%)	27 (81.8%)	82 (84.5%)	
Yes	9 (14.1%)	6 (18.2%)	15 (15.5%)	
Previous surgery donor knee				0.488
No	59 (92.2%)	29 (87.9%)	88 (90.7%)	
Yes	5 (7.8%)	4 (12.1%)	9 (9.3%)	

Table 10. Donor site characteristics of the follow-up population; BS: bone and soft tissue, OC: osteocartilaginous. Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

3.2.1. Objective follow-up examination

3.2.1.1. Outer appearance of the donor knee

An obviously decreased outer appearance of the donor knee due to scarring or other deformity was evident in 9.6% (9/97) of the follow-up cohort. There was no significant difference ($p = 0.394$) between the BS flap (disturbed outer appearance: 11.5%) and the OC flap subgroup (disturbed outer appearance: 6.1%) (Figure 29).

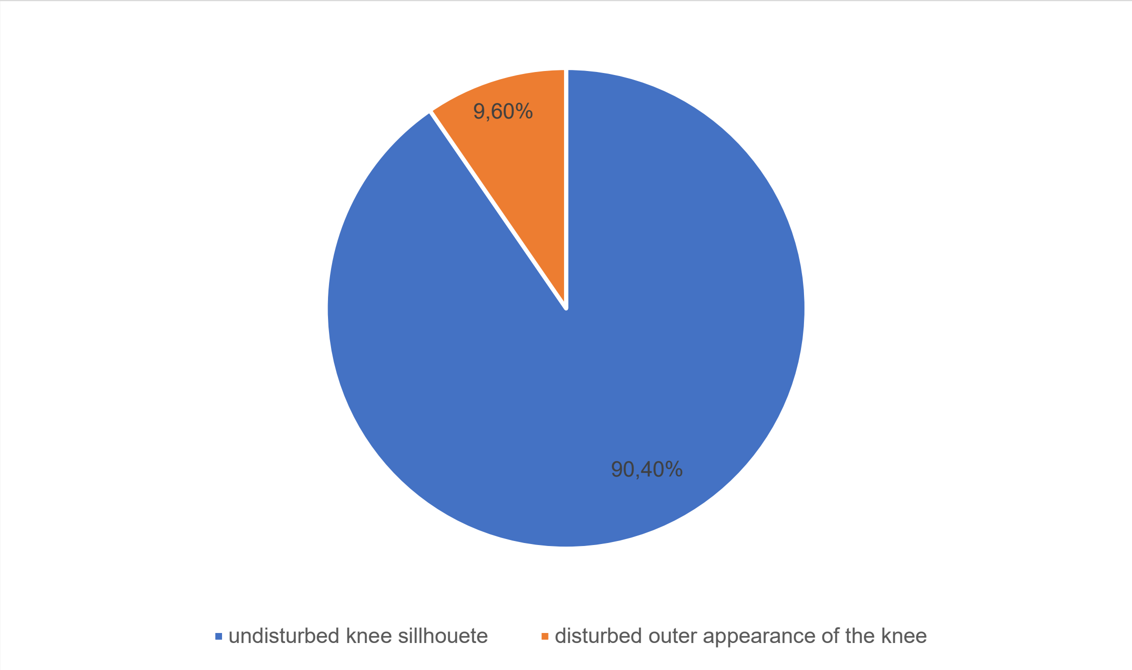

Figure 29. Outer appearance of the donor knee.

3.2.1.2. Range of motion (ROM)

The mean active ROM of the donor knees at follow-up was 130.4 (± 11.3) and showed no significant difference among the BS flap subgroup (131.1; ± 11.1) and the OC flap subgroup (129.1; ± 11.8). The mean passive ROM of the donor knees at follow-up was 137.4 (± 10.9) and again showed no significant difference between the BS and OC flap subgroups (Figure 30).

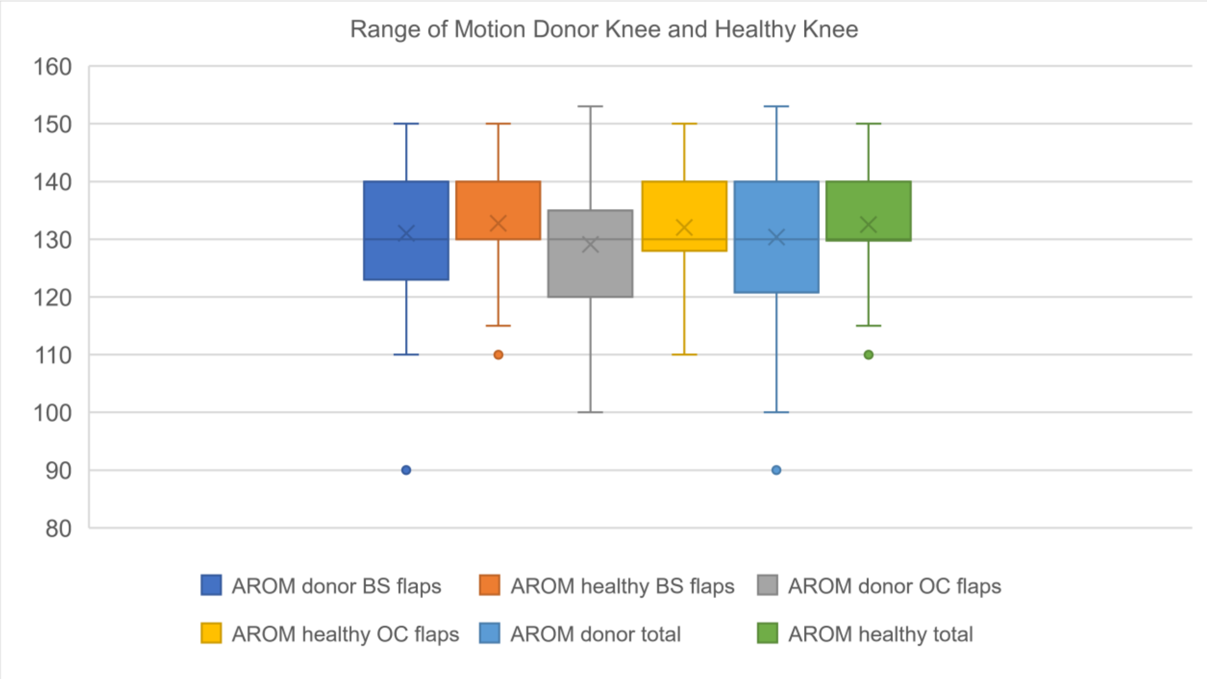

Figure 30. Range of motion of all flap subgroups and the healthy knee; BS: bone and soft tissue, OC: osteocartilaginous.

The potential active motion (PAM) was 98.7% for BS flaps and 97.8% for OC flaps. In cases of a BS flap harvest, the active range of motion of the donor knee (131.1; ± 11.1) did not significantly differ ($p = 0.082$) from the active range of motion of the healthy opposite knee (132.8 ± 9.6). Similar to the BS flap subgroup, the direct comparison of the active range of motion in the OC flap subgroup did not show a significant difference ($p = 0.167$) between the donor knee (129.1; ± 11.8) and the healthy opposite knee (132.1 ± 11.8).

3.2.1.3. Objective knee function scores

Knee Society Score (KSS)

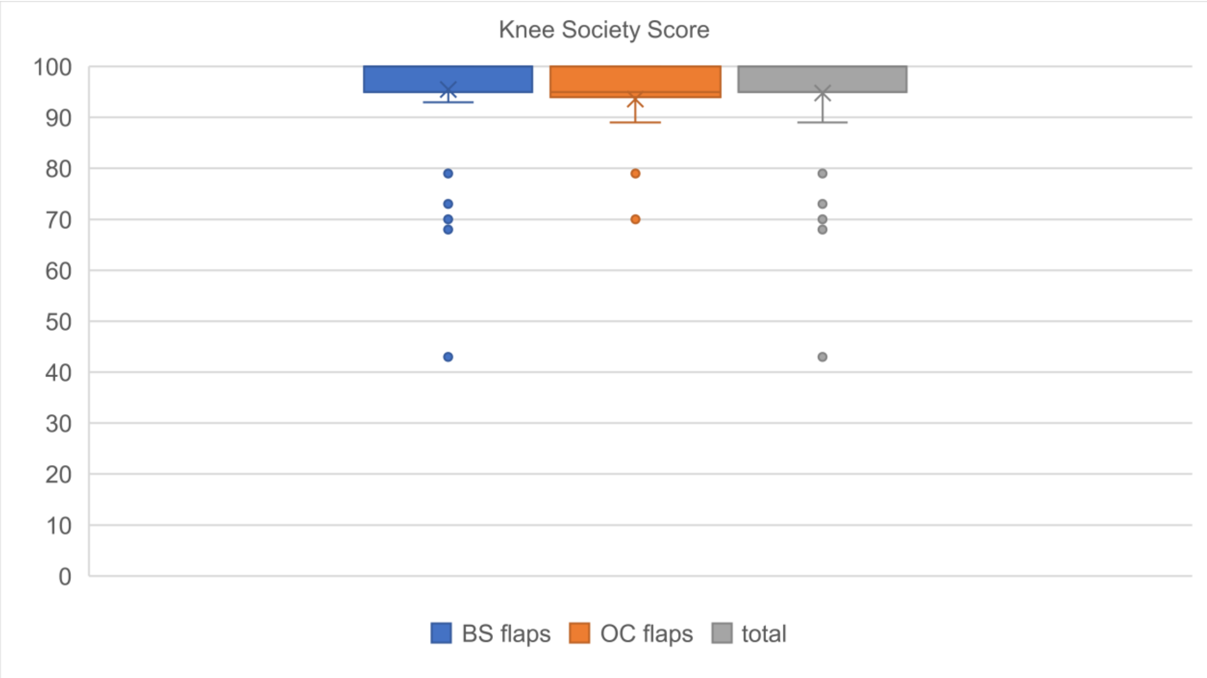

Figure 31. Knee function in the Knee Society Score; BS: bone and soft tissue, OC: osteocartilaginous.

The overall Knee Society Score was 94.8 (± 10.1) with an excellent outcome according to the Knee Society Score rating system in 90% (81/97) of the follow-up cohort. A "poor" functional outcome was only evident in one BS flap patient (1.1%; 1/97). A direct comparison between the BS and OC flap subgroup showed a significantly higher (p = 0.026) DSM for OC flaps (mean KSS: 93.6 ± 9.2) compared to the BS flap subgroup (mean KSS: 95.5 ± 10.6) although none of the OC flaps had a "poor" outcome according to the Knee Society Score rating system (Figure 31, Table 11). A significant site-specific donor site morbidity between flaps from the medial (mean KSS: 95.3 ± 9.8) and lateral (mean KSS: 93.2 ± 11) femoral condyle region was not evident (p = 0.562).

	BS lateral (N=9)	BS medial (N=55)	OC lateral	OC medial	Total (N=97)	p-value
Knee Society Score						0.107
N-Miss	0	7	0	0	7	
Mean (SD)	93.1 (11.4)	96.0 (10.4)	93.2 (11.2)	93.8 (8.2)	94.8 (10.1)	
Median (range)	100.0 (68.0-100.0)	100.0 (43.0-100.0)	98.5 (70.0-100.0)	95.0 (70.0-100.0)	100.0 (43.0-100.0)	

Table 11. Outcome of the Knee Society Score; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.

Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

The mean KSS for BS and OC flaps in upper extremity reconstruction was 96.9 (± 7.5) respectively 92.4 (± 9.8). In cases of lower extremity reconstruction, the mean KSS was 91.6 (± 16.1) for the BS flap subgroup and 99.0 (± 2.0) for the OC flap subgroup. The reconstruction site (upper vs. lower extremity reconstruction) of all flaps did not have a significant impact on the DSM (BS flaps: p = 0.100; OC flaps: p = 0.056).

Larson Knee Score (LKS)

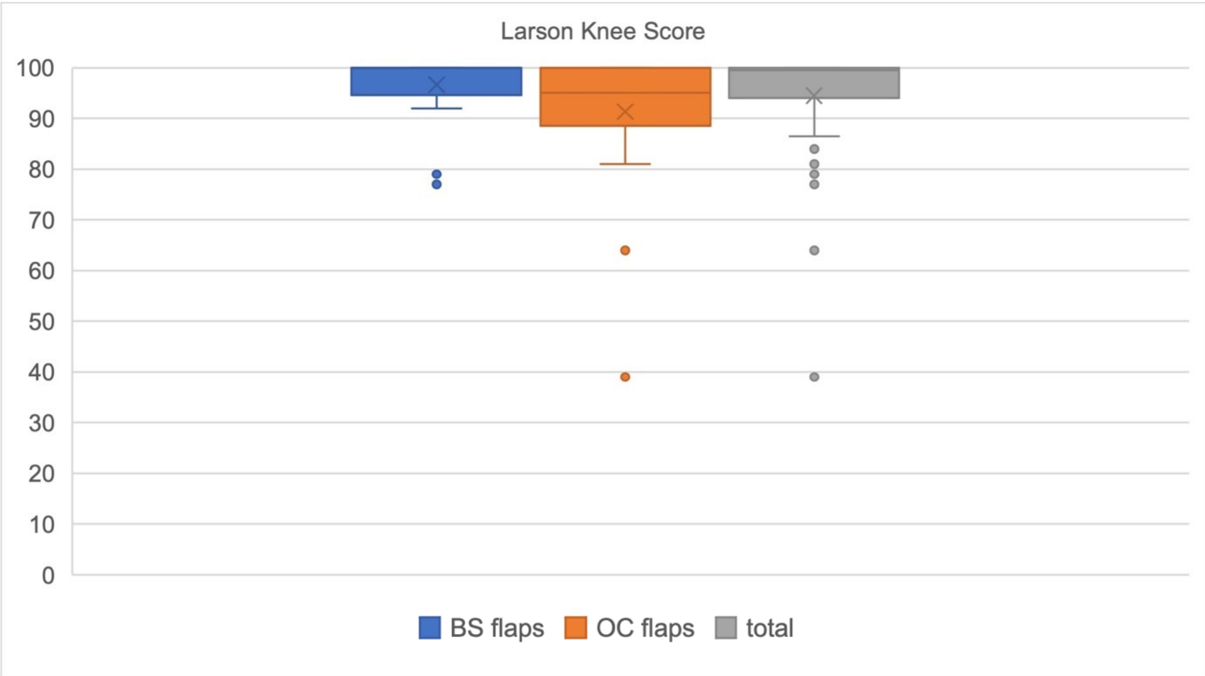

Figure 32. Knee function in the Larson Knee Score; BS: bone and soft tissue, OC: osteocartilaginous.

The overall LKS was 94.5 (± 10.1) with an excellent outcome according to the LKS rating system in 91.5% (65/97) of the follow-up cohort. A “poor” functional outcome was evident in only one patient (1.4%; 1/97) in the OC flap group. A direct comparison between the BS and OC flap subgroup showed a significant higher ($p = 0.016$) DSM for OC flaps (mean LKS: 91.3 ± 13.1) compared to the BS flap subgroup (mean LKS: 96.6 ± 6.7) (Figure 31, Table 12). A significant site-specific donor site morbidity between flaps from the medial (mean LKS: 94.8 ± 8.4) and lateral (mean LKS: 93.5 ± 13.6) femoral condyle region was not evident ($p = 0.261$).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
Larson Knee Score						0.066
N-Miss	0	22	1	3	26	
Mean (SD)	96.9 (3.5)	96.5 (7.3)	90.6 (18.0)	91.7 (9.6)	94.5 (10.1)	
Median (range)	99.5 (92.0-100.0)	100.0 (77.0-100.0)	95.5 (39.0-100.0)	95.0 (64.0-100.0)	99.5 (39.0-100.0)	

Table 12. Outcome of the Larson Knee Score; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

OAK Knee Score (OAK)

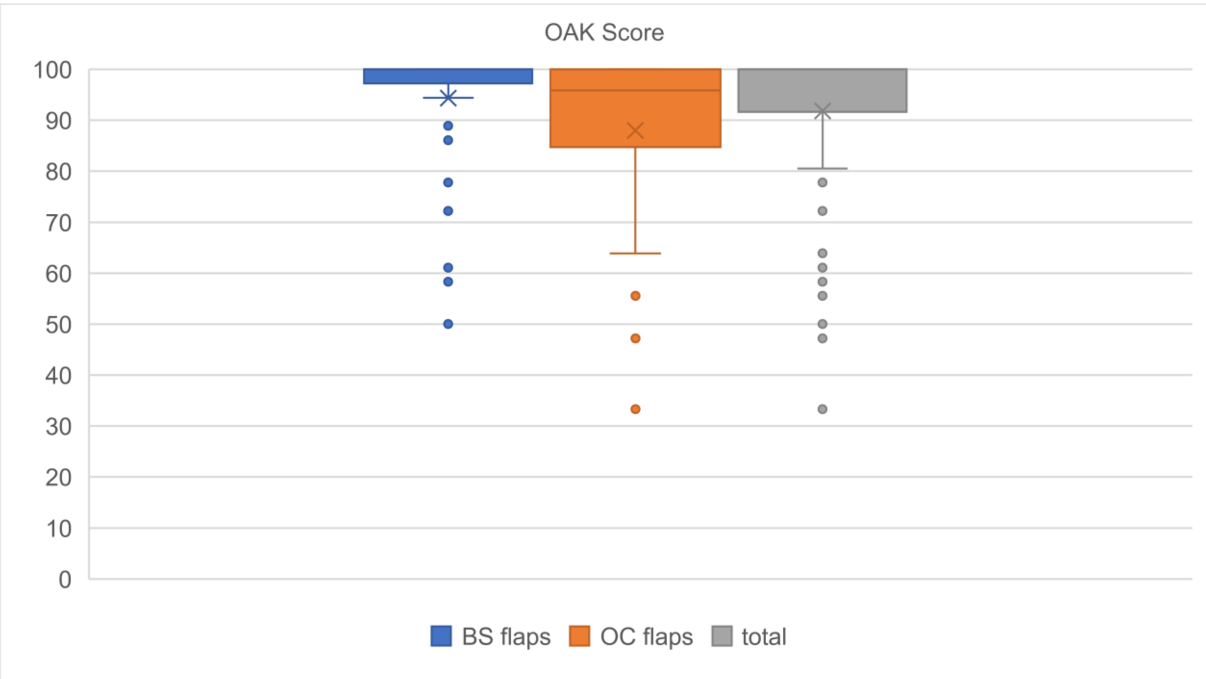

Figure 33. Knee function in the OAK Score; BS: bone and soft tissue, OC: osteocartilaginous.

The overall OAK was 95.5 (± 6.6) with an excellent outcome according to the OAK rating system in 80.3% (57/97) of the follow-up cohort. A “poor” functional outcome was evident in only one patient (1.4%; 1/97) in the OC flap group. A direct comparison between the BS and OC flap subgroup showed a significant higher (p = 0.030) DSM for OC flaps (mean OAK: 93.5 ± 7.8) compared to the BS flap subgroup (mean OAK: 96.8 ± 5.3) (Figure 33, Table 13). A significant site-specific donor site morbidity between flaps from the medial (mean OAK: 96.0 ± 6.0) and lateral (mean OAK: 94.1 ± 7.9) femoral condyle region was not evident (p = 0.297).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
OAK Score						0.117
N-Miss	0	21	2	3	26	
Mean	95.6 (5.5)	97.1 (5.3)	92.7 (9.6)	93.9 (6.9)	95.5 (6.6)	
Median	98.0 (85.0-100.0)	99.5 (77.0-100.0)	97.0 (70.0-100.0)	96.0 (76.0-100.0)	98.0 (70.0-100.0)	

Table 13. Outcome OAK Score; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

3.2.1.4. Scar assessment – POSAS Observer Scale (POSAS-O)

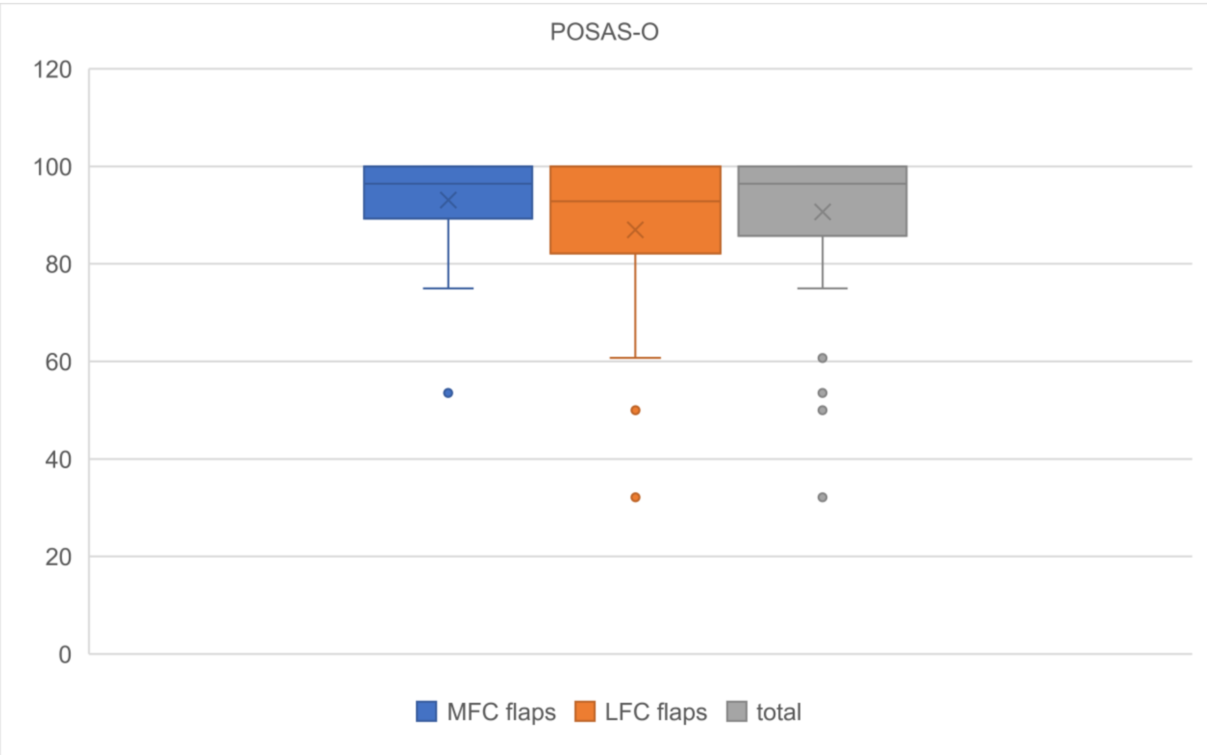

Figure 34. Outcome of the POSAS Observer Scale; MFC: medial femoral condyle, LFC: lateral femoral condyle.

The mean POSAS-O was 11.9 (± 6.0) and showed no significant difference among the BS flaps (mean score: 11.8 ± 6.1) and the OC flaps (mean score: 12.0 ± 5.8). With a mean score of 11.3 (± 4.8) for flaps from the MFC and 14.0 (± 8.9) for flaps from the LFC, a significant site-specific difference in scar appearance was not evident in our follow-up cohort (p = 0.650) (Figure 34, Table 14).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
POSAS-O						0.489
N-Miss	0	1	0	0	1	
Mean (SD)	16.6 (10.2)	11.1 (4.9)	12.1 (7.8)	11.9 (4.5)	11.9 (6.0)	
Median (range)	14.0 (6.0-35.0)	10.0 (6.0-33.0)	10.0 (6.0-33.0)	10.0 (6.0-23.0)	10.0 (6.0-35.0)	

Table 14. Outcome in the POSAS Observer Scale; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

3.2.2. Patient-reported follow-up examination

3.2.2.1. Patient-reported knee scores

IKDC Score (IKDC)

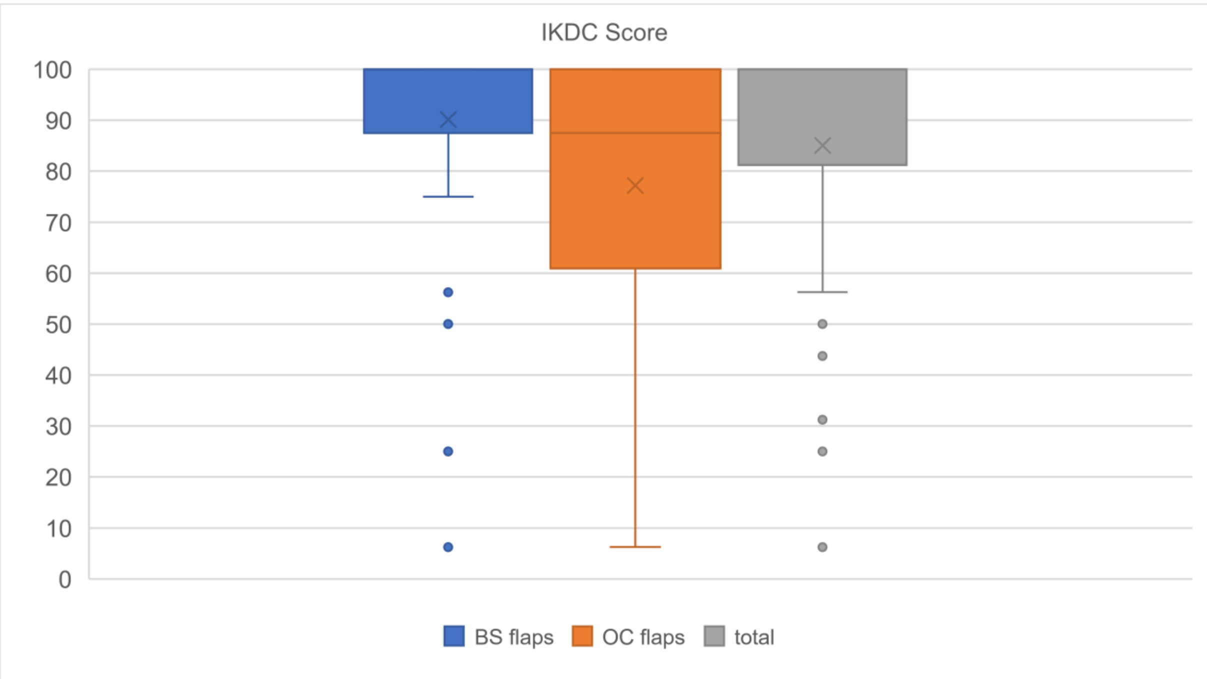

Figure 35. Patient-reported outcome in the IKDC Score; BS: bone and soft tissue, OC: osteocartilaginous.

The overall IKDC Score was 86.7 (± 17.4). With a mean score of 89.9 (± 15.9), BS flaps scored significantly better (p = 0.026) compared to OC flaps with a mean score of 81.9 (± 18.8). A significant site-specific donor site morbidity between flaps from the medial (mean IKDC: 87.1 ± 18) and lateral (mean IKDC: 85.9 ± 16) femoral condyle region was not evident (p = 0.348) (Figure 35, Table 15).

	BS lateral (N=9)	BS medial	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
IKDC						0.147
N-Miss	0	21	2	3	26	
Mean (SD)	90.3 (11.4)	89.8 (17.0)	81.8 (19.0)	82.0 (19.2)	86.7 (17.4)	
Median (range)	95.4 (73.6-100.0)	97.7 (35.6-100.0)	85.7 (35.6-100.0)	86.8 (28.7-100.0)	94.3 (28.7-	

Table 15. Patient-reported outcome in the IKDC Score; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

The knee function of the follow-up cohort prior to the flap harvest was rated on average 9.5 points (± 1.2) without any significant difference among the flap subgroups (BS flaps: 9.5 ± 1.4; OC flaps: 9.5 ± 0.9). The knee function of the follow-up cohort after the flap harvest was rated on average 8.5 points (± 2.2) and showed significantly (p = 0.041) better knee function for the BS flaps (8.8 points ± 2.1) compared to the OC flaps (8.2 points ± 2.2) (Figure 36).

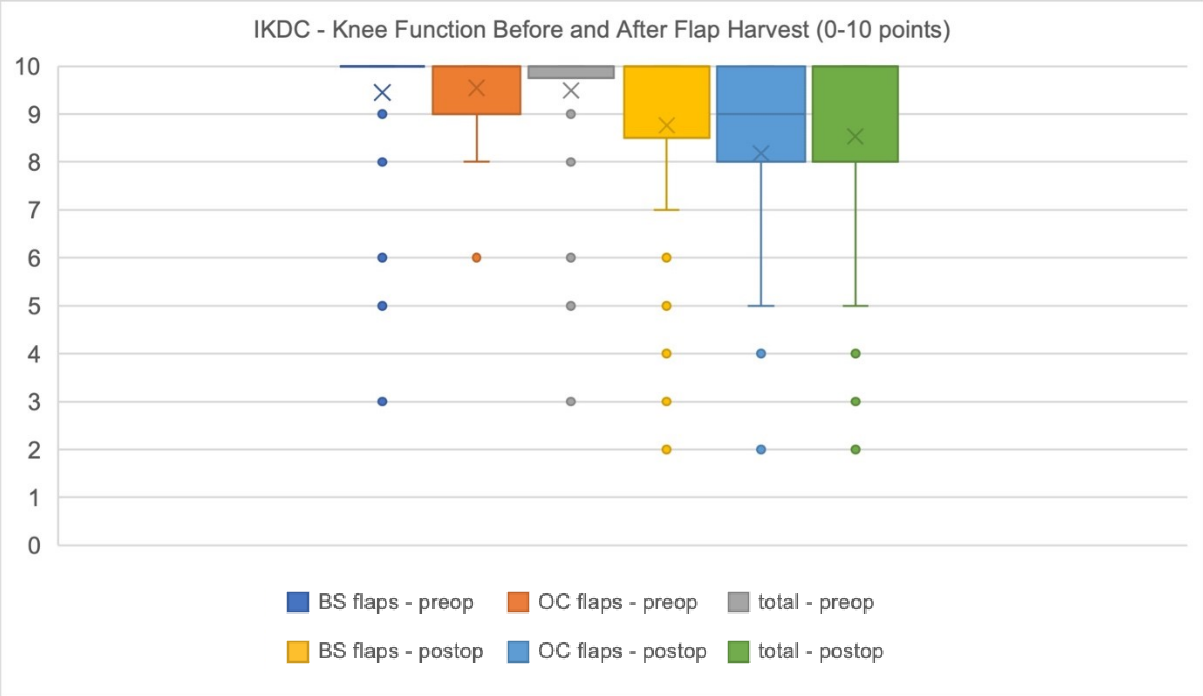

Figure 36. Knee function before and after flap harvest in the IKDC Score; BS: bone and soft tissue, OC: osteocartilaginous.

Knee Society Function Score (KSFS)

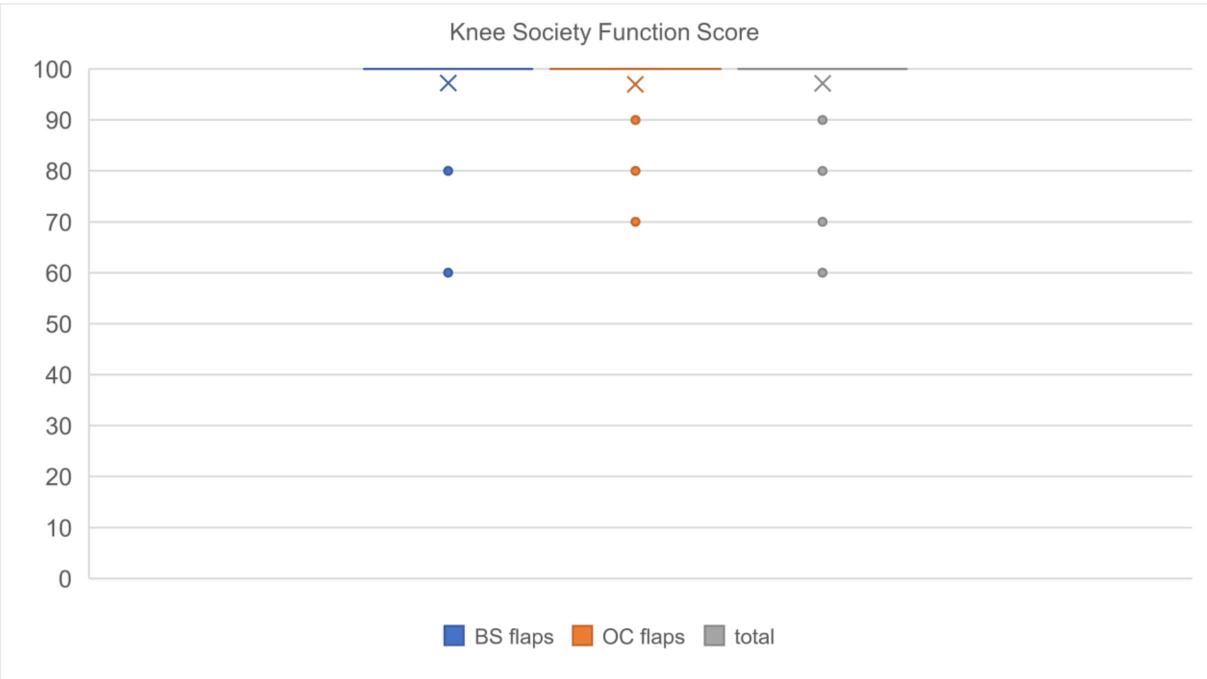

Figure 37. Patient-reported outcome in the Knee Society Function Score; BS: bone and soft tissue, OC: osteocartilaginous.

The overall Knee Society Function Score was 97.2 (± 7.7) with an "excellent" outcome according to the Knee Society Score rating system in 97.3% (72/97) of the follow-up cohort. None of the follow-up patients rated their knee function as "poor".

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
KSFS						0.559
N-Miss	0	20	0	3	23	
Mean (SD)	100.0 (0.0)	96.6 (9.1)	96.7 (8.9)	97.2 (5.7)	97.2 (7.7)	
Median	100.0 (100.0-	100.0 (60.0-100.0)	100.0 (70.0-100.0)	100.0 (80.0-100.0)	100.0 (60.0-100.0)	

Table 16. Patient-reported outcome in the Knee Society Function Score (KSFS); BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-Miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

A direct comparison between the BS and OC flap subgroup showed no significant (p = 0.393) difference in the outcome among the BS flap subgroup (mean KSS: 97.3 ± 8.2) and the OC flap subgroup (mean KSS: 97.0 ± 7.0) (Figure 37). A significant site-specific donor site morbidity between flaps from the medial (mean KSFS: 96.8 ± 8.0) and lateral (mean KSS: 98.1 ± 6.8) femoral condyle region was not evident (p = 0.427) (Table 16).

KOOS

KOOS Pain (KOOS-P)

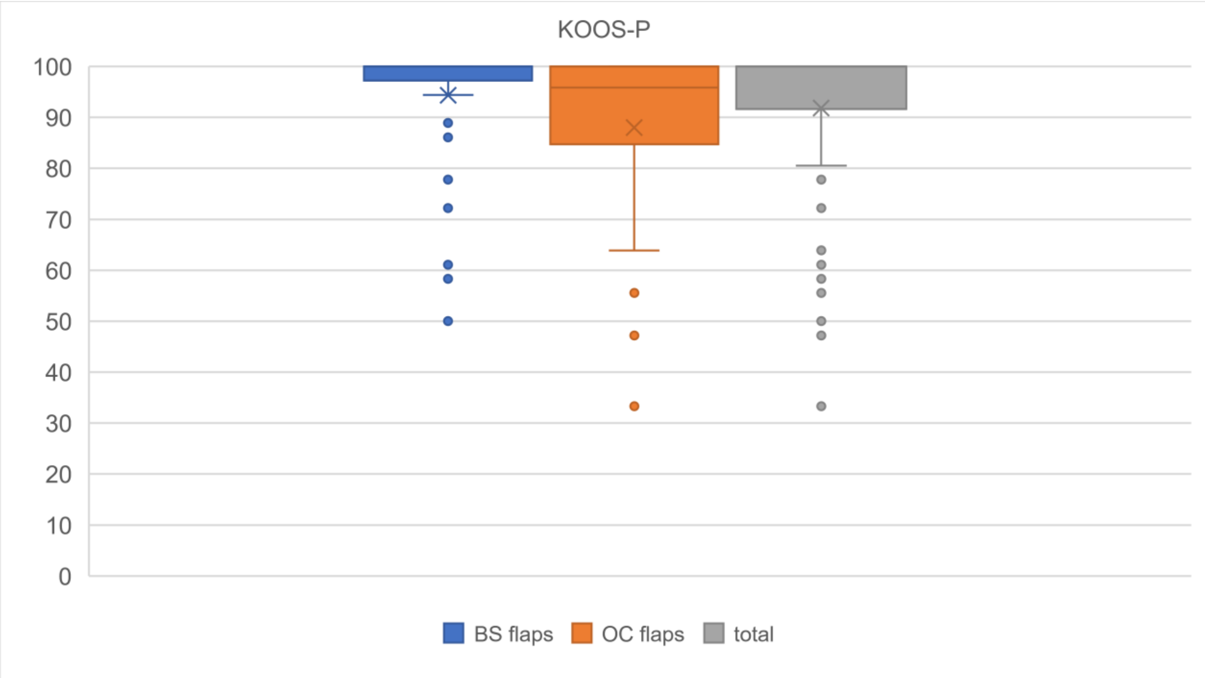

Figure 38. Patient-reported outcome of the KOOS Pain subscore; BS: bone and soft tissue, OC: osteocartilaginous.

The KOOS subgroup analysis for pain in the follow-up population reached an average score of 91.9 (± 15.0). With a mean score of 88.0 (± 18.2), the OC flap subgroup reported significantly ($p = 0.033$) higher pain levels compared to the BS flap subgroup (mean score: 94.4 ± 12.2) (Figure 38). A significant site-specific difference for the pain subgroup between flaps from the medial (mean score: 91.86 ± 15.5) and lateral (mean score: 92.7 ± 14.1) femoral condyle region was not evident ($p = 0.834$) (Table 17).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
KOOS-P						0.184
N-Miss	0	21	2	3	26	
Mean (SD)	97.2 (4.6)	93.6 (13.5)	88.6 (18.4)	87.7 (18.5)	91.9 (15.0)	
Median (range)	100.0 (86.1-100.0)	100.0 (50.0-100.0)	98.6 (47.2-100.0)	94.4 (33.3-100.0)	100.0 (33.3-100.0)	

Table 17. Patient-reported outcome in the KOOS Pain subscore; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

KOOS Other Symptoms (KOOS-S)

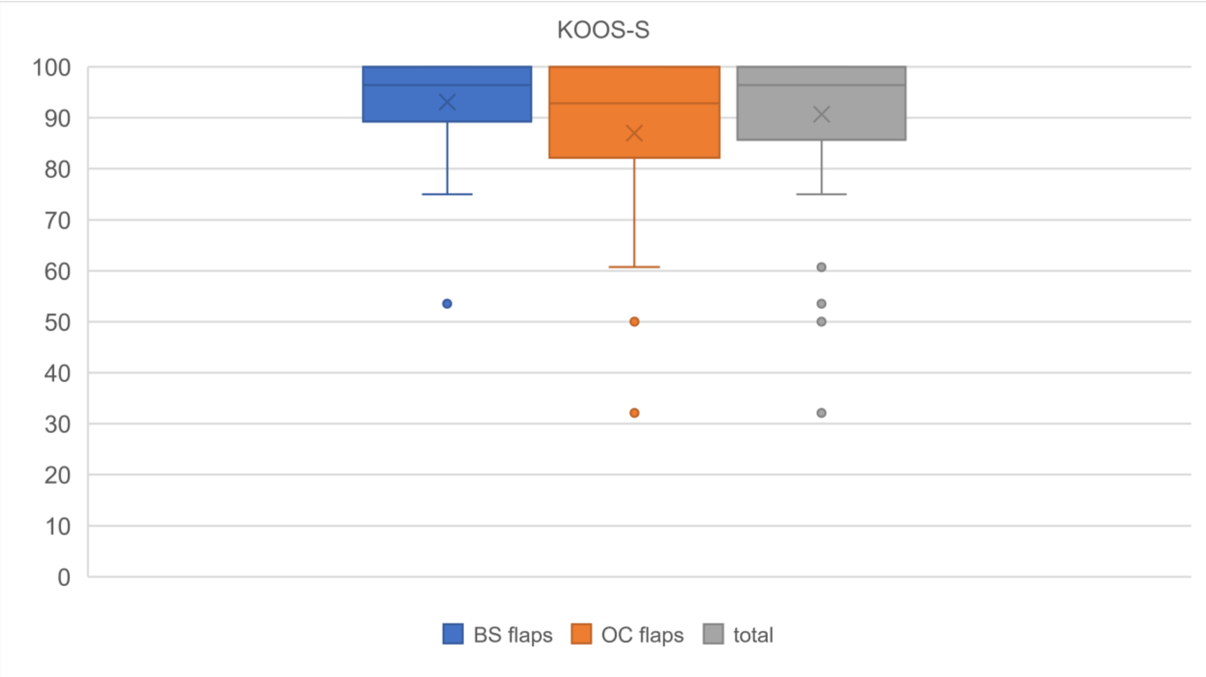

Figure 39. Patient-reported outcome of the KOOS Symptoms subscore; BS: bone and soft tissue, OC: osteocartilaginous.

The KOOS subgroup analysis for symptoms in the follow-up population reached an average score of 90.7 (± 13.2). OC flaps (mean score: 87.0 ± 16.5) and BS flaps (mean score: 93.1 ± 10.1) showed no significant (p = 0.087) difference in the analysis of the KOOS subgroup for symptoms (Figure 39). A significant site-specific difference for the pain subgroup between flaps from the medial (mean score: 91.3 ± 12.1) and lateral (mean score: 88.9 ± 16.1) femoral condyle region was not evident (p = 0.440) (Table 18).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
KOOS-S						0.293
N-Miss	0	21	2	3	26	
Mean (SD)	94.4 (8.2)	92.8 (10.6)	83.9 (20.0)	88.7 (14.5)	90.7 (13.2)	
Median	96.4 (75.0-100.0)	98.2 (53.6-100.0)	89.3 (32.1-100.0)	92.9 (50.0-100.0)	96.4 (32.1-100.0)	

Table 18. Patient-reported outcome in the KOOS Symptoms subscore; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

KOOS Activities of Daily Living (KOOS-ADL)

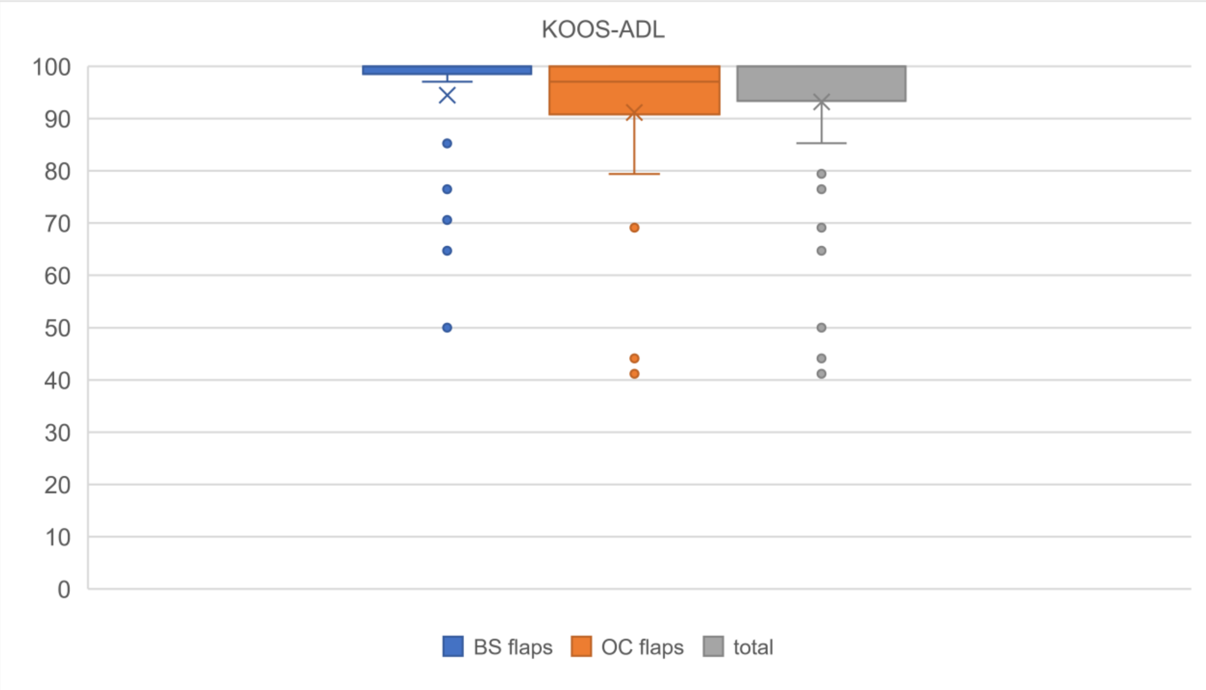

Figure 40. Patient-reported outcome of the KOOS Activities of Daily Living subscore; BS: bone and soft tissue, OC: osteocartilaginous.

The KOOS subgroup analysis for ADLs in the follow-up population reached an average score of 93.2 (± 13.9). With a mean score of 91.2 (± 15.5), the OC flap subgroup reported significantly ($p = 0.028$) higher restrictions of ADLs compared to the BS flap subgroup (mean score: 94.5 ± 12.7) (Figure 40). A significant site-specific difference for the pain subgroup between flaps from the medial (mean score: 93.1 ± 14.4) and lateral (mean score: 93.5 ± 13.6) femoral condyle region was not evident ($p = 0.342$) (Table 19).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
KOOS-ADL						0.150
N-Miss	0	21	2	3	26	
Mean (SD)	96.6 (5.6)	93.9 (14.0)	90.7 (17.9)	91.4 (14.6)	93.2 (13.9)	
Median (range)	100.0 (86.8-100.0)	100.0 (50.0-100.0)	97.1 (41.2-100.0)	97.8 (44.1-100.0)	100.0 (41.2-100.0)	

Table 19. Patient-reported outcome in the KOOS Activities of Daily Living subscore; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

KOOS Sport (KOOS-S)

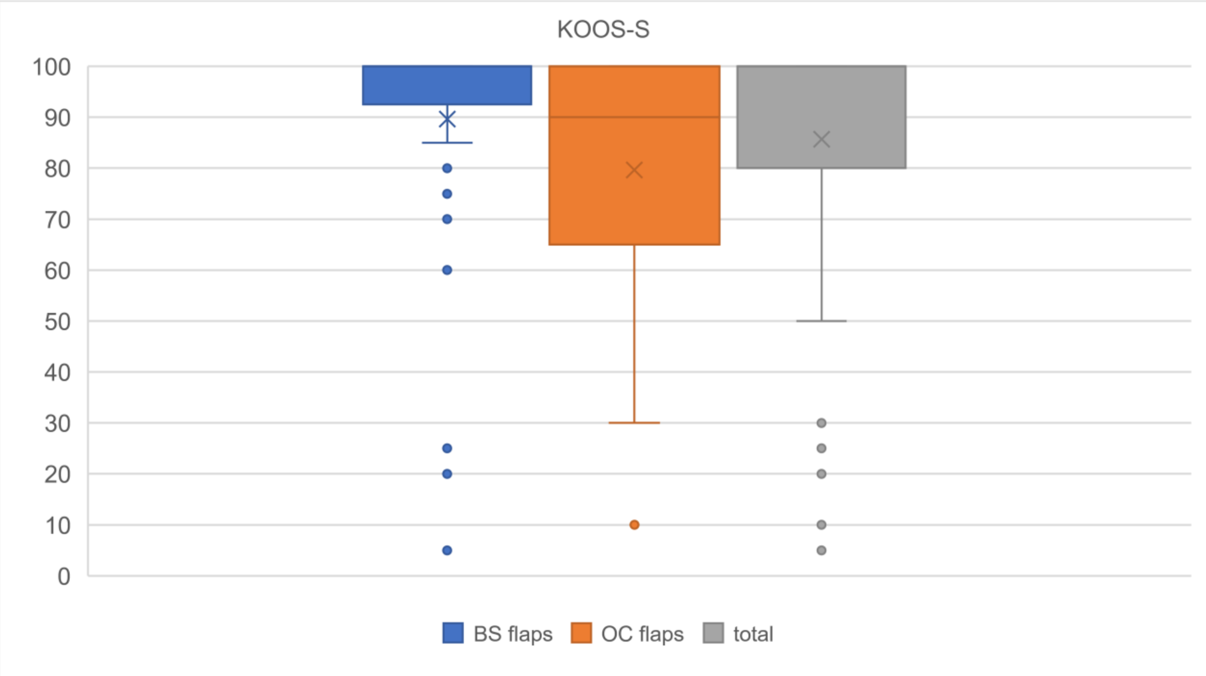

Figure 41. Patient-reported outcome of the KOOS Sport subscore; BS: bone and soft tissue, OC: osteocartilaginous.

The KOOS subgroup analysis for sports activity in the follow-up population reached an average score of 85.7 (± 24.6). With a mean score of 79.6 (± 27.0), the OC flap subgroup reported significantly ($p = 0.024$) higher restrictions to sports activity compared to the BS flap subgroup (mean score: 89.7 ± 22.4) (Figure 41). A significant site-specific difference in the sport subgroup of KOOS between flaps from the medial (mean score: 85.7 ± 25.6) and lateral (mean score: 85.8 ± 22.5) femoral condyle region was not evident ($p = 0.378$) (Table 20).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
KOOS-S						0.134
N-Miss	0	21	2	3	26	
Mean (SD)	92.8 (9.4)	88.8 (24.8)	79.5 (29.0)	79.7 (26.7)	85.7 (24.6)	
Median (range)	95.0 (75.0-100.0)	100.0 (5.0-100.0)	90.0 (10.0-100.0)	92.5 (10.0-100.0)	100.0 (5.0-100.0)	

Table 20. Patient-reported outcome in the KOOS Sport subscore; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

KOOS Quality of Life (KOOS-QOL)

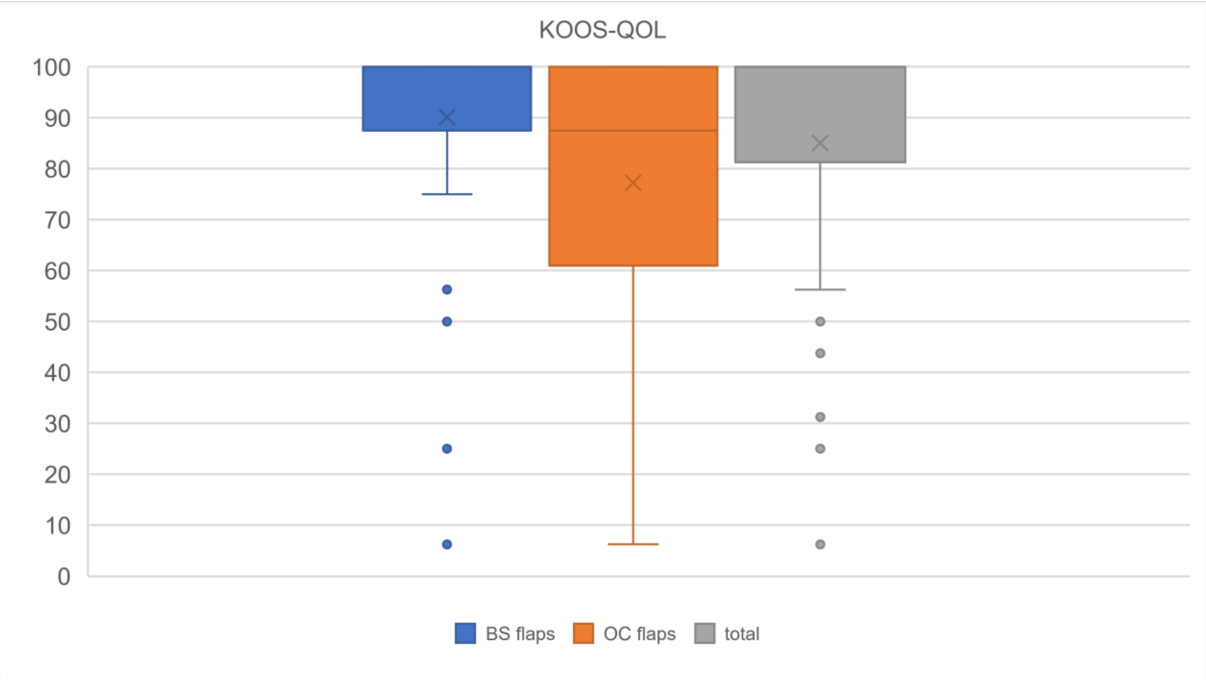

Figure 42. Patient-reported outcome of the KOOS Quality of Life subscore; BS: bone and soft tissue, OC: osteocartilaginous.

The KOOS subgroup analysis for quality of life in the follow-up population reached an average score of 85.0 (± 24.1). With a mean score of 77.2 (± 27.4), the OC flap subgroup reported significantly (p = 0.035) higher restrictions to the quality of life compared to the BS flap subgroup (mean score: 90.1 ± 20.4) (Figure 42). A significant site-specific difference in the quality-of-life subgroup of KOOS between flaps from the medial (mean score: 85.0 ± 24.4) and lateral (mean score: 85.2 ± 23.9) femoral condyle region was not evident (p = 0.598) (Table 21).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
KOOS-QOL						0.215
N-Miss	0	21	2	3	26	
Mean (SD)	94.4 (8.5)	89.0 (22.5)	76.9 (30.2)	77.4 (26.7)	85.0 (24.1)	
Median (range)	100.0 (75.0-100.0)	100.0 (6.2-100.0)	87.5 (6.2-100.0)	90.6 (25.0-100.0)	100.0 (6.2-100.0)	

Table 21. Patient-reported outcome in the KOOS Quality of Life subscore; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

KOOS Total (KOOS-T)

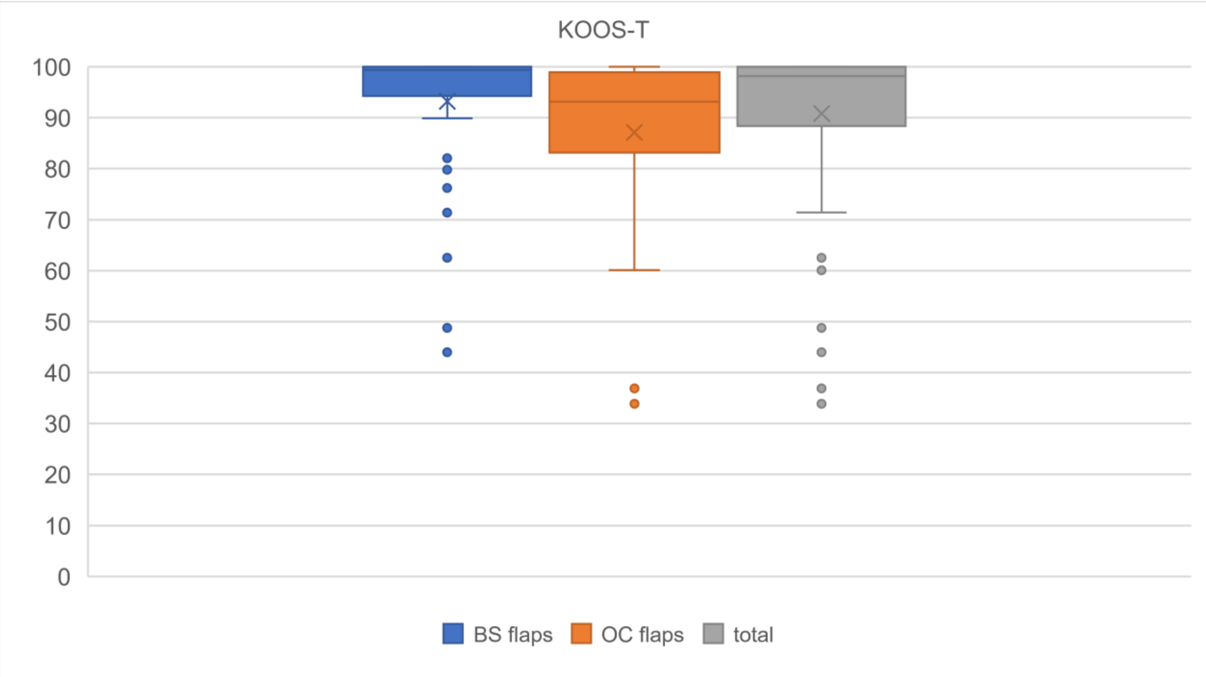

Figure 43. Overall patient-reported outcome in the KOOS assessment; BS: bone and soft tissue, OC: osteocartilaginous.

The overall Knee Injury and Osteoarthritis Outcome Score (KOOS) in the follow-up population reached an average of 91.9 (± 15.0) points. OC flaps (mean score: 84.6 ± 19.4) reported significantly higher donor site morbidity in the KOOS compared to the BS flap subgroup (mean score: 92.3 ± 14.8) (Figure 43). A significant site-specific donor site morbidity in the overall KOOS for flaps from the MFC (mean score: 89.3 ± 17.2) or LFC (mean score: 89.2 17.2) was not evident (Table 22).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
KOOS-T						0.071
N-Miss	0	21	2	3	26	
Mean (SD)	95.1 (6.8)	91.6 (16.3)	83.9 (21.9)	85.0 (18.5)	89.3 (17.1)	
Median (range)	97.6 (79.6-100.0)	99.3 (35.5-100.0)	89.5 (27.4-100.0)	92.1 (32.5-100.0)	97.9 (27.4-100.0)	

Table 22. Patient-reported outcome in the total KOOS assessment; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.

Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

3.2.2.2. Scar assessment – POSAS Patient Scale (POSAS-P)

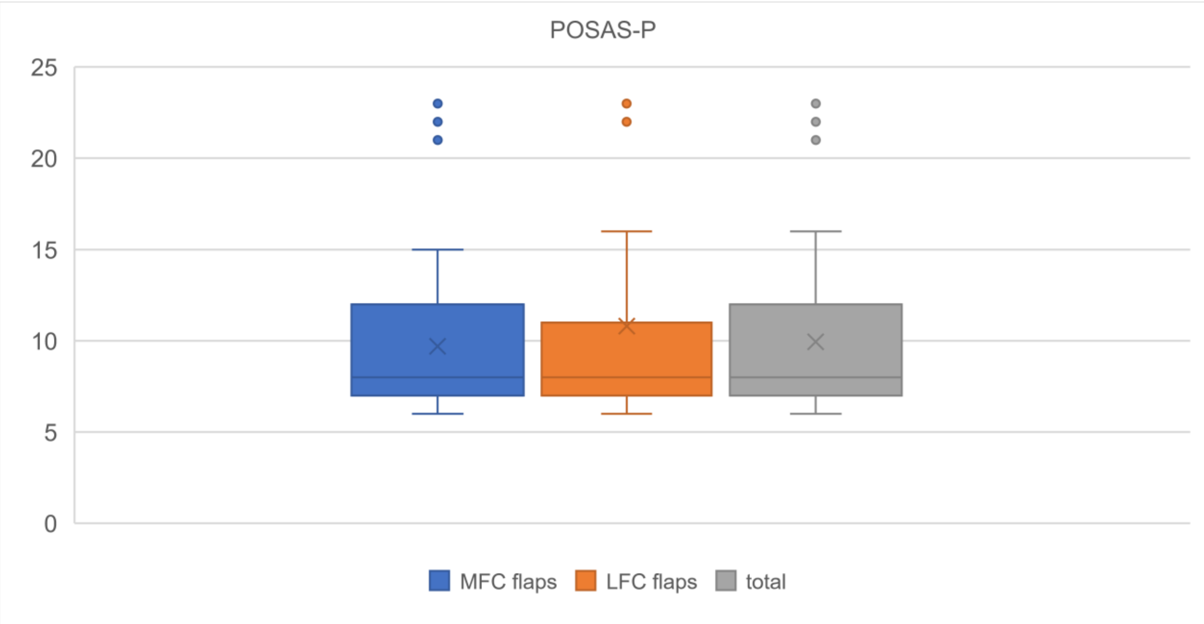

Figure 44. Outcome of the POSAS Patient Scale; MFC: medial femoral condyle, LFC: lateral femoral condyle.

The mean POSAS-P was 9.9 (± 4.6) and showed no significant (p = 0.31) difference among the BS flap subgroup (mean score: 10.5 ± 5.1) and the OC flap subgroup (mean score: 8.9 ± 3.3) (Figure 44). With a mean score of 9.7 (± 4.3) for flaps from the MFC and 10.8 (± 5.6) for flaps from the LFC, significant site-specific differences in scar appearance was not evident in our follow-up cohort (p = 0.664) (Table 23).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
POSAS-P						0.111
N-Miss	0	1	0	0	1	
Mean (SD)	13.1 (5.9)	10.0 (4.8)	9.1 (4.9)	8.9 (2.2)	9.9 (4.6)	
Median (range)	11.0 (7.0-23.0)	8.0 (6.0-23.0)	7.0 (6.0-22.0)	9.0 (6.0-13.0)	8.0 (6.0-23.0)	

Table 23. Outcome in the POSAS Patient Scale; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.

Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

3.2.2.3. Scar assessment – POSAS total score

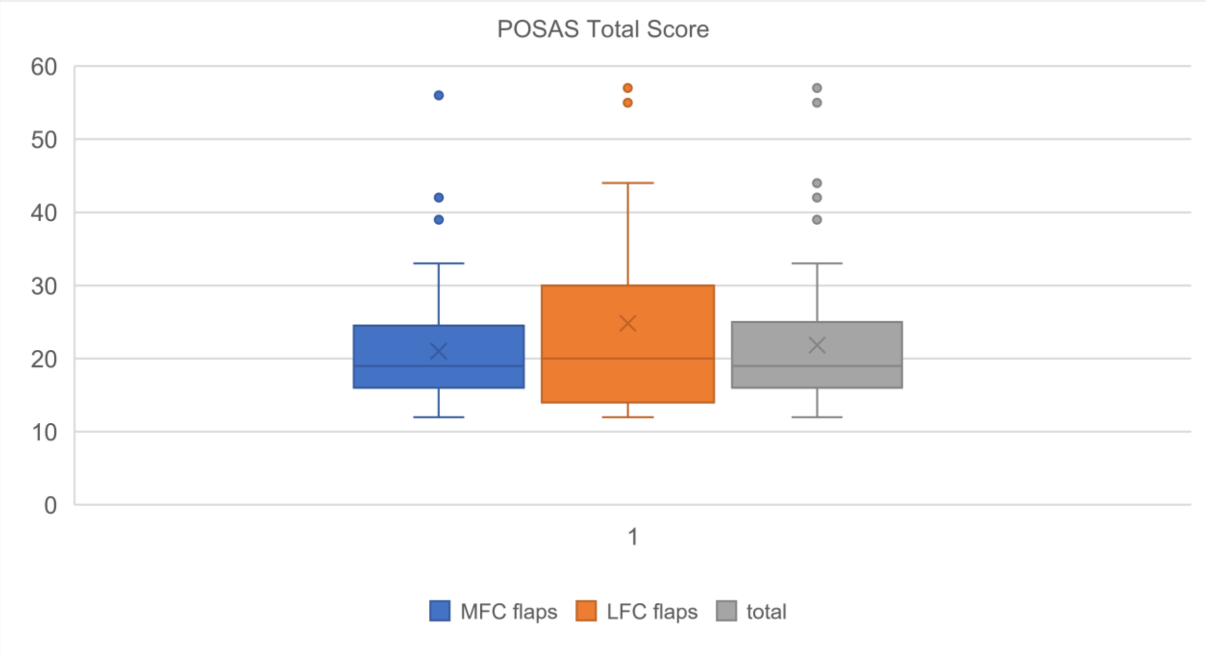

Figure 45. Overall outcome in the POSAS assessment (POSAS-O and POSAS-P); MFC: medial femoral condyle, LFC: lateral femoral condyle.

The overall Patient and Observer Scar Assessment Score (POSAS) of the follow-up population was 21.8 (± 9.3). There was no significant difference (p = 0.671) among the outcomes of the BS flap subgroup (mean score: 22.3 ± 9.8) and the OC flap subgroup (mean score: 20.9 ± 8.2) (Figure 45). Furthermore there was no significant (p = 0.709) site-specific morbidity regarding the scar quality between flaps from the MFC (mean score: 21.0 ± 7.5) and LFC (mean score: 24.8 ± 13.6) (Table 24). The simultaneous harvesting of a skin island from the MFC or LFC (n = 13/97) was associated with significantly (p = 0.036) higher morbidity in the POSAS (mean score with skin island: 28.9 ± 9.3; mean score linear scar: 21.3 ± 8.8).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
POSAS total						0.297
N-Miss	0	1	0	0	1	
Mean (SD)	29.7 (14.8)	21.1 (8.3)	21.2 (12.0)	20.8 (5.3)	21.8 (9.3)	
Median (range)	30.0 (14.0-57.0)	19.0 (12.0-56.0)	16.5 (12.0-55.0)	20.0 (13.0-32.0)	19.0 (12.0-57.0)	

Table 24. Outcome in the total POSAS assessment; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

3.2.2.4. Sensory testing – Ten Test

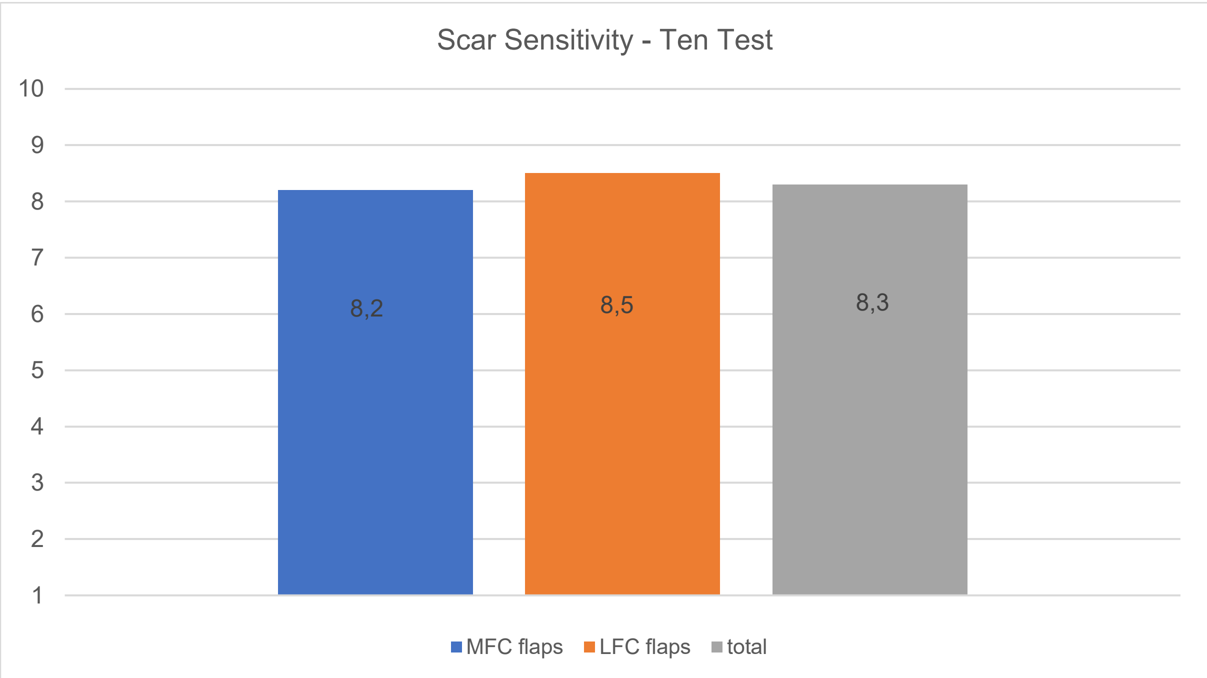

Figure 46. Scar sensitivity at the donor sites in the Ten Test, MFC: medial femoral condyle, LFC: lateral femoral condyle.

The sensitivity around the donor scar was rated with average 8.3 ± 2.2 points in the Ten Test without any significant (p = 0.611) difference between the BS flaps subgroup (mean score: 8.3 ± 2.2) and the OC flap subgroup (mean score: 8.2 ± 2.2) (Figure 46, Table 25).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
Ten Test scar						0.837
N-Miss	0	1	0	0	1	
Mean (SD)	8.6 (1.5)	8.3 (2.3)	8.4 (2.4)	8.1 (2.1)	8.3 (2.2)	
Median (range)	9.0 (7.0-10.0)	9.5 (1.0-10.0)	9.5 (2.0-10.0)	9.0 (4.0-10.0)	9.0 (1.0-10.0)	

Table 25. Outcome of the Ten Test; BS: bone and soft tissue flap, OC: osteochondral flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

In cases involving a MFC flap, impaired sensation was described around the scar (infrapatellar branch, IPB: 22.7%) by 54.7% (41/76), compared to 52.4% (11/21) for LFC flaps (Table 26).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)
Ten Test IPB					
N-Miss	9	1	12	0	22
Mean (SD)	NA	8.7 (2.4)	NA	9.6 (1.2)	9.0 (2.2)
Median (range)	NA	10.0 (1.0-10.0)	NA	10.0 (6.0-10.0)	10.0 (1.0-

Table 26. Outcome of the Ten Test around the infrapatellar area; BS: bone and soft tissue flap, OC: osteocartilaginous flap, IPB: infrapatellar branch; N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 202. With permission of publisher, Elsevier[1]

A significant site-specific difference in the results of the Ten Test for flaps from the MFC (mean score: 21.0 ± 7.5) and LFC (mean score: 24.8 ± 13.6) was not evident (p = 0.709) (Table 25).

3.2.2.5. VAS scores

VAS pain at follow-up

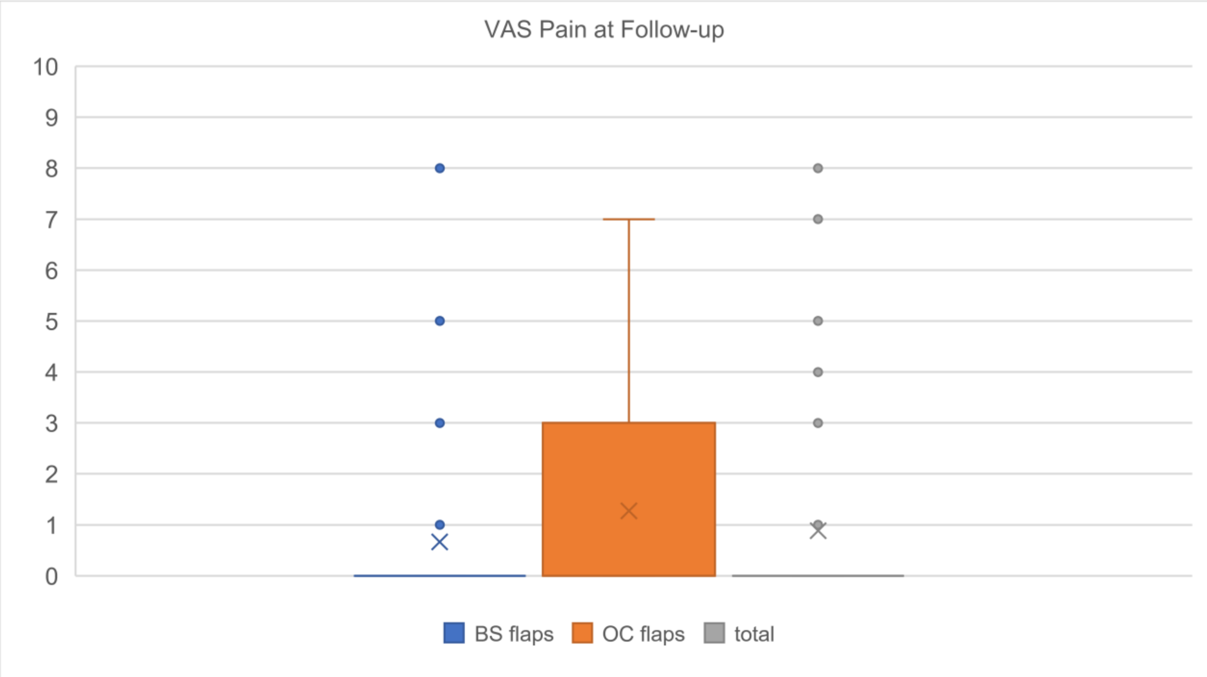

Figure 47. Pain levels using the VAS at the follow-up examination; VAS: visual analogue scale, BS: bone and soft tissue, OC: osteocartilaginous.

The pain level at follow-up was rated on average of 0.3 ± 1.1 points in the VAS. A direct comparison of the pain level at follow-up between the BS flap subgroup (mean score: 0.3 ± 1.2) and the OC flap subgroup (mean score: 0.2 ± 1.0) did not show a significant (p = 0.545) difference in outcome (Figure 47). Furthermore there was no significant (p = 0.482) difference in the pain levels at follow-up between flaps from the MFC (mean score: 0.3 ± 1.2) and LFC (mean score: 0.1 ± 0.7) (Table 27).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
VAS Pain FU						0.624
N-Miss	0	3	0	0	3	
Mean (SD)	0.0 (0.0)	0.4 (1.3)	0.2 (0.9)	0.2 (1.1)	0.3 (1.1)	
Median (range)	0.0 (0.0-0.0)	0.0 (0.0-6.0)	0.0 (0.0-3.0)	0.0 (0.0-5.0)	0.0 (0.0-6.0)	

Table 27. Pain levels at the follow-up examination using the VAS; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.

Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

VAS activity-Related Pain (ARP)

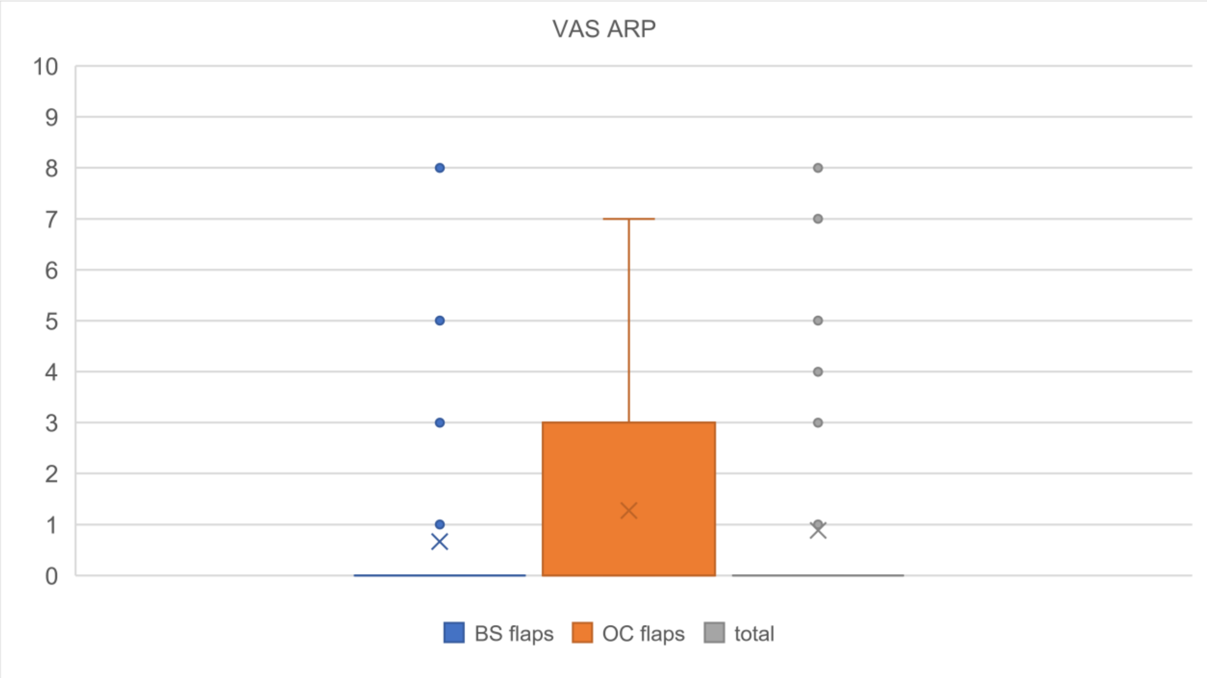

Figure 48. Pain levels in the VAS during physical activity; VAS: visual analogue scale BS: bone and soft tissue, OC: osteocartilaginous.

The activity-related pain level was rated on average 0.9 ± 1.9 points in the VAS. A direct comparison of the activity related pain between the BS flap subgroup (mean score: 0.7 ± 1.8) and the OC flap subgroup (mean score: 1.3 ± 1.9) showed significantly ($p = 0.037$) higher pain levels during physical activity for the OC flap subgroup (Figure 48). There was no significant ($p = 0.905$) difference in the pain levels at follow-up between flaps from the MFC (mean score: 1.0 ± 2.0) and LFC (mean score: 0.6 ± 1.2) (Table 28).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
VAS activity-related pain						0.105
N-Miss	1	3	0	0	4	
Mean (SD)	0.5 (1.1)	0.7 (1.9)	0.7 (1.4)	1.6 (2.2)	0.9 (1.9)	
Median (range)	0.0 (0.0-3.0)	0.0 (0.0-8.0)	0.0 (0.0-4.0)	0.0 (0.0-7.0)	0.0 (0.0-8.0)	

Table 28. Activity-related pain levels of the follow-up population using the VAS; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.
Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

VAS Functional Donor Site Morbidity

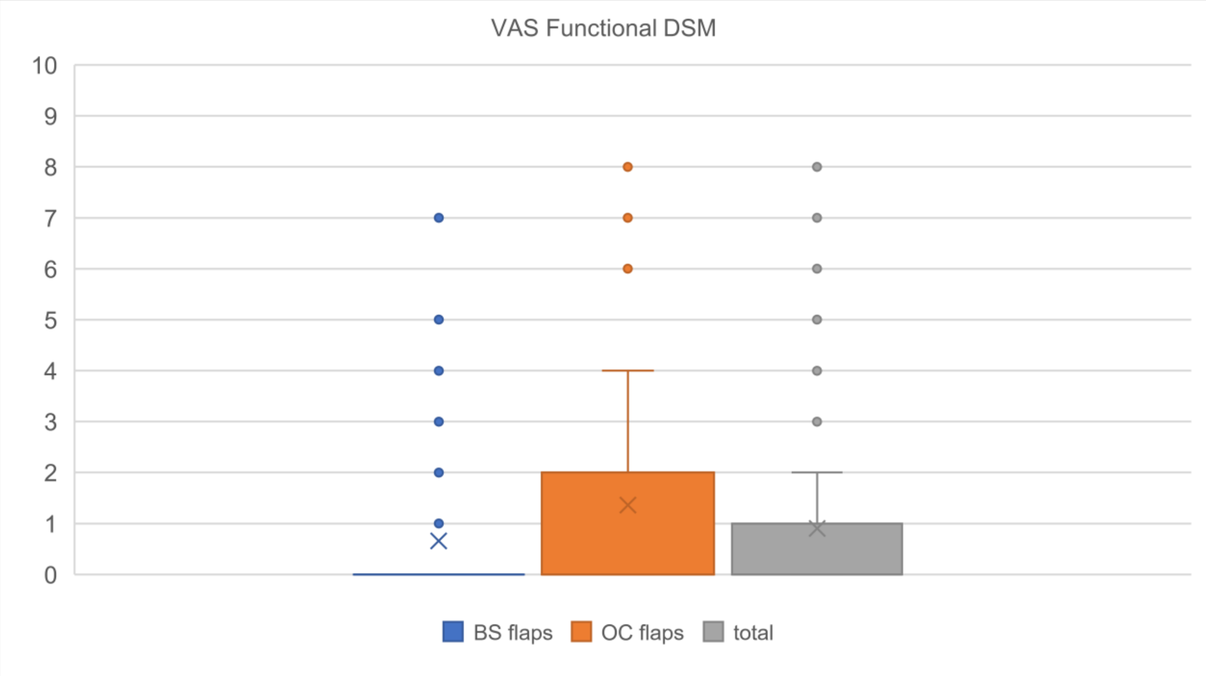

Figure 49. Functional DSM in the VAS; DSM: donor site morbidity, VAS: visual analogue scale, BS: bone and soft tissue, OC: osteocartilaginous.

The functional donor site morbidity was rated on average 0.9 ± 1.9 points in the VAS. A direct comparison of the functional donor site morbidity assessment in the VAS between the BS flap subgroup (mean score: 0.7 ± 1.5) and the OC flap subgroup (mean score: 1.4 ± 2.3) did not show a significant (p = 0.061) difference in outcome (Figure 49). Furthermore there was no significant (p = 0.624) difference in the functional donor site morbidity between flaps from the MFC (mean score: 0.9 ± 1.9) and LFC (mean score: 0.8 ± 1.9) (Table 29).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
VAS functional DSM						p = 0.142
N-Miss	0	3	0	0	3	
Mean (SD)	0.6 (1.3)	0.7 (1.6)	0.9 (2.3)	1.6 (2.3)	0.9 (1.9)	
Median (range)	0.0 (0.0-4.0)	0.0 (0.0-7.0)	0.0 (0.0-8.0)	0.0 (0.0-7.0)	0.0 (0.0-8.0)	

Table 29. Functional DSM in the VAS; DSM: donor site morbidity, VAS: visual analogue scale, BS: bone and soft tissue, OC: osteocartilaginous.

VAS Aesthetic Donor Site Morbidity

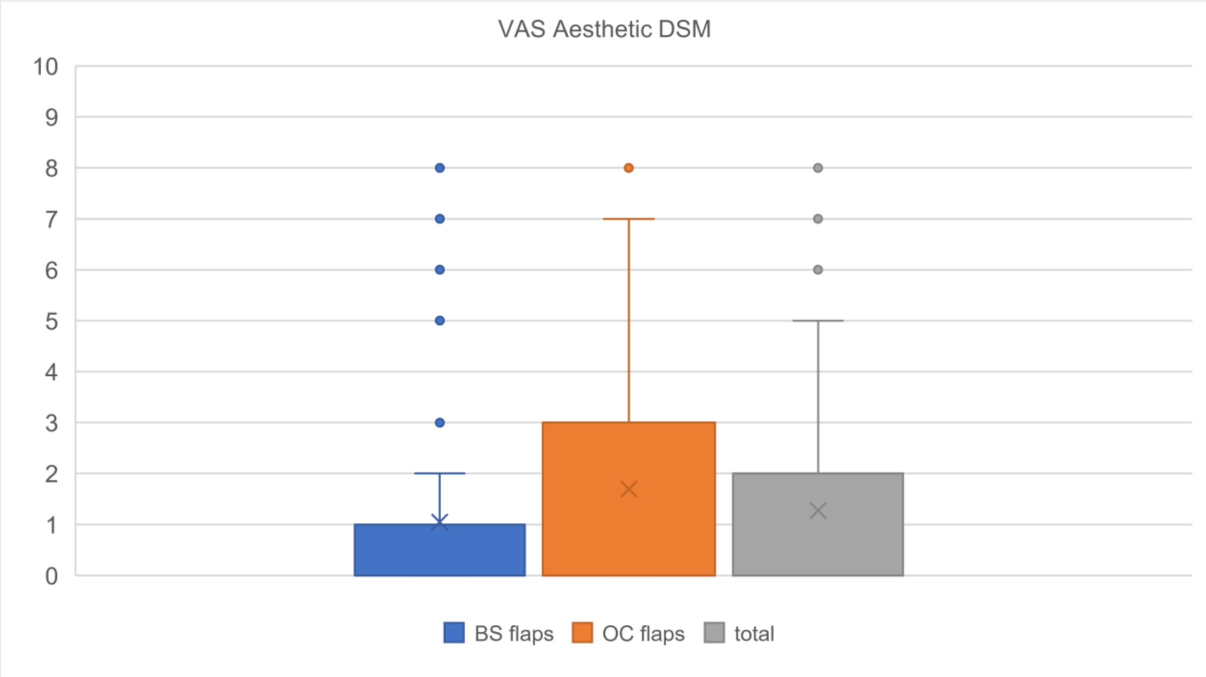

Figure 50. Aesthetic DSM in the VAS; DSM: donor site morbidity, VAS: visual analogue scale, BS: bone and soft tissue, OC: osteocartilaginous.

The aesthetic appearance of the donor site was rated on average 1.3 ± 2.2 points in the VAS. A direct comparison of the aesthetic donor site morbidity assessment in the VAS between the BS flap subgroup (mean score: 1.0 ± 2.1) and the OC flap subgroup (mean score: 1.7 ± 2.5) did not show a significant (p = 0.269) difference in outcome (Figure 50). Additionally there was no significant (p = 0.945) difference in the aesthetic donor site morbidity between flaps from the MFC (mean score: 0.8 ± 1.8) and LFC (mean score: 1.5 ± 2.9) (Table 30).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
VAS aesthetic DSM						0.622
N-Miss	0	2	0	0	2	
Mean (SD)	1.6 (2.8)	1.0 (1.9)	1.3 (2.4)	1.9 (2.6)	1.3 (2.2)	
Median (range)	0.0 (0.0-7.0)	0.0 (0.0-8.0)	0.0 (0.0-7.0)	0.0 (0.0-8.0)	0.0 (0.0-8.0)	

Table 30. Aesthetic appearance of the donor sites in the VAS score; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.

Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

VAS overall satisfaction with the donor site morbidity

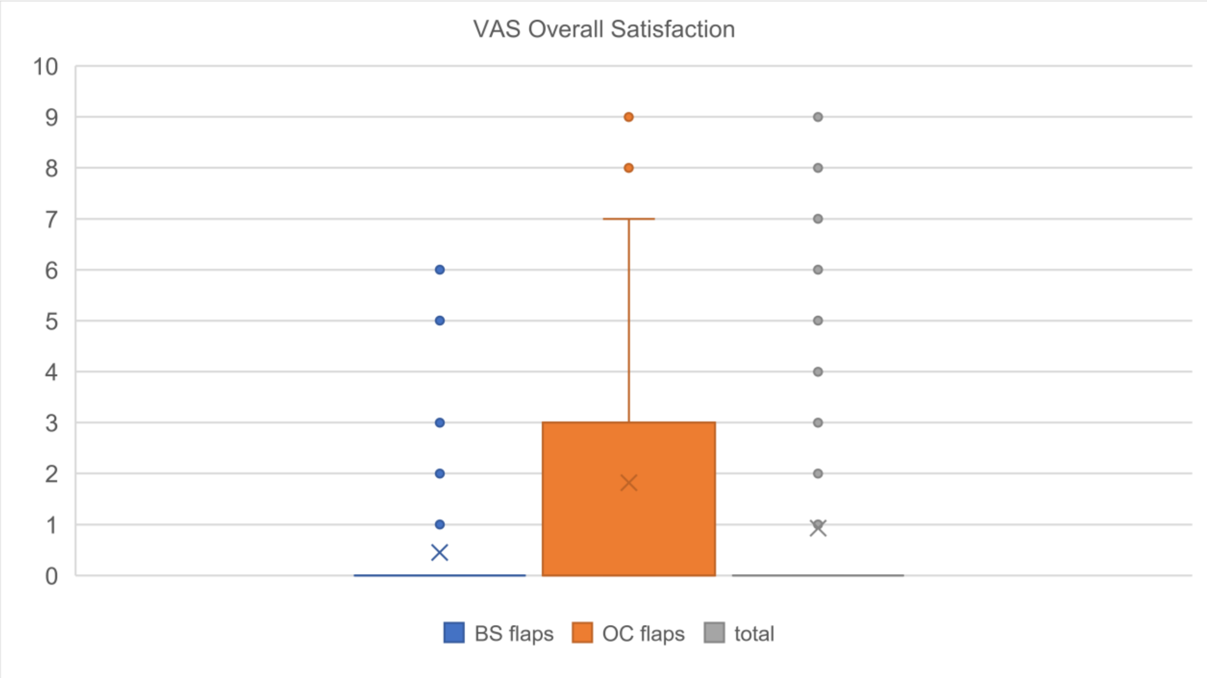

Figure 51. Overall satisfaction with the DSM in the VAS; DSM: donor site morbidity, VAS: visual analogue scale BS: bone and soft tissue, OC: osteocartilaginous.

The overall donor site morbidity was rated on average 1.9 ± 2.1 points in the VAS. A direct comparison of the aesthetic donor site morbidity assessment in the VAS between the BS flap subgroup (mean score: 0.5 ± 1.2) and the OC flap subgroup (mean score: 1.8 ± 3.0) showed significantly ($p = 0.021$) higher overall donor site morbidity for OC flaps (Figure 51). There was no significant ($p = 0.756$) difference in the overall donor site morbidity between flaps from the MFC (mean score: 1.2 ± 2.2) and LFC (mean score: 1.4 ± 2.5) (Table 31).

	BS lateral (N=9)	BS medial (N=55)	OC lateral (N=12)	OC medial (N=21)	Total (N=97)	p-value
VAS DSM						0.144
N-Miss	0	2	0	0	2	
Mean (SD)	0.7 (2.0)	0.4 (1.0)	2.1 (3.3)	1.7 (2.9)	0.9 (2.1)	
Median (range)	0.0 (0.0-6.0)	0.0 (0.0-5.0)	0.0 (0.0-9.0)	0.0 (0.0-9.0)	0.0 (0.0-9.0)	

Table 31. Overall satisfaction with the donor site morbidity in the VAS; BS: bone and soft tissue flap, OC: osteocartilaginous flap, N-miss: numbers missing.

3.2.2.6. Job change

One patient (1%) of the follow-up cohort, who underwent a BS flap harvest, reported a job change due to postoperative donor site morbidity. None of the OC flap patients reported a job change due to donor site morbidity.

3.2.2.7. Physical activity

Overall, 5.2% (5/97) of patients were not able to do carry out their usual athletic activities due to donor site morbidity. There was no significant difference between the BS flaps subgroup (physical activity not possible: 3.1%) and the OC flaps subgroup (physical activity not possible: 9.4%).

3.2.2.8. Satisfaction

In total 87.5% (84/97) stated that they would choose the same donor region, whereas 2.1% (2/97) were not sure and 10.4% stated that they would not choose this donor region again. There was a significant (p = 0.005) difference between the BS flap subgroup (satisfaction: 95.2%) and the OC flap subgroup (satisfaction: 72.7%), with a clearly higher willingness to undergo this procedure again for the BS flap group.

3.2.2.9. Correlation between the objective and patient-reported knee scores

A direct comparison between the results of the objective knee scores (KSS, OAK, LKS) and the patient-reported questionnaires (IKDC, KOOS, KSFS) showed a positive correlation between the objective and the patient reported knee function for all scores. (Figure 51).

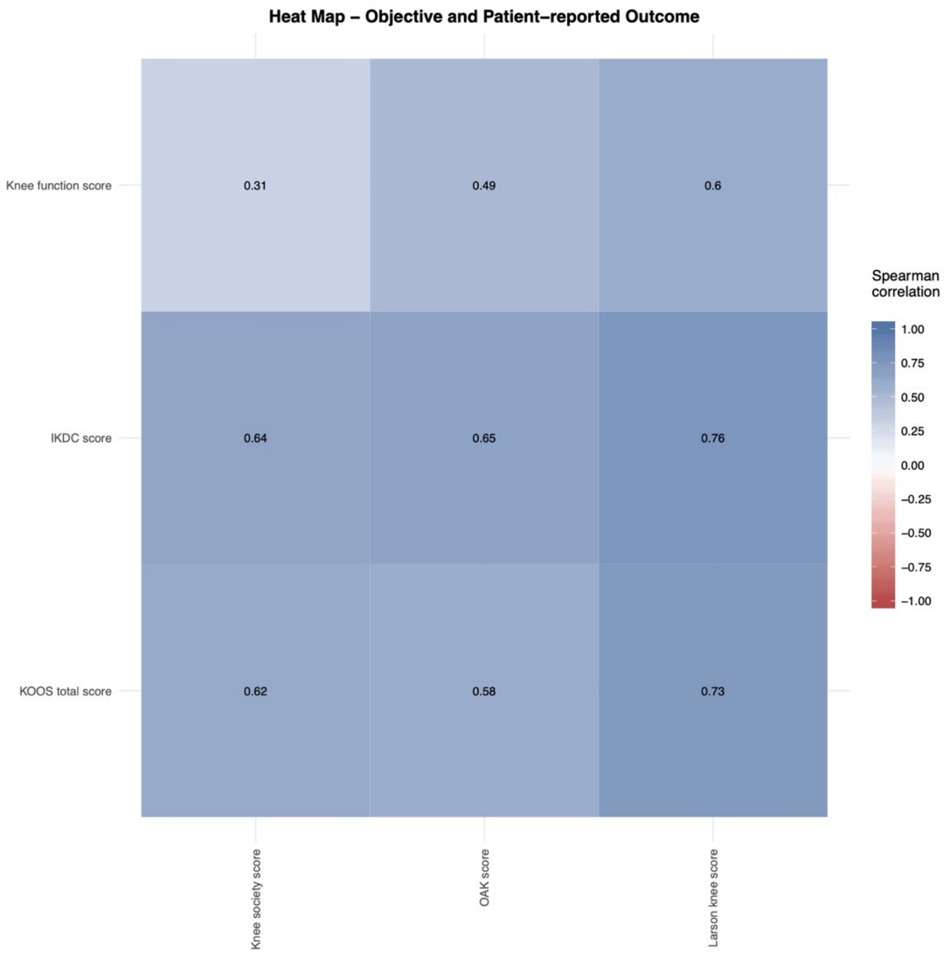

Figure 52. Correlation between the objective and patient-reported knee scores.
Reproduced from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

3.2.3. Radiologic follow-up examination

3.2.3.1. Kellgren and Lawrence grading system – BS flaps

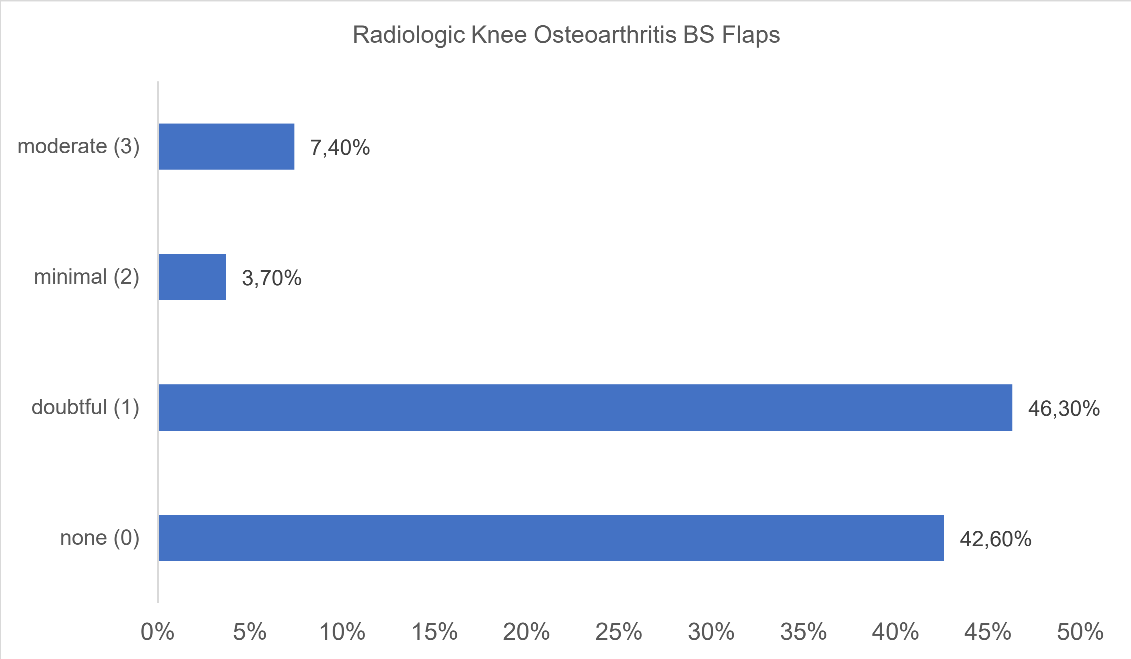

Figure 53. Radiologic outcome of the BS-flap subgroup in the Kellgren and Lawrence Score; BS: bone and soft tissue.

The majority of the BS flaps showed no signs (grade 0: 42.6%, 23/64) or doubtful signs (grade 1: 46.3%, 25/64) of knee osteoarthritis (Figure 53). In cases of a BS flap from the medial femoral condyle region, a grade of 0 or 1 was present in 87.2% (41/55) of people compared to 100% (9/9) of the BS flaps from the lateral femoral condyle region (Table 32). Minimal signs (grade 2) of knee osteoarthritis were evident in 3.7% of the BS patients (BS MFC: 4.3%; BS LFC: 0%). Knee x-rays were rated at 3 (moderate signs of knee osteoarthritis) in the Kellgren and Lawrence system in 7.4% of patients (4/64, BS MFC: 8.5; BS LFC: 0%). Severe knee osteoarthritis could not be detected in the follow-up cohort (Figure 52, Table 32).

Kellgren-Lawrence Score	BS lateral (N=9)	BS medial	BS total (N=64)	p: 0.390
N-Miss	2	8	10	
0	5 (71.4%)	18 (38.3%)	23 (42.6%)	
1	2 (28.6%)	23 (48.9%)	25 (46.3%)	
2	0 (0.0%)	2 (4.3%)	2 (3.7%)	
3	0 (0.0%)	4 (8.5%)	4 (7.4%)	

Table 32. Outcome of the BS flaps in the Kellgren and Lawrence grading system; BS: bone and soft tissue flap, N-miss: numbers missing.

Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

3.2.3.2. MOAKS – OC flaps

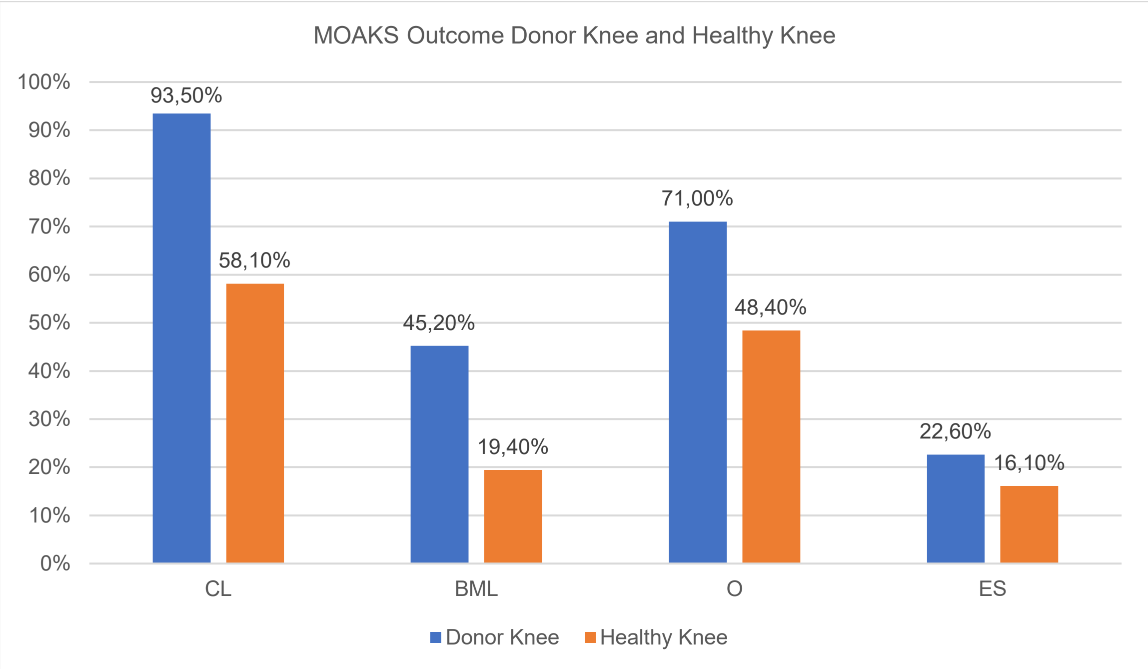

Figure 54. Outcome of the OC-flap subgroup in the MOAKS; OC: osteocartilaginous.

- Cartilage loss

Cartilage defects were significantly (p = 0.006) more often present at the donor knees (occurrence rate: 93.5%, 29/33) compared to the healthy opposite sides (occurrence rate: 58.1%, 18/33) (Figure 54). A direct comparison of the occurrence rates of CL between MFC flaps (CL: 95%, 19/21) and LFC flaps (CL: 90.9, 10/12) flaps showed comparable results (p = 0.324). CL at the donor region (MFC or LFC) was present in 95% (19/21) of the MFC flaps and 90.9% (10/12) of the LFC flaps. Severe cartilage defects were present in 90.3% (28/33) of the donor knees, without a significant difference (p = 0.935) between MFC flaps (occurrence rate:

90%, 18/21) and LFC flaps (occurrence rates: 90.9%, 10/12). Severe CL occurred significantly (p = < 0.001) more often at the donor knee (occurrence rate: 90.3%, 28/33) compared to the opposite healthy side (occurrence rate: 19.4, 6/33) (Table 32).

- Bone marrow lesions

Although not statistically significant (p = 0.080), BML's occurred more often at the donor knees (45.2% (14/33) compared to the healthy opposite sides (BML rate: 19.4%, 6/33) (Figure 53). A direct comparison of the occurrence rates of BML between MFC flaps (BML: 45.0, 9/21) and LFC flaps (BML: 45.5%, 5/12) showed nearly similar results (p = 0.981). A BML at the donor region (MFC or LFC) was present in 45% (9/21) of the MFC flaps and 45.5% (5/12) of the LFC flaps. Large BML was present in 29% (9/33) of the donor knees without a significant difference (p = 0.234) between MFC flaps (occurrence rate: 35%, 7/2) and LFC flaps (occurrence rate: 18.2%, 2/12). Large BML's occurred significantly (p = 0.013) more often in the donor knee (occurrence rate: 29%, 9/33) compared to the opposite healthy side (occurrence rate: 3.2%, 1/33) (Table 32).

- Osteophytes

Although not statistically significant (p = 0.070), osteophytes occurred more often at the donor knees (occurrence rate: 71%, 22/33) compared to the healthy opposite sides (occurrence rate: 48.4%, 15/33) (Figure 54). A direct comparison of the occurrence rates of O between MFC flaps (occurrence rate: 75%, 15/21) and LFC flaps (occurrence rate: 63.6%, 7/12) flaps showed quite similar results (p = 0.505). O at the donor region (MFC or LFC) was present in 75% (15/21) of the MFC flaps and 27.3% (3/12) of the LFC flaps. Large O were present in 58.1% (18/33) of the donor knees without a significant difference (p = 0.291) between MFC flaps (occurrence rate: 65%, 13/21) and LFC flaps (occurrence rate: 45.5%, 5/12) (Table 32).

- Effusion synovitis

At 22.6% (7/33), ES was present more often in the healthy knee compared to the donor knee (ES rate: 16.1%, 5/33) (Figure 54). ES was present more often at the donor knee after MFC flap harvest (occurrence rate: 30%, 6/21) compared to the LFC flaps where ES occurred in 9.1% (1/12) (Table 32).

MOAKS	OC lateral (N=12)	OC medial (N=21)	OC total (N=33)	p value
N-Miss	1	1	2	
MOAKS - BML anywhere donor knee				0.981
0	6 (54.5%)	11 (55.0%)	17 (54.8%)	
1	5 (45.5%)	9 (45.0%)	14 (45.2%)	
MOAKS - BML anywhere healthy knee				0.408
0	8 (72.7%)	17 (85.0%)	25 (80.6%)	
1	3 (27.3%)	3 (15.0%)	6 (19.4%)	
MOAKS - CL anywhere donor knee				0.657
0	1 (9.1%)	1 (5.0%)	2 (6.5%)	
1	10 (90.9%)	19 (95.0%)	29 (93.5%)	
MOAKS - CL anywhere healthy knee				0.220
0	3 (27.3%)	10 (50.0%)	13 (41.9%)	
1	8 (72.7%)	10 (50.0%)	18 (58.1%)	
MOAKS - O anywhere donor knee				0.505
0	4 (36.4%)	5 (25.0%)	9 (29.0%)	
1	7 (63.6%)	15 (75.0%)	22 (71.0%)	
MOAKS - O anywhere healthy knee				0.208
0	4 (36.4%)	12 (60.0%)	16 (51.6%)	
1	7 (63.6%)	8 (40.0%)	15 (48.4%)	
MOAKS - ES anywhere donor knee				0.183
0	10 (90.9%)	14 (70.0%)	24 (77.4%)	
1	1 (9.1%)	6 (30.0%)	7 (22.6%)	
MOAKS - ES anywhere healthy knee				0.211
0	8 (72.7%)	18 (90.0%)	26 (83.9%)	
1	3 (27.3%)	2 (10.0%)	5 (16.1%)	
MOAKS - BML at harvest region				
0	6 (54.5%)	11 (55.0%)		
1	5 (45.5%)	9 (45.0%)		
MOAKS - BML severe at harvest region				
0	10 (90.9%)	15 (75.0%)		
1	1 (9.1%)	5 (25.0%)		
MOAKS - CL at harvest region				
0	1 (9.1%)	1 (5.0%)		
1	10 (90.9%)	19 (95.0%)		
MOAKS - CL severe at harvest region				
0	2 (18.2%)	2 (10.0%)		
1	9 (81.8%)	18 (90.0%)		
MOAKS - O at harvest region				
0	8 (72.7%)	5 (25.0%)		
1	3 (27.3%)	15 (75.0%)		
MOAKS - O severe at harvest region				
0	8 (72.7%)	7 (35.0%)		
1	3 (27.3%)	13 (65.0%)		

Table 33. Outcome of the OC flaps in the MOAKS; MOAKS: MRI Osteoarthritis Knee Score, BML: bone marrow lesions, CL: cartilage loss, O: osteophytes, ES: effusion synovitis.

Reproduced with modifications from Neuwirth M, Ziegler T, Benedikt S, Winter R, Kamolz LP, Schintler M, Rab M, Mueller-Eggenberger M, Mischitz M, Palle W, Hoenck K, Schoellnast H, Janek E, Borenich, Buerger H. Donor site morbidity after the harvest of microvascular flaps from the medial and lateral femoral condyle region: Objective, radiologic and patient-reported outcome of a multi-center trial. Journal of Plastic, Reconstructive and Aesthetic Surgery 2022. With permission of publisher, Elsevier[1]

3.2.3.3. Impact of MRI pathologies on objective and patient-reported knee function

- Impact of the occurrence of BML on knee function

A BML anywhere at the donor knee was present in 45.2% (14/31) of the OC flap group while 54.8% (17/31) did not show any BML at the donor knee after an OC flap harvest. A direct comparison of the functional outcome of these two subgroups (no BML: 0; BML: 1) showed comparable results in the KOOS total score (0: mean score 83.6 ± 23.0; 1: mean score: 85.8 ± 15.0), the IKDC score (0: mean score 80.9 ± 21.0; 1: mean score: 83.1 ± 16.6) and the KSS (0: mean score 94.2 ± 8.1; 1: mean score: 92.4 ± 11.1).

- Impact of the occurrence of CL on knee function

A CL anywhere at the donor knee was present in 93.5% (29/31) of the OC flap group while 6.5% (2/31) did not show a CL at the donor knee after an OC flap harvest. A direct comparison of the functional outcome of these two subgroups (no CL: 0; CL: 1) in the KOOS total score (0: mean score 98.0 ± 2.8; 1: mean score: 83.6 ± 19.8), the IKDC score (0: mean score 97.7 ± 3.3; 1: mean score: 80.7 ± 19.0) and the KSS (0: mean score 100 ± 0.0; 1: mean score: 92.9 ± 9.6) indicated a negative impact on the occurrence of CL on knee function at follow-up.

- Impact of the occurrence of O on knee function

An O anywhere at the donor knee site was present in 71% (22/31) of the OC flap group while 29% (9/31) did not show any O at the donor knee after an OC flap harvest. A direct comparison of the functional outcome of these two subgroups (no O: 0; O: 1) showed comparable results in the KOOS total score (0: mean score 88.2 ± 13.5; 1: mean score: 83.2 ± 21.5), the IKDC score (0: mean score 85.1 ± 15.8; 1: mean score: 80.7 ± 20.1) and the KSS (0: mean score 91.6 ± 12.8; 1: mean score: 94.1 ± 8.0).

4. Discussion

In the last decade, the medial and lateral femoral condyle region has become one of the most important donor areas for small, microvascular bone or cartilage grafts. One reason for the ongoing success of this donor region in reconstructive microsurgery is the wide range of reconstructive possibilities. From the first report by Sakai et al. in 1991 until today, there are hardly any donor regions which have a comparable amount of published possible applications and clinical indications.[85]

In addition to the treatment of carpal bone non-unions as a classic indication, flaps from the femoral condyle region have proven their surgical potential in the reconstruction of bony defects or non-unions on nearly the entire skeleton.[4,37,38,41,57,59,62,64,67-71,74,76,78,82,91,94,98,100,107-109] The subsequent introduction of osteochondral flaps from the medial and lateral femoral condyle region have further expanded the reconstructive possibilities of this region and opened the new field of microvascular cartilage reconstruction.[23-25]

The specific use of osteochondral flaps from the knee has encountered some criticism, especially from knee surgeons, and raised the question about the long-term donor site morbidity of these flaps. In addition to all reconstructive advantages and possibilities, a low DSM can be considered as the ultimate success factor of every new donor region. In contrast to the exploding number of promising case reports or clinical case studies that focused on the primary reconstructive potential of these flaps at the recipient sites, only a very few investigated DSM after the harvesting of bone or cartilage flaps from the medial femoral condyle region.[120-124] To the best of our knowledge, the DSM of the lateral femoral condyle region has not been investigated up to this point.

The overall complication rate of our population at the donor sites was 9.6 %, with a major complication rate of 3%. In their meta-analysis of 283 patients who underwent a medial femoral condyle flap harvest (bone or cartilage), Giladi et al. reported a similar cumulative complication rate.[125] Since most of the cited papers of this meta-analysis had their primary focus on the reconstructive outcome at the recipient site and did not report donor site complications in detail, a direct comparison of our complication rates is not possible without involving bias. Regarding our overall complication rate at the donor sites, one might think that there is a serious risk of developing a donor site complication when harvesting a microvascular flap from the medial or lateral condyle region. Aside from the fact that we had very strict inclusion criteria for postoperative complications at the donor site, a closer look to the type of donor site complications shows that the majority of our respective complications can be categorized as "minor"; they did not have any negative impact on long-term donor site morbidity.

Compared to BS flaps, the overall complication rate of our OC flap subgroup was significantly higher. The increased complication rate that is associated with the harvest of OC flaps from the knee joint can logically be explained by the more invasive nature of the flap harvest itself (opening of the knee joint) as well as the flap composition (piece of cartilage from the knee).

As mentioned above, the majority of our complications did not have any negative impact on long-term donor site morbidity. Major complications at the donor site occurred in 2.6% of patients. As a major complication, a knee joint infection occurred in three cases, and we had one case of a supracondylar fracture at the donor site after a fall in the outpatient phase. Interestingly, the majority of the above-mentioned major complications occurred in the BS flap subgroup and did not show the expected collection of major complications in the OC flap subgroup.

A fracture of the distal femur associated with flap harvesting, as occurred in our population, is one of the most dreaded complications related to this procedure and has been reported previously after the harvesting of a corticoperiostal flap from the MFC.[93] Similar to this case, our flap involved a large corticoperiostal flap from the MFC that was used to treat a postraumatic varus deformity on the ipsilateral tibia. Regarding the scientific and clinically relevant question concerning which flap size at the distal femur can be safely tolerated without an increased fracture risk, two biomechanical studies that focused on the stability of the distal femur after the harvest of various sized bone flaps have already been published.

Katz et al. investigated the axial stability of a composite femur model after the harvesting of various sized (3cm-24cm) corticocancellous blocks at the MFC.[126] This study reported a retained axial stability under supraphysiologic forces, even after the harvesting of large-sized flaps. This study reported retained axial stability under supraphysiologic forces even after the harvest of large flaps. A subsequent study by Endara et al. investigated the clinically more relevant torsional stability of the MFC after the harvest of corticocancellous flaps.[127] They examined the ability of the MFC to resist torsional loads after the harvesting of various sized (3cm, 5cm and 7cm in length) corticocancellous flaps from the MFC on 16 pairs of cadaver legs. In contrast to the findings by Katz et al., the harvesting of a corticocancellous flap of any size did significantly decrease the donor site failure torque. Furthermore they observed an increased fracture risk at the donor sites after the harvesting of large flaps (> 7cm). However, the failure torque that was applied in this study clearly exceeded the torsional loads that are exerted on the knee during activities of daily living. Considering the reported clinical cases and the above-mentioned biomechanical findings, there seems to be an increased fracture risk that is associated with an excessive weakening of the surface tension in the transition zone between metaphysis to diaphysis as it occurs with the harvesting of larger flaps that expand to the distal diaphysis.

As reported above, all donor knees showed unimpaired ligament stability at the follow-up examination without any significant change in the range of motion of the donor knees compared to the healthy opposite side.[120,122,123] A direct comparison between the BS and OC flaps subgroup did not show increased morbidity in terms of ligament stability and range of motion after the harvesting of OC flaps. Regarding these findings, the harvesting of bone or cartilage flaps from the medial or lateral femoral condyle region does not have any relevant impact on knee stability or range of motion.

The results of our knee function scores showed nearly unimpaired knee function for our BS-flaps, indicating negligible functional donor site morbidity. This is in accordance with the findings of Struckmann et al. who investigated the DSM of bone flaps from MFC for extremity reconstruction.[123] In this study the OAK score at the time of follow-up examination reached an average of 92.8 points and did not show a significant difference between upper and lower extremity reconstruction. A recent study by Zeman-Kuhnert evaluated the DSM of MFC bone flaps for facial reconstruction and reported a mean score of 96.8 points in the KSS.[122] In this study the majority of patients (73.7%) had similar function scores in the donor knee and the healthy opposite side, underlining the minimal functional DSM of these flaps. Both of the above-mentioned studies also investigated the impact of the flap indication and the flap size on functional DSM. In agreement with the results of our study, they reported no significant impact on the flap indication or flap size on objective knee function.[122,123]

Since all of the studies cited above investigated the DSM of bone flaps from the MFC, one could raise the question if these findings can be transferred to the lateral condyle region. Although our study is the first that investigated the DSM of BS and OC flaps from the LFC, our findings (no difference in knee function scores between the MFC and LFC) indicate that the functional DSM of all BS flaps from the distal femur (MFC and LFC) is negligible. Although still minimal, the direct comparison of the outcome in the knee function scores between our BS and OC flaps shows a significantly higher DSM for our OC flaps. Though never objectively quantified, this observation has been reported before for OC flaps from the MFC and seems to be logical.[125]

To the best of our knowledge there are no studies that focused on the DSM after the harvesting of BS and OC flaps from the LFC. Garretson et al. investigated the contact pressures in the patellofemoral joint.[128] They observed increased contact pressures at the LFC compared to the MFC and therefore derived an increased functional morbidity of the knee after the harvesting of chondral grafts from the LFC. Interestingly these biomechanical findings are in contrast to the results of our follow-up examination where a direct comparison of our BS and OC flaps from the MFC and LFC did not show any significant site-specific morbidity in the knee function scores. Compared to the MFC, the LFC is a relatively new donor region for BS and OC flaps and the above-mentioned findings should be interpreted with caution since the total number of cases as well as the follow-up period clearly differs from that of MFC flaps.

In addition to all of the reconstructive advantages, the acceptability to the patient ultimately determines the long-term success of any new technique in reconstructive microsurgery. Aside from the outcome at the recipient site, the DSM makes a major contribution to determining the overall patient-reported satisfaction and makes it clear whether a new donor region has the potential to become a standard procedure in the microsurgical toolbox.[129] The overall results of our subjective knee questionnaires indicate a minimal patient-reported DSM. This is in accordance with studies that have been published before that investigated the DSM of BS and OC flaps from the MFC for extremity reconstruction as well as head and neck reconstruction.[120-124]

One of the tools we used to assess the patient-reported DSM in our follow-up population was the IKDC score.[114] Regarding the scientific question concerning how the findings of a knee questionnaire should be clinically interpreted, Greco et al. investigated the amount of change the can be clinically perceived by the patients in the in the IKDC score 12 months following knee cartilage repair.[130] They reported a minimum clinically important difference of 16.7 points. In none of our BS flap patients, the above-mentioned amount of change from the maximum score could be observed, indicating that none of our BS flaps patients had a clinically relevant restriction in the subjective knee function at the time of the follow-up examination.

Since there are only very few studies that focused on the patient-reported DSM with various knee questionnaires, a direct comparison of these studies with our results is limited. Zeman-Kuhnert et al. used the KSFS to evaluate patient-reported DSM of MFC bone flaps in head and neck reconstruction.[122] With an average score of 97.1 points, they recorded a patient-reported outcome that is comparable to ours. Furthermore, they evaluated the impact on flap harvesting by analyzing the preoperative and postoperative knee function using the Tegner Lysholm Score. Since the majority of patients did show comparable results, and aside from pain none of Tegner Lysholm subscores showed a significant difference to the baseline subscores preoperatively, they assumed minimal impact of flap harvesting on postoperative knee function. Struckmann et al., who investigated the DSM of MFC bone flaps for extremity reconstruction, support these findings. Besides unimpaired knee function in the lower extremity functional scale, they reported unimpaired gait pattern in the three-dimensional gait analysis of all tested patients (n=4).[123] Similarly to our results, both of these publications could not show a correlation between flap indication or transplant volume and the patient-reported DSM.[122,123]

This study furthermore used the IKDC function subscale (0-10) to investigate the impact of a BS or OC flap harvest from the MFC or LFC on patient-reported knee function at the time to of the follow-up examination. With a drop of on average 0.7 points from the preoperative baseline score of 9.5 points for BS flaps and 1.3 points for OC flaps (preoperative baseline score: 9.5 points), our results indicate a minimal impact of flap harvesting on postoperative knee function, especially after the harvesting of BS flaps. Since this is the first report that analyzed the DSM after the harvest of free flaps from the LFC, we further analyzed any site-specific DSM between the MFC and LFC. Interestingly, our results in the patient-questionnaires did not show any patient-reported site-specific DSM. In conclusion, there seems to be only marginal patient-reported DSM for BS flaps without any site-specific difference between the MFC and LFC region.

In addition to BS flaps, where one could expect a low DSM, there has been some concern about the long-term DSM that is associated with the use of microvascular cartilage grafts from the knee joint. Looking at our findings, the patient-reported DSM of OC flaps from the MFC and LFC can be considered to be low. Compared to the patient-reported outcome of our BS flaps, the OC flap subgroup showed a significantly higher DSM in the IKDC and KOOS. However, this observation was not supported by the results of the KSFS, which showed nearly equal outcomes for both subgroups. Aside from our study, there is only one additional study that focused on the patient-reported DSM of OC flaps from the MCR for carpal reconstruction.[120] With an average score of 96 points in the IKDC, the patient-reported outcome of this study even exceeded the results of our BS flap subgroup and does not support our observation of a higher functional DSM after the harvesting of OC flaps.[120]

For all of our OC flaps, the cut-off level for clinically relevant changes in the IKDC as reported by Greco et al. was slightly exceeded.[130] Generally, the patient-reported DSM of OC flaps can be considered to be low. Compared to the negligible patient-reported DSM after the use of BS flaps, the harvesting of OC flaps from the MFC and LFC can have a specific impact on the postoperative knee function.

In addition to all functional considerations, donor site pain is a decisive factor that influences quality of life and long-term satisfaction. We evaluated the pain at the donor site with the visual analog scale (VAS). With a mean score of 0.3 points, the donor site pain levels at the time of the follow-up examination were negligible. Interestingly, the analysis of the pain levels for rest of the subgroups (BS, OC, MFC, LFC) did not show any significant difference in donor site pain at follow-up and did not support the above-mentioned trend towards a higher patient reported DSM for OC flaps. A closer look to the activity-related pain levels showed a minimal increase in all subgroups, with significantly higher activity-related donor site pain for the OC flap subgroup. The low pain levels are in accordance with the results of Struckmann et al., who reported a mean VAS score for pain at rest of 0.1 points and activity related pain of 0.6 points after the harvesting of bone flaps from the MFC for extremity reconstruction. [123] Regarding our clinical experience and the findings of these studies, the harvesting of OC flaps is especially associated with some activity-related knee pain in the early postoperative phase, which is usually self-limiting and can be easily handled with some occupational therapy. OC flaps in general tend to elicit higher pain levels at the donor sites at rest, and also during activity, although these pain levels are minimal and do not seem to be a major concern in the late outpatient phase.

In the past, several studies pointed out the risk of a saphenous nerve injury during the harvesting of free flaps from the MFC.[121,124,125] In our follow-up population, 22.7% of patients reported some impaired sensation in the distal saphenous nerve territory (infrapatellar branch) which was quantified with a mean score of 9.0 in the Ten Test. Since this score represents nearly normal sensation of the skin and does not indicate any major damage to the saphenous nerve, we believe that an iatrogenic nerve injury can be easily avoided through careful dissection during flap harvesting. Since the knee region represents a visually exposed area of the body, the quality of the donor scar is another issue that contributes to the overall DSM. Zeman-Kuhnert et al. evaluated the donor site scars of 38 patients that underwent a bone flap harvest from the MFC using the POSAS.[122] With an average POSAS-P of 6.8 and POSAS-O of 15.2, they reported scar quality that is close to the optimal result. With a mean score of 9.9 in the POSAS-P and 11.9 in the POSAS-O, we achieved comparable results (MFC and LFC region). In accordance to the finding of Zeman-Kuhnert, the harvesting of a skin island was associated with significantly worse scar quality.[122] A overall score of 1.3 points in the VAS for the aesthetic appearance of the donor site underlines the above mentioned findings. In conclusion, the aesthetic DSM can be considered to be low and does not seem to be a big issue for most of the patients. Since the scar at the LFC is clearly more exposed then the scar at the MFC, we expected a clear site-specific difference in the aesthetic donor site outcome. Interestingly, our results did not support this theory and showed comparable results in the POSAS and VAS.

Since the BS flap subgroup showed negligible DSM in the patient-reported outcome and knee scores, we did not expect a serious impact on the radiologic knee status after the harvesting of these flaps. This theory was supported by the fact that, aside from our case of a flap harvest associated fracture of the distal femur, none of the harvest sites could be detected through conventional knee x-ray. Furthermore, the majority of our BS flaps had normal knee radiographs and no signs or doubtful signs of knee OA according to the Kellgren and Lawrence grading system.

The minimal influence of a bone flap harvest from the femoral condyle region has been reported before by Rao et al. [121] In their clinical study, they investigated the impact of a MFC flap harvest with bilateral (operated and healthy side) computed tomographic scans of the distal femur and knee joints in fifteen patients. Similarly to our findings in the Kellgren and Lawrence grading system, they did not observe any flap harvest related signs of degenerative joint disease in the direct comparison of both knees.[121] In contrast to our findings, where the bone donor sites at the distal femur could not be detected through conventional x-ray, they observed a minimal reparative bone formation at the MFC donor sites in a follow-up period longer than one year.[121] This observation explains our clinical case of a distal femur fracture 68 days after the surgery. Regarding our complication and the observation of Rao et al., there seems to be a consistent risk for iatrogenic distal femur fractures after the harvesting of larger bone flaps, even in the late postoperative phase, and a predictable critical time window in which iatrogenic fractures can be prevented due to partial load mobilization programs seems not to exist. We could not detect a significant site-specific difference in the radiologic DSM of our bone flaps from the MFC and LFC.

To the best of our knowledge, no study ever objectively addressed the radiologic DSM after the harvesting of OC flaps from the medial or lateral femoral trochlea. The use of osteochondral flaps from the knee joint has not been without controversy, although any critical impact of these flaps on the postoperative knee function could not be derived from our objective and patient-reported follow-up results, and this has not been reported by others.[120] To reduce any bias, only patients without a relevant knee pathology or surgery in the past as well as any injury on the donor leg that could negatively affect the knee function were included in our MRI follow-up examination. Since we were not able to collect preoperative MRI scans of the donor knee, we made bilateral MRI scans of the knees, and directly compared the findings of the donor knee with the healthy contralateral side. All findings of the MRI scans were transferred to the MRI Osteoarthritis Knee Score, which has been proven reliable for the objective detection of the majority of structural changes that are associated with knee OA and all relevant structural changes one would expect from the harvesting of OC flaps.[131]

As expected, CL at the donor region were evident in nearly all OC flap patients. CL furthermore showed a significantly higher occurrence rate at the donor knee compared to the healthy contralateral knee. Besides the obvious flap-related accumulation of CL at the donor knee, all other relevant features (BML, O, ES) that would indicate a more severe radiologic impact of OC flaps on the radiologic DSM did not show any significant accumulation at the donor knees. Aside from the direct comparison of the bilateral MRI scans of each patient, we also analyzed the impact of the donor region (MFC vs. LFC) on the radiologic outcome in the MRI Osteoarthritis Knee Score. Our results did not show any signs of an increased DSM for OC flaps from the LFC compared to MFC OC flaps. Regarding the above-mentioned findings of the MRI follow-up examination, the obvious cartilage defects at the femoral trochlea donor sites are not associated with further knee pathologies that would indicate any severe impact of these flaps on knee function. Furthermore the defects verified by MRI do not seem to have any serious impact on the long-term knee function.

Regarding the reliability of the anatomy that allows for fast and safe flap harvesting, the reconstructive potential that enables various flap configurations and shapes as well as the low DSM, the medial and lateral femoral condyle region remains an unrivaled donor source for medium to small-sized bone flaps. Since local bone flaps are associated with some major limitations regarding local restriction and range as well as the limited size, these flaps can be used in selected cases in carpal reconstruction but cannot be seen as a serious alternative in common clinical practice. In the case of corticocancellous bone flaps, the deep circumflex iliac crest artery (DCIA) bone flap can be mentioned as an alternate source for medium sized vascularized bone grafts. Since the surgical accessibility of the iliac crest can be challenging and the harvesting of DCIA bone flaps is clearly more invasive compared to MFC and LFC flaps, an increased risk for postoperative complications has been reported and the harvesting of these flap can be associated with reduced hip function in the postoperative phase.[132,133]

A recent study of Rendenbach et al. analyzed the long-term DSM of DCIA bone flaps for mandible reconstruction.[134] With an average follow-up time of 29 months, they confirmed the above-mentioned findings and reported a significant reduction in postoperative hip function regarding the range of motion and Harris Hip Score. Furthermore, they observed persistent sensory deficits in the late postoperative phase in 35.7% of patients and load dependent pain as well as limitations to daily activities in 21.4% of patients.[134] Although the baseline characteristics of the above cited studies that investigated the DSM for the DCIA flap clearly differed from ours regarding the DSM, there seems to be a clear advantage of the femoral condyle region as a source of small bone flaps compared to the existing alternatives. Additionally, the femoral condyle region remains the only area that offers the unique possibility for harvesting osteochondral grafts for microsurgical cartilage repair.

Nonetheless, when interpreting the findings of this study, there are some major limitations that need to be addressed. Since MFC flaps were introduced to reconstructive microsurgery years before the LFC flap, and flap indications varied among the subgroups, no homogeneity regarding follow-up time and sample size could be achieved. Furthermore, the findings of our follow-up examination were interpreted without any preoperative baseline data.

5. Conclusion

Regarding the objective, patient-reported and radiologic findings of this study, the DSM for BS flaps from the MFC or LFC seems to be negligible, regardless of the indication or composition of these flaps. The occurrence of a flap-associated supracondylar femur fracture as the major complication of these flaps can be avoided by strictly restricting the donor site to the femoral condyle region. The overall DSM of OC flaps can be considered to be low. Compared to BS flaps, the harvesting of these flaps is associated with significantly higher objective, patient-reported and radiologic DSM, although the majority of our OC-flap patients did not exceed the cut-off level of a clinically relevant impact on knee function in objective and patient-reported knee scores.

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7. Appendix

7.1. Follow-up evaluation form

1. Patientendaten

- ID:
- Geschlecht: männlich: ☐ weiblich: ☐
- Alter (zum follow-up): ________________ Jahre
- Größe (cm): ________________
- Gewicht (kg): ________________
- Body mass index (BMI): ________________

2. Anamnese

- Relevante Grunderkrankungen?:

  ☐ nein

  ☐ ja wenn ja, welche?: ____

- Relevante Risikofaktoren?:

  ☐ nein ☐ ja

  ☐ Diabetes

  ☐ PAVK

  ☐ Osteoporose

  ☐ Nikotin pack years: __________________

  ☐ andere: ____

- Probleme am Spenderknie vor der OP?

  ☐ nein

  ☐ ja wenn ja, welche?: ____

- Voroperationen am betroffenen Knie?

  ☐ nein

  ☐ ja wenn ja welche und wieviele?: ____

- Weitere relevante Probleme an der betroffenen Extremität (Bein)?

  ☐ nein

  ☐ ja wenn ja, welche: ____

- Voroperationen an der betroffenen Extremität (Bein)?

  ☐ nein

  ☐ ja wenn ja welche und wieviele?: ____

- Wurde nach der OP (Lappenplastik) eine ambulante Physiotherapie für das betroffene Knie durchgeführt?

  ☐ nein ☐ ja wenn ja, wie lange? (Wochen): _________________________________

- Stattgehabtes Trauma nach der OP am betroffenen Knie?

  ☐ nein

- ☐ ja wenn ja welches?: ____

- Beruf zum Zeitpunkt der OP: ____
- Berufswechsel aufgrund des Hebedefektes? ☐ nein ☐ ja
- Regelmäßige sportliche Betätigung? ☐ nein ☐ja

  Wenn ja welche? : ____

  Wenn nein aufgrund des Hebedefektes? ☐ nein ☐ ja

3. Follow-up – Objektives Outcome

- **Äußeres Erscheinungsbild Knie:**

  ☐ normal

  ☐ gestört in welcher Art?: ____

- **Druckdolenz Knie** OAK Score

  ☐ keine (5)

  ☐ gering (3)

  ☐ mäßig (1)

  ☐ stark (0)

- **Schmerzen** Knee Society Score (KSS)

  ☐ kein Schmerz (50)

  ☐ leicht oder gelegentlich (45)

  ☐ nur beim Treppensteigen (40)

  ☐ beim Gehen und Treppensteigen (30)

  ☐ mäßiger Schmerz gelegentlich (20)

  ☐ mäßiger Schmerz ständig (10)

  ☐ starker Schmerz (0)

- **Schmerzen** Larson Knee Score (LKS)

  ☐ Kein Schmerz (30)

  ☐ Leichter Schmerz (ohne Einschränkung bei Aktivität) (25)

  ☐ Milder Schmerz (20)

  ☐ Moderater Schmerz (15)

  ☐ Starker Schmerz (5)

  ☐ Bewegungsverhindernder Schmerz (0)

- **Beweglichkeit**
  - ROM (aktiv!) betroffenes Knie in Grad KSS, OAK : _____ / _____ / _____ (Ext/Flex)
  - ROM (passiv!) betroffenes Knie in Grad: _____ / _____ / _____ (Ext/Flex)
  - ROM (aktiv) gesunde Gegenseite in Grad : _____ / _____ / _____ (Ext/Flex)

  5° = 1 Punkt! Max. 25 Punkte für 125°

  0-5° ☐ 6-10° ☐ 11-15° ☐ 16-20° ☐ 21-25° ☐ 26-30° ☐ 31-35° ☐ 36-40 ☐ 41-45☐

  46-50 ☐ 51-55 ☐ 56-60 ☐ 61-65 ☐ 66-70 ☐ 71-75 ☐ 76-80 ☐ 81-85 ☐ 86-90 ☐

  91-95 ☐ 96-100° ☐ 101-105° ☐ 106-110° ☐ 111-115°☐ 116-120° ☐ 121-125° ☐

  - Punktezahl (ROM aktiv, betroffenes Knie): ___________ Punkte

- **Stabilität** [KSS, OAK]
  - Anterior-posterior: ☐ <5mm (10)
    - ☐ 5-10mm° (5)
    - ☐ >10mm° (0)
  - Medio-lateral: ☐ <5° (15)
    - ☐ 6-9° (10)
    - ☐ 10-14° (5)
    - ☐ >15° (0)
- **Anatomie**[LKS]
  - Genu valgum oder varum[LKS] ☐ 0-15° (2)
    - ☐ 15-30° (1)
    - ☐ > 30° (0)
  - Patella[LKS] ☐ Keine Veränderung (1)
    - ☐ Laterale Position (0)
    - ☐ Patella alta (0)
    - ☐ Gesteigerte Beweglichkeit (0)
  - Genu recurvatum?[LKS] ☐ Nein (1)
    - ☐ > 5° (0)
  - Oberschenkelatrophie?[LKS] (Messpunkt 15cm Proximal des Knies)
    - Differenz in cm zur Gegenseite: ________________cm
    - ☐ Keine Differenz (keine) (2)
    - ☐ <1cm Differenz (1,5)
    - ☐ 1-3cm Differenz (1)
    - ☐ >3cm (0)
  - Schwellung?[LKS] ☐ Keine (3)
    - ☐ Leicht oder gelegentlich (1)
    - ☐ Moderat oder häufig (0,5)
    - ☐ Deutlich oder immer (0)
- **Abzüge (Minuspunkte!)** [KSS]
  - Flexionskontraktur passiv? [KSS+LKS] ☐ nein (0) ☐ ja, wenn ja: ☐ 5-10° (-2)
    - ☐ 10-15° (-5)
    - ☐ 16-20° (-10)
    - ☐ >20° (-15)
  - Streckdefizit aktiv? [KSS] ☐ nein (0)
    - ☐ ja, wenn ja wieviel Grad?: ______________
    - ☐ <10° (-5)
    - ☐ 10-20° (-10)
    - ☐ >20° (-15)

- Anatomischer Tibiofemoralwinkel KSS (Valgus femorotibial, Achsenabweichung)
  - ☐ 0-4° Valgus (3 Punkte/ Grad, max. -15)
  - ☐ 5-10° Valgus (0) = Normalwert
  - ☐ 11-15° Valgus(3 Punkte/ Grad, max. -15)
  - ☐ >15° Valgus (-20)

- **Funktion KSS +LKS**
  - Gangbild LKS
    - ☐ Uneingeschränkt (5)
    - ☐ Leichte Einschränkung (3)
    - ☐ Moderate Einschränkung (1)
    - ☐ Deutliche Einschränkung (0)
  - Gehhilfe LKS
    - ☐ Keine (5)
    - ☐ Gehstock (3)
    - ☐ Krücken (1)
    - ☐ Knie trägt kein Gewicht (0)
  - Gehstrecke KSS
    - ☐ Unbegrenzt (50)
    - ☐ Über 1000m (40)
    - ☐ 500-1000m (30)
    - ☐ Weniger als 500m (20)
    - ☐ Hausgebunden (10)
    - ☐ Gehunfähig (0)
  - Gehstrecke LKS
    - ☐ Unbegrenzt (20)
    - ☐ Leicht eingeschränkt (15)
    - ☐ Moderat eingeschränkt (10)
    - ☐ Stark eingeschränkt (5)
    - ☐ Gehunfähig (0)
  - Treppensteigen KSS
    - ☐ Normal rauf und runter (50)
    - ☐ Normal rauf, runter mit Geländer (40)
    - ☐ Rauf und runter mit Geländer (30)
    - ☐ Rauf mit Geländer, runter nicht möglich (15)
    - ☐ Nicht möglich (0)
  - Treppen oder Steigung raufgehen LKS
    - ☐ Uneingeschränkt (5)
    - ☐ Leichte Einschränkung (3)
    - ☐ Eine Stufe nach der anderen/ instabil (1)
    - ☐ Unfähig (0)
  - Hüpfen LKS
    - ☐ Ohne Schwierigkeiten (2)
    - ☐ Unfähig (2)
  - Kniebeugen LKS
    - ☐ Ohne Schwierigkeiten (5)

- ☐ Leichte Einschränkung (4)
- ☐ Moderate Einschränkung, nicht über 90° möglich (3)
- ☐ Unfähig (0)

- Laufen [LKS]
  - ☐ Ohne Schwierigkeiten (5)
  - ☐ Leichte Einschränkung (4)
  - ☐ Nur geradeaus (3)
  - ☐ Unmöglich (0)
- Abzüge [KSS]
  - ☐ Benützung eines Gehstockes (-5)
  - ☐ Benützung von zwei Gehstöcken (-10)
  - ☐ Benützung von Krücken oder Rollator (-20)

- **Funktionstests** [OAK Score]
  - Einbeinsprung

    ☐ frei ☐ mit Mühe ☐ nicht möglich
  - Ganz Kauern/Entengang

    ☐ frei ☐ mit Mühe ☐ nicht möglich
  - Einbein-Kniebeugeübung

    ☐ frei ☐ mit Mühe ☐ nicht möglich

- **Bandapparat (betroffenes Knie)** [OAK Score]
  - Medial aufklappbar (in 30° Flexion, mediales Seitenband)

    ☐ negativ. ☐ 1+ ☐ 2+ ☐ 3+
  - Lateral aufklappbar (in 30° Flexion, laterales Seitenband)

    ☐ negativ. ☐ 1+ ☐ 2+ ☐ 3+
  - Lachmann Test (in 15-30° Flexion)

    ☐ negativ. ☐ 1+ ☐ 2+ ☐ 3+

    Vorderer Endpunkt: ☐ fest ☐ weich
  - Vordere Schublade (AP-Translation in 90° Flexion)

    ☐ negativ. ☐ 1+ ☐ 2+ ☐ 3+
  - Hintere Schublade (AP-Translation in 90° Flexion)

    ☐ negativ. ☐ 1+ ☐ 2+ ☐ 3+
  - Pivot-Shift-Test

    ☐ negativ. ☐ fraglich ☐ positiv
  - Reversed Pivot-Shift-Test

    ☐negativ. ☐positiv
- **Meniskus (betroffenes Knie)**
  - Steinmann I

    ☐ negativ ☐ +Innenmeniskus ☐ +Außenmeniskus
  - Mc Murray

    ☐ negativ ☐ +Innenmeniskus ☐ +Außenmeniskus

- **Beurteilung der Narbe**
  Patient and Observer Scar Assessement Scale (Untersucherteil! Vom Untersucher auszufüllen!)

  - Durchblutung (Blass > Pink > Rot > Lila > Gemischt)
    Normale Haut 1 2 3 4 5 6 7 8 9 10 schlimmstmögliche Narbe
  - Pigmentierung (Hypo > Hyper > Gemischt)
    Normale Haut 1 2 3 4 5 6 7 8 9 10 schlimmstmögliche Narbe
  - Dicke (Dünn > Dick)
    Normale Haut 1 2 3 4 5 6 7 8 9 10 schlimmstmögliche Narbe
  - Oberflächenrelief (Mehr > Weniger > Gemischt)
    Normale Haut 1 2 3 4 5 6 7 8 9 10 schlimmstmögliche Narbe
  - Geschmeidigkeit (Geschmeidig > Steif > Gemischt)
    Normale Haut 1 2 3 4 5 6 7 8 9 10 schlimmstmögliche Narbe
  - Oberfläche (Geschmeidig > Steif > Gemischt)
    Normale Haut 1 2 3 4 5 6 7 8 9 10 schlimmstmögliche Narbe
  - Gesamteindruck
    Normale Haut 1 2 3 4 5 6 7 8 9 10 schlimmstmögliche Narbe
  - Gesamtpunktezahl (6-60 Punkte): ________ Punkte

- **Sensibilität im Bereich der Narbe** (Ten-Test Gefühl im Vergleich zur gesunden Gegenseite!)
  - Sensibilität im Narbenbereich
    Ungestört 1 2 3 4 5 6 7 8 9 10 größtmögliche Hyposensibilität
  - Medialer Femurkondy als Entnahmeregion? – wenn Ja, Sensibilität subpattelar?
    Ungestört 1 2 3 4 5 6 7 8 9 10 größtmögliche Hyposensibilität

4. **Follow-up – Subjektives Outcome** (Patiententeil, vom Patienten erfragbar!)
   - **Visuelle Analogskala (0-10)**
     - Schmerz am Hebedefekt zum follow-up (= zum Zeitpunkt der Untersuchung)
       kein Schmerz 0 1 2 3 4 5 6 7 8 9 10 größter Schmerz
     - Schmerz am Hebedefekt in Bewegung
       kein Schmerz 0 1 2 3 4 5 6 7 8 9 10 größter Schmerz
     - Funktionelle Hebedefektmorbidität:
       keine Morbidität 0 1 2 3 4 5 6 7 8 9 10 größte Morbidität

- Ästhetische Hebedefektmorbidität:
  bestes Ergebnis 0 1 2 3 4 5 6 7 8 9 10 schlechtestes Erg.

- Generelle Zufriedenheit mit der Hebedefektmorbidität:
  größte Zufr. 0 1 2 3 4 5 6 7 8 9 10 geringste Zufr.

- Nochmal?: ja: ☐ nein: ☐ wenn nein warum?:
  ____

- **Kniefunktion**
  - Dauer postoperativer Schmerz am betroffenen Knie (Tage) ___________Tage

  - Anzahl der Tage bis Kniefunktion im Alltagsleben wieder uneingeschränkt war?:
    ____________ Tage

  - International Knee Documentation Committee (IKDC) Subjective Knee Form Gesamtpunktezahl: ___________ (0-100 Punkte)

  - The Knee Injury and Osteoarthritis Outcome Score (KOOS) Gesamtpunktezahl: __________ (0-100 %)

- **Narbe**
  - POSAS Score (Patiententeil, vom Patienten erfragbar!)
    - War die Narbe in den letzten Wochen schmerzhaft?

    Nein, nicht im geringsten 1 2 3 4 5 6 7 8 9 10 Ja, sehr stark

    - Hat die Narbe in den letzten Wochen gejuckt?

    Nein, nicht im geringsten 1 2 3 4 5 6 7 8 9 10 Ja, sehr stark

    - Farbe der Narbe im Moment anders als normale Haut?

    Nein, wie normale Haut 1 2 3 4 5 6 7 8 9 10 Ja, großer Unterschied

    - Steifheit der Narbe im Moment anders als normale Haut?

    Nein, wie normale Haut 1 2 3 4 5 6 7 8 9 10 Ja, großer Unterschied

    - Höhe der Narbe im Moment anders als normale Haut?

    Nein, wie normale Haut 1 2 3 4 5 6 7 8 9 10 Ja, großer Unterschied

    - Narbe im Moment irregulärer als normale Haut?

    Nein, wie normale Haut 1 2 3 4 5 6 7 8 9 10 Ja, großer Unterschied

    - Gesamteindruck Narbe im Vergleich zur gesunden Haut?

    wie normale Haut 1 2 3 4 5 6 7 8 9 10 großer Unterschied

- Gesamtpunktezahl (6-60 Punkte): ________ Punkte

- Gesamtpunktezahl POSAS Untersucherteil (Seite 8) + Patiententeil (oben) (12-120 Punkte): ________ Punkte

7.2. IKDC Score

Symptome

Was ist die höchste Aktivitätsstufe, die Sie ohne erhebliche Schmerzen im Knie ausüben können?

1. Sehr anstrengende Aktivitäten wie Springen oder Drehbewegungen bei einseitiger Fußbelastung (Basketball oder Fußball)
2. Anstrengende Aktivitäten wie schwere körperliche Arbeit, Skilaufen oder Tennis
3. Mäßig anstrengende Aktivitäten wie mäßige körperliche Arbeit, Laufen oder Joggen
4. Leichte Aktivitäten wie Gehen, Haus- oder Gartenarbeit
5. Ich kann aufgrund meiner Schmerzen im Knie keine der oben genannten Aktivitäten ausführen.

Wie oft hatten Sie in den vergangenen 4 Wochen oder seit dem Auftreten Ihrer Verletzung Schmerzen?

0 1 2 3 4 5 6 7 8 9 10
Nie ständig Schmerzen

Wie stark sind Ihre Schmerzen?

0 1 2 3 4 5 6 7 8 9 10
Keine Schmerzen unerträgliche Schmerzen

Wie steif oder geschwollen war Ihr Knie während der vergangenen 4 Wochen oder seit dem Auftreten Ihrer Verletzung?

1. ☐ überhaupt nicht
2. ☐ etwas
3. ☐ ziemlich
4. ☐ sehr
5. ☐ extrem

Was ist das höchste Aktivitätsstufe, die Sie ohne erhebliches Anschwellen des Knies ausüben können?

1. Sehr anstrengende Aktivitäten wie Springen oder Drehbewegungen bei einseitiger Fußbelastung (Basketball oder Fußball)
2. Anstrengende Aktivitäten wie schwere körperliche Arbeit, Skilaufen oder Tennis
3. Mäßig anstrengende Aktivitäten wie mäßige körperliche Arbeit, Laufen oder Joggen
4. Leichte Aktivitäten wie Gehen, Haus- oder Gartenarbeit
5. Ich kann aufgrund meiner Schmerzen im Knie keine der oben genannten Aktivitäten ausführen.

Hatten Sie in den vergangenen 4 Wochen oder seit dem Auftreten Ihrer Verletzung ein gesperrtes Knie oder ist Ihr Knie aus- und wieder eingeschnappt?

1. Ja
2. Nein

Was ist die höchste Aktivitätsstufe, die Sie ohne erhebliche durch Knieschwäche verursachte Gangunsicherheit einhalten können?

1. Sehr anstrengende Aktivitäten wie Springen oder Drehbewegungen bei einseitiger Fußbelastung (Basketball oder Fußball)
2. Anstrengende Aktivitäten wie schwere körperliche Arbeit, Skilaufen oder Tennis
3. Mäßig anstrengende Aktivitäten wie mäßige körperliche Arbeit, Laufen oder Joggen
4. Leichte Aktivitäten wie Gehen, Haus- oder Gartenarbeit
5. Ich kann aufgrund meiner Schmerzen im Knie keine der oben genannten Aktivitäten ausführen.

Sportliche Betätigung

Was ist die höchste Aktivitätsstufe, an der Sie regelmäßig teilnehmen können?

1. Sehr anstrengende Aktivitäten wie Springen oder Drehbewegungen bei einseitiger Fußbelastung (Basketball oder Fußball)
2. Anstrengende Aktivitäten wie schwere körperliche Arbeit, Skilaufen oder Tennis
3. Mäßig anstrengende Aktivitäten wie mäßige körperliche Arbeit, Laufen oder Joggen
4. Leichte Aktivitäten wie Gehen, Haus- oder Gartenarbeit
5. Ich kann aufgrund meiner Schmerzen im Knie keine der oben genannten Aktivitäten ausführen.

Wie schwierig sind aufgrund Ihres Knies die folgenden Aktivitäten für Sie?

		Überhaupt nicht schwierig	Minimal schwierig	Ziemlich schwierig	Extrem schwierig	unmöglich
1.	Treppensteigen	☐	☐	☐	☐	☐
2.	Treppe hinuntergehen	☐	☐	☐	☐	☐
3.	Auf dem vorderen Knie knien	☐	☐	☐	☐	☐
4.	Normal sitzen	☐	☐	☐	☐	☐
5.	Vom Stuhl aufstehen	☐	☐	☐	☐	☐
6.	Geradeaus laufen	☐	☐	☐	☐	☐
7.	Hochspringen und auf dem betroffenen Bein landen	☐	☐	☐	☐	☐
8.	Beim Gehen (bzw. Laufen wenn Sie Sportler(in sind) schnell anhalten und starten	☐	☐	☐	☐	☐

Funktion

Funktionsfähigkeit des Knies vor der Operation

0 1 2 3 4 5 6 7 8 9 10

Kann keine täglichen Aktivitäten ausführen — Keine Einschränkung der täglichen Aktivitäten

Derzeitige Funktionsfähigkeit des Knies

0 1 2 3 4 5 6 7 8 9 10

Kann keine täglichen Aktivitäten ausführen — Keine Einschränkung der täglichen Aktivitäten

7.3. KOOS

Beschwerden

S1. War Ihr Knie geschwollen?

niemals ☐ selten ☐ manchmal ☐ oft ☐ immer ☐

S2. Haben Sie ein Knirschen verspürt, ein Klicken oder irgendein anderes Geräusch gehört, wenn Sie Ihr Knie bewegten?

Niemals ☐ selten ☐ manchmal ☐ oft ☐ immer ☐

S3. Ist Ihr Knie hängen geblieben, oder hat es blockiert, wenn Sie es bewegten?

Niemals ☐ selten ☐ manchmal ☐ oft ☐ immer ☐

S4. Konnten Sie Ihr Knie ganz strecken?

immer ☐ oft ☐ manchmal ☐ selten ☐ niemals ☐

S5. Konnten Sie Ihr Knie ganz beugen?

immer ☐ oft ☐ manchmal ☐ selten ☐ niemals ☐

Steifigkeit

S6. Wie stark war Ihre Kniesteifigkeit morgens direkt nach dem Aufstehen?

keine ☐ schwach ☐ mäßig ☐ stark ☐ sehr stark ☐

S7. Wie stark war Ihre Kniesteifigkeit später am Tag, nachdem Sie saßen, lagen, oder sich ausruhten?

keine ☐ schwach ☐ mäßig ☐ stark ☐ sehr stark ☐

Schmerzen

P1. Wie oft tut Ihnen Ihr Knie weh?

niemals ☐ mindestens einmal im Monat ☐ mindestens einmal in der Woche ☐
mindestens einmal am Tag ☐ immer ☐

Wie stark waren die Schmerzen in Ihrem Knie in der letzten Woche bei den folgenden Tätigkeiten?

P2. Drehbewegung des Beins mit dem Knie

keine ☐ schwach ☐ mäßig ☐ stark ☐ sehr stark ☐

P3. Ihr Knie ganz strecken

keine ☐ schwach ☐ mäßig ☐ stark ☐ sehr stark ☐

P4. Ihr Knie ganz beugen

keine ☐ schwach ☐ mäßig ☐ stark ☐ sehr stark ☐

P5. Auf ebenem Boden gehen

keine ☐ schwach ☐ mäßig ☐ stark ☐ sehr stark ☐

P6. Treppen hinauf- oder hinuntergehen

keine ☐ schwach ☐ mäßig ☐ stark ☐ sehr stark ☐

P7. Nachts im Bett

keine ☐ schwach ☐ mäßig ☐ stark ☐ sehr stark ☐

P8. Sitzen oder Liegen?

keine ☐ schwach ☐ mäßig ☐ stark ☐ sehr stark ☐

P9. Aufrecht stehen?

keine ☐ schwach ☐ mäßig ☐ stark ☐ sehr stark ☐

Körperliche Funktionsfähigkeit, Aktivitäten des täglichen Lebens

A1. Treppen hinuntersteigen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A2. Treppen hinaufsteigen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A3. Vom Sitzen aufstehen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A4. Aufrecht stehen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A5. Sich zu Boden bücken, etwas vom Boden aufheben

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A6. Auf ebenem Boden gehen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A7. Ins Auto einsteigen oder aus dem Auto aussteigen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A8. Einkaufen gehen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A9. Socken/Strümpfe anziehen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A10. Vom Bett aufstehen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A11. Socken/Strümpfe ausziehen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A12. Im Bett liegen (beim Umdrehen, oder wenn das Kniegelenk längere Zeit unverändert in einer Stellung ist)

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A13. In die Badewanne oder aus der Badewanne steigen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A14. Sitzen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A15. Sich auf die Toilette setzen oder aufstehen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A16. Schwere Hausarbeit verrichten (schwere Kisten bewegen, schwere Einkäufe tragen usw.)

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

A17. Leichte Hausarbeit verrichten (kochen, Staub wischen usw.)

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

Körperliche Funktionsfähigkeit, Sport und Freizeitaktivitäten

SP1. Hocken

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

SP2. Laufen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

SP3. Springen

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

SP4. Drehbewegung des Beins mit dem kranken Knie

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

SP5. Knien

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

Lebensqualität

Q1. Wie oft denken Sie an Ihr Knieproblem?

niemals ☐ mindestens einmal im Monat ☐ mindestens einmal in der Woche ☐
mindestens einmal am Tag ☐ immer ☐

Q2. Haben Sie Ihre Lebensweise verändert, um Tätigkeiten zu vermeiden, die Ihrem Knie schaden könnten?

gar nicht ☐ wenig ☐ etwas ☐ stark ☐ vollständig ☐

Q3. Wie sehr macht es Ihnen zu schaffen, dass Sie sich auf Ihr Knie nicht verlassen können?

gar nicht ☐ wenig ☐ mäßig ☐ ziemlich ☐ sehr ☐

Q4. Wie viele Schwierigkeiten haben Sie durch das Knie insgesamt?

keine ☐ wenig ☐ einige ☐ große ☐ sehr große ☐

7.4. Knee Society Function Score

Gehfähigkeit

☐ Ich kann unbegrenzt gehen. 50
☐ Ich kann mehr als 1 km gehen. 40
☐ Ich kann 500 m bis 1000 m gehen. 30
☐ Ich kann weniger als 500 m gehen. 20
☐ Ich bin an das Haus gebunden. 10
☐ Ich kann nicht gehen 0

Treppensteigen

☐ Ich kann normal treppauf und treppab gehen. 50
☐ Ich kann normal treppauf gehen, treppab nur mit Geländer. 40
☐ Ich gehe treppauf und treppab mit Geländer. 30
☐ Ich gehe treppauf mit Geländer, treppab ist nicht möglich. 15
☐ Ich kann keine Treppen gehen. 0

Abzüge bei

☐ 1 Gehstock/-stütze - 5
☐ 2 Gehstöcke/-stützen - 10
☐ Gehbank/Rollator, Achselstützen etc. - 20