



## Myodesis or myoplasty in *trans*-femoral amputations. What is the best option? An explorative study



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### Background

In the Netherlands, approximately 3300 amputations of the lower extremity (LLA), of which almost 20% is a *trans*-femoral amputation (TFA), are performed annually, amputations of the toes excluded [1]. Almost 95% of these amputations are performed in patients with vascular problems, often in combination with diabetes mellitus [1,2]. The remaining percentage includes amputations performed following an accident or trauma, an infection, a tumor, or a congenital disorder [3]. Most patients who undergo an LLA are 65 years or older [1,2].

During a TFA, two different techniques can be used to secure the muscles in the residual limb. These are myodesis, also known as myopexy, and myoplasty [3,4]. In the Netherlands, myodesis is mostly used by orthopedic surgeons [3,6] and myoplasty by vascular surgeons [2]. In myodesis, the dissected muscle groups are attached directly to the bone [3,6,8]. After the femoral bone is cut, the surgeon drills holes in the distal end of the femur and secures the muscle fascia in these holes [3]. In myoplasty, the surgeon brings the posterior muscles over the end of the femur and stitches them to the anterior muscle groups so as to enclose the end of the bone [8–11]. The residual limb is supposed to be more stable after a myodesis than after a myoplasty [3,7]. There is however no causal relationship described in literature between a more stable residual limb and a more constant volume with fewer fluctuation.

There is a paucity of data on the outcomes of the two surgical techniques [9]. Data are lacking on, for instance, healing of the wound site, efficient use of a prosthesis, pain, muscle control, and complications after a specific technique. Such data could play a decisive role when it comes to choosing one of the techniques. Also, there is no information on the amount of intermuscular fat in the residual limb. Intermuscular fat plays an important role in the functional outcomes of TFA patients, for less intermuscular fat leads to better motor control and protection of the residual limb end.

It is therefore necessary to explore which technique, myodesis or

myoplasty, is most beneficial for TFA patients in terms of functional outcomes, residual limb healing and decrease of complication risk.

### Hypothesis

Deciding for a *trans*-femoral amputation is a difficult decision with a great impact for the patient. Careful consideration should be made in the choice between myodesis and myoplasty in the decision process.

### Methods

This study employed a mixed-method design combining quantitative (scoping literature search) and qualitative (interviews) data. In addition, 3D models created from Magnetic Resonance Imaging (MRI) of the residual limb were analyzed (a pilot study).

### Literature search

A literature search of the electronic databases PubMed, EMBASE, PsycINFO, and PEDro was performed in May 2018. No limits were set on the publication date. The search was limited to the English, German, or Dutch language. No Medical Subject Headings (MeSH) were used (Appendix 1).

Fig. 1 shows a flowchart of the included articles. Articles were excluded if they did not specifically focus on TFA, if they were animal studies, or if the surgical technique was not mentioned in the abstract.

### Qualitative research

One of the researchers (SvdS) interviewed six experts using a semi-structured method (Appendix 2). The experts were experienced surgeons (n = 4) working at the University Medical Center Groningen (UMCG), the Netherlands and experienced prosthetists (n = 2)

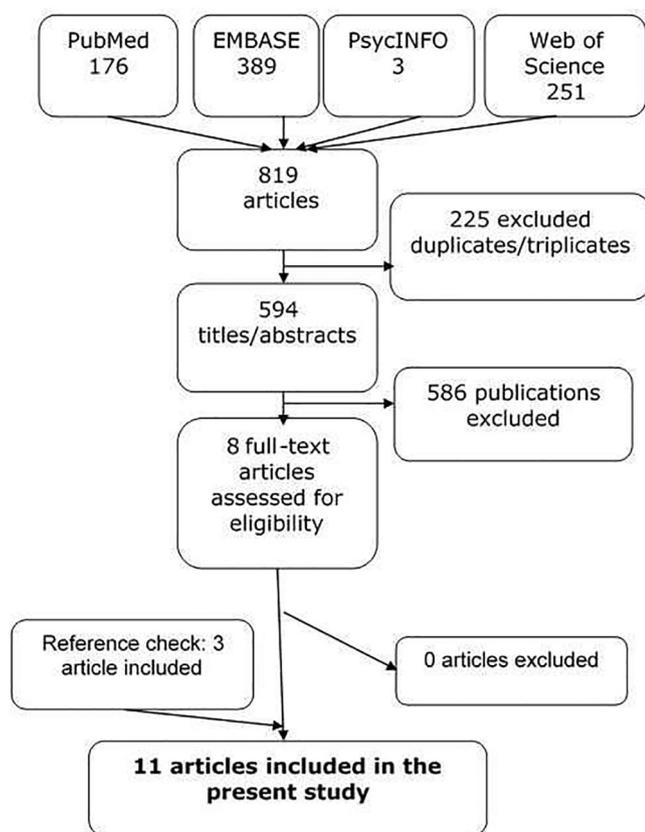
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**Fig. 1.** Flowchart of the included articles. The literature search was performed in four different databases. After excluding duplicates, 594 articles were left for title and abstract analysis. A further 586 articles were excluded because they did not specifically focus on TFA, they were animal studies, or the surgical technique was not mentioned in the abstract. Eight articles were left for full-text analysis. Three articles were added after checking the reference lists. In total, eleven articles were included in this study.

**Table 1**  
Characteristics of the experts.

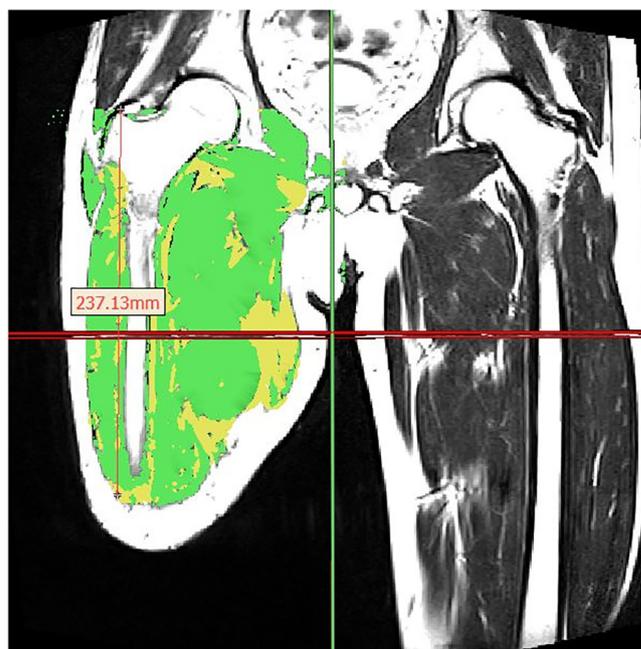
Expert	Gender	Age (year)	Profession	Expertise (year)
Expert 1 (E1)	Male	64	Vascular surgeon	31
Expert 2 (E2)	Male	42	Vascular surgeon	14
Expert 3 (E3)	Male	49	Orthopedic surgeon	13
Expert 4 (E4)	Male	45	Trauma surgeon	17
Expert 5 (E5)	Male	58	Certified prosthetist	35
Expert 6 (E6)	Male	51	Certified prosthetist	28

(Table 1). The aim of the interviews was to explore which technique, myodesis or myoplasty, is preferred by the surgeons and why, and which technique is most beneficial for the use and control of a prosthesis.

All interviews were recorded with a smart voice recorder, with the verbal consent of all included experts. The individual interviews were transcribed verbatim and analyzed (SvdS) using Atlas.ti, version 6.2 (Scientific Software Development GmbH).

### 3D model

Jaegers et al. reported on a method for quantification of the degree of atrophy in dissected muscles [5]. The contours of the bones and muscles were traced in 3D models, which were created from MRI data. Atrophy was determined by comparing the muscle volumes of the amputated side with the intact side. They found no significant



**Fig. 2a.** MRI of a myodesis (coronal slice). The patient underwent the amputation in 2012; the MRI was performed in 2016. The length of the femur is measured and marked with the vertical red line and the calculation of muscle (green) and intermuscular fat (yellow) volumes. The MRI data were taken in transverse relaxation time (T2) and the slice thickness was 5 mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

differences in degree of atrophy after myodesis or myoplasty.

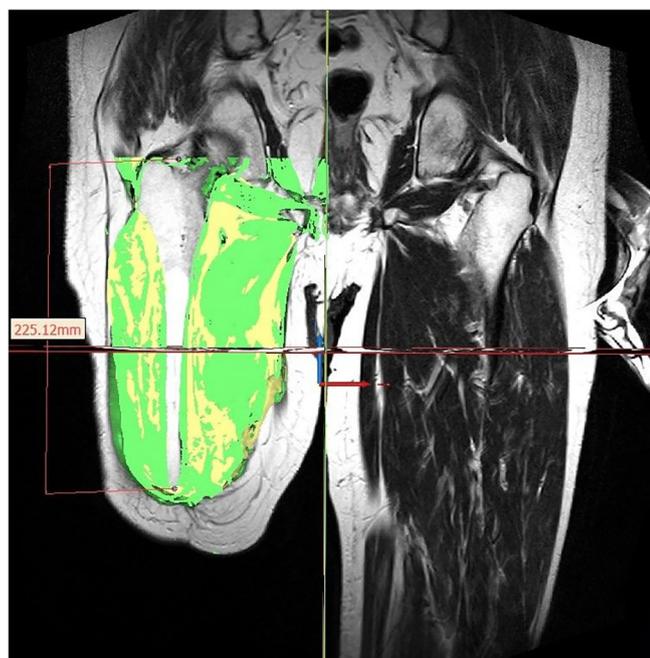
In the current study, a similar method was developed for the quantification of intermuscular fat in the residual limb of TFA patients. The 3D models were created from available MRI data on two cases involving myodesis and two cases involving myoplasty, so as to gain insight into the results of both techniques. The obtained images were used with permission of the patients involved. The 3D models include both muscle and intermuscular fat volumes, based on thresholding and manual adaption of the images in dedicated 3D software (Mimics Medical 18, Materialize, Leuven, Belgium).

On each MRI dataset, a region of interest (ROI) was selected using chosen landmarks: the trochanter major as the mid-coronal starting point and the trochanter major as the upper ROI border. The lower ROI border was the distal end of the residual limb. In anterior-posterior direction, a 5 mm margin was included in both directions from the mid-coronal starting point. The selected ROIs were representative and reproducible on each MRI. Fig. 2a shows the selected ROI in a myodesis case, and Fig. 2b shows the selected ROI in a myoplasty case [12,13].

Next, the muscle and intermuscular fat volumes were segmented within the selected ROIs. All selections were checked and approved by an experienced radiologist. The volume percentages of the muscle and intermuscular fat tissue were calculated, and the length of the residual femur was measured.

In addition to the 3D volume assessment, the Goutallier classification was applied to the MRI data in order to indicate the presence of intermuscular fat relative to muscle tissue [14]. The scale is ranked from zero to four. Grade zero means no fatty deposits until grade four means less muscle than fat [14]. The five-point scale was used, based on the expertise of the radiologist, to indicate the degree of intermuscular fat.

The 4 3D models were compared to see whether there was a difference in intermuscular fat and muscle volume percentages between the amputation techniques. The radiologist assessed the degree of intermuscular fat for each model on three levels: Proximal at the point of



**Fig. 2b.** MRI of a myoplasty (coronal slice). The patient underwent the amputation in 2005; the MRI was performed in 2009. The length of the femur is measured and marked with the vertical red line and the calculation of muscle (green) and intermuscular fat (yellow) volumes. The MRI data were taken in transvers relaxation time (T2) and the slice thickness was 5 mm.

the trochanter major, through the midsection of the femur, and at the distal end of the femur.

**Results**

*Literature search*

The literature search yielded 819 articles. Two researchers (SvdS and JG) independently reviewed the titles and abstracts of the articles (Cohen’s kappa = 0.92). Eight articles were selected for full text analysis. No articles were excluded after full text analysis (Cohen’s kappa = 1.0). Next, the reference lists of the included articles [3,7,9,11,15–18] were checked for other relevant articles. Consequently, three more articles were selected for full text analysis [5,19,20]. In total, 11 relevant articles were included (Table 2) [3,7,9,11,15–18].

The existing literature predominantly concerns experts’ opinions [3,9,11,15,16,18,20]. Three studies involved research on patient groups [5,7,17]. Only Jaegers et al. [5] studied two muscle fixation techniques, myodesis and myoplasty. The other two studies involved only patients who underwent a myodesis procedure [7,17].

Of the 11 included articles, 4 referred to myodesis and myoplasty [5,9,16,20]. Murdoch [4] and Tintle et al. [8] mentioned a preference for myodesis. Although Chadwick & Lewis [16] did not do any research with patients, they mentioned the same as Jaegers et al. [5], they claimed that accurate fixation of muscles is more important than the

technique of fixation.

The study by Dederich et al. only reported on myoplasty as a fixation technique [11]. This can be explained by the fact that this study was performed before the myodesis technique came in to practice.

In summary, 8 articles reported a preference for the myodesis technique [3,7,9,15,17–20]. The overall conclusion of these articles, without high level evidence, is that myodesis results in a more stable femur and residual limb control, which in turn results in better bio-mechanical functionality than myoplasty [3,7,9,15,17,18,20].

**Expert surgeons and prosthetists**

For the qualitative part of this article, four surgeons and two prosthetists were interviewed (Table 1).

All surgeons mentioned myodesis and myoplasty as techniques for muscle fixation. E2 also mentioned the so-called “tobacco-pouch” as a different technique. This technique entails suturing the edges of the inner and outer fascia to each other, whereas the antagonists are not taken into account.

The main reason to opt for the myodesis is the patient’s ability to have more control over the femur postoperatively. Myodesis results in better stability of the muscle-bone unit, comparable to that of the femur on the intact side. Moreover, based on their observations, the surgeons state that the muscular system stays in better condition after a myodesis, which is beneficial for the patient when walking with a prosthesis. There is no evidence that a more stable femur results in a better residual limb coordination and prosthesis functionality.

The myoplasty is mostly used in older, vascular patients. According to the vascular surgeons, it is highly unlikely that these patients will walk again (E1, E2). Orthopedic surgeons mostly operate on young adults without comorbidities. It is more likely that these patients will return to a high level of functioning after their amputation.

Quote:

*‘In young patients, the myodesis technique is possible because of their potential to regain the ability to walk after the amputation, but in older patients the risks outweigh the advantages.’ [E1]*

All experts were taught the specific amputation techniques from their supervisors. The reasons to select a given technique were mostly based on experts’ opinions in medical textbooks.

Quote:

*‘I have been a surgeon for 40 years and have learned by bitter experience. The information provided in the literature is miserable and I often disagree with the arguments.’ [E1]*

**Myodesis**

According to E3, it is not possible to stitch the muscles directly to the bone because of the lack of fascia structures. E3 drills four holes (at 12, 3, 6, and 9 o’clock in the transverse plane) in the femur bone and positions the antagonist muscles opposite each other so they can scar up to both the antagonist and the bone to keep their specific function. Securing the muscles and their fascia to the femur provides a fixed starting point for the scar tissue and a nice coverage of the distal femur to prevent pressure sores. In his opinion, it is important to create a balance between the antagonists (medial-lateral and frontal-dorsal), so that the antagonist forces are balanced in proportion. Care must be taken not to attach them in a too much flexed position of the hip joint to prevent a flexion contracture. Compromises are made when a muscle is too short or too atrophied. Nevertheless, both E3 and E4 try to use myodesis in these cases as well.

E3 mentions that lower shear forces are one of the biggest advantages of the myodesis. A rigid fixation is not possible, given that bone is connected to soft tissue and a bone-to-bone connection is absent. However, E3 has found that muscle structure will become connected to the bone by means of fibrosis within 6 weeks.

Quote:

**Table 2**  
Goutallier classification [14].

Grade	Explanation
0	No fatty deposits
1	Some fatty streaks
2	More muscle than fat
3	As much muscle as fat
4	Less muscle than fat

*‘I think that especially in the beginning the situation is more balanced, and I believe that after a while [...] the muscles will become fixed by means of scar tissue, a fibrotic connection.’ [E2]*

A disadvantage of the myodesis is that it takes more time than the myoplasty. E2 mentioned that the quality of the patient’s bone is important. Generally, elderly patients have thinner and weaker bones, which can result in fracturing of the bone while drilling holes.

Quote:

*‘Considering that elderly bones are weaker than teenage bones, I predict problems when drilling holes in the femur bone, such as ossification or ruptured bones.’ [E2]*

E1 mentioned some other drawbacks to the myodesis. First, because more muscles have to be dissected free of the femur, more soft tissue is damaged. Second, the wound remains open for a longer period of time, resulting in an increased susceptibility to infection. Third, because the drilling of holes in the bone might generate bone particles, there is a greater risk of calcifications in soft tissue.

Quote:

*‘When you remove too much soft tissue, it becomes more difficult to recreate the natural situation, [...] from experience, we know that it is not possible to recreate the situation before the amputation; the development of atrophy is unavoidable.’ [E4]*

### Myoplasty

In the literature, myoplasty is described as attaching the muscles to one another. However, given that muscle tissue itself cannot be stitched, this actually implies that the fascia of the muscles are attached to one another. Ideally, the surgeon tries to secure the vastus lateralis muscle to the adductor longus muscle and the quadriceps muscles to the hamstrings.

Quote:

*‘Connections between fasciae are very strong, so this is enough. You do not have to drill holes and secure muscles to the femur.’ [E1]*

The prosthetists had no additional arguments. They both stated that the myodesis results in a more stable femur, which is beneficial for motor control of the residual limb when prosthesis is used.

### 3D model

The volumes of intermuscular fat and muscle and the total volume percentage were calculated after making the 3D models (Table 3). The presence of more intermuscular fat indicates more atrophy, which could compromise functional motor control of the limb [10]. The first and second and column show the volumes of intermuscular fat and muscle in cubic centimeters. The total volume was calculated from the volumes of intermuscular fat and muscle tissue. Nerves, arteries, and other structures are not included in the total volume.

**Table 3**

Characteristics of the amputated patients and parameters of the 3D model and the Goutallier classification [14].

	IM Fat volume (cm <sup>3</sup> )	Muscular volume (cm <sup>3</sup> )	Volume percentage	Total volume (cm <sup>3</sup> )*	Goutallier Classification			Year of birth	Amputation year	Year MRI	K-Level
					TM	MF	DE				
Myodesis 1	28	164	15% F, 85% M	192	1	1	1	1992	2012	2016	K1
Myodesis 2	65	158	29% F, 71% M	223	2	2	3	1960	1979	2011	K2
Myoplasty 1	67	100	40% F, 60% M	167	4	4	4	1954	1980	2014	K2
Myoplasty 2	94	197	32% F, 68% M	291	2	2	2	1950	2005	2009	K2

IM fat = Intermuscular fat.

TM = Trochanter major.

F = fat.

MF = Mid femur.

M = muscle.

DE = Distal end.

\*total volume of intermuscular fat and muscles together. Nerves, arteries and other structures are not included in these 3D models.

The results of the Goutallier classification were based on a complete evaluation by the radiologist. As shown in Goutallier et al. (2003), a higher Goutallier score corresponds with a higher percentage of intermuscular fat [14]. We aimed to use an objective method to quantify intermuscular fat alongside the Goutallier classification, given the subjective nature of the latter. In this respect, it is interesting to note that the results of the 3D analysis and the Goutallier scores are in agreement with each other (Table 4). A higher percentage of intermuscular fat results in a higher Goutallier score.

Table 3 also shows the characteristics of the patients. The K-levels [21] (an indication of the walking limitation) were determined in the period the MRI was performed, for it is not yet standard protocol to perform an MRI directly after the amputation.

Fig. 2a shows a MRI of a patient who underwent a myodesis in 2012. Fig. 2b shows a MRI of a patient who underwent a myoplasty in 2005. As seen in these images, both cases show an increase in intramuscular fat, however the percentage of intramuscular fat in Fig. 2a is less than Fig. 2b. Fig. 2a shows more intermuscular fat on the medial side of the femur, and Fig. 2b shows more intermuscular fat more proximal in the residual limb. Although the amputations were performed in different years, this has no influence on the intermuscular fat volumes since major changes in local anatomy are not to be expected more than two years postoperatively.

### Discussion

The three-step approach of this study consisted of a literature search, qualitative research, and 3D analysis. To our knowledge, this is the first study to compare patients who underwent either a myodesis or a myoplasty. The lack of relevant studies makes it difficult to obtain evidenced-based conclusions on the outcomes of both techniques.

From the review of the literature, it became clear that myodesis is the preferred technique. It should be noted, however, that the literature mostly consisted of expert opinions rather than clinical evidence. Chadwick & Lewis and Jaegers et al. claimed that accurate fixation of muscles is more important than the actual technique of fixation [5,16]. These studies did not express a preference for a specific technique.

The experts who were interviewed in this study based their preferences on the instructions of their supervisors during training and on their own experiences. They all mentioned the importance of the patient’s age when it comes to technique selection. In younger patients, myodesis is the preferred technique, whereas the weaker and thinner bones of elderly patients pose a relative contraindication for myodesis. For the vascular surgeons, the question of whether the patient will regain the ability to walk after the surgery is pivotal. Myodesis results in better stability of the muscle-bone unit and hence in a fixed point of action. This will, in turn, result in better motor control of the residual limb. If there is only a small chance that the patient is going to walk

**Table 4**  
Parameters of the 3D model and the Goutallier classification [14].

	Femur length (cm)	Intermuscular fat volume (cm <sup>3</sup> )	Muscular volume (cm <sup>3</sup> )	Total volume (cm <sup>3</sup> )*	Volume percentage	Goutallier Classification		
						Trochanter major	Mid femur	Distal end
Myodesis 1	23.7	28	164	192	15% fat, 85% muscle	1	1	1
Myodesis 2	20.9	65	158	223	29% fat, 71% muscle	2	2	3
Myoplasty 1	23.3	67	100	167	40% fat, 60% muscle	4	4	4
Myoplasty 2	22.5	94	197	291	32% fat, 68% muscle	2	2	2

\*total volume of intermuscular fat and muscles together. Nerves, arteries and other structures are not included in these 3D models.

again; however, the vascular surgeons choose to perform a myoplasty and to close the wound as soon as possible, so as to lower the chance of infections.

Our analysis of 3D models adds a new dimension to the research on the outcomes of TFA. The 3D models provide reproducible quantitative information and can be easily compared with the Goutallier classification. This makes them a valuable tool for evaluation of the outcomes of the two techniques. There appears to be a trend between the Goutallier [14] score given by the radiologist and the 3D volume percentages. In the present study, the authors focused only on intermuscular fat. The presence of more intermuscular fat indicates more atrophy, which could compromise functional motor control of the limb [10]. The 3D analysis of the four cases suggests that compared with myoplasty, myodesis results in minor occurrence of intermuscular fat.

A limitation of this study is that these data must be interpreted with caution, given the small number of cases we analyzed. It is recommended that 3D analysis is applied to more cases to be able to draw reliable conclusions. Ideally, a longitudinal, prospective, randomized, controlled trial is undertaken, but a single scan at a fixed time post operation following a standardized procedure would already be very helpful.

Little is known about the functional status of TFA patients in general, and about elderly TFA patients in particular. This lack of knowledge may impair the decision-making process. Currently, technique selection is determined by a prediction of the patient’s chance to regain the ability to walk after the surgery. If, however, a myodesis had been performed instead of a myoplasty, would the functional outcome have been better? Future studies should address this topic.

**Conclusion**

In conclusion, the results from the literature search, qualitative research, and the 3D analysis suggest that myodesis is the preferred technique in TFA. Future research is needed to further support and substantiate this tentative conclusion.

There was no conflict of interest between the authors of this manuscript.

All authors contributed equally in the preparation of this manuscript.

**Appendix 1. Search strategies**

PubMed: (Trans-femoral amputation\*[tiab] OR Trans femoral amputation\*[tiab] OR Above-knee amputation\*[tiab] OR above knee amputation\*[tiab] OR Myodesis[tiab] OR Myopexy[tiab] OR Myoplastic[tiab]) AND (“Surgical Procedures, Operative”[Mesh] OR “surgery”[Subheading] OR surger\*[tiab] OR myopexy[tiab] OR myodesis[tiab] OR myoplastic[tiab]) NOT (rehabilitation[tiab] OR therap\*[tiab] OR case[tiab] OR risk factor\*[tiab] OR result\*[tiab] OR eye\*[tiab] OR rat\*[tiab])

Web of Science: “trans-femoral amputation” OR “Trans-femoral amputations” OR “Trans femoral amputation” OR “Trans femoral amputations” OR “Above-knee amputation” OR “Above-knee amputations” OR “above knee amputation” OR “above knee amputations” combined with surger\* OR myopexy OR myodesis OR myoplastic

PsycINFO

Trans femoral amputation AND surgery

Embase: “trans-femoral amputation”:ab,ti OR “Trans-femoral amputations”:ab,ti OR “Trans femoral amputation”:ab,ti OR “Trans femoral amputations”:ab,ti OR “Above-knee amputation”:ab,ti OR “Above-knee amputations”:ab,ti OR “above knee amputation”:ab,ti OR “above knee amputations”:ab,ti combined with surgery:ab,ti OR surgeries:ab,ti OR surgical:ab,ti OR myopexy:ab,ti OR myodesis:ab,ti OR myoplastic:ab,ti

## Appendix 2. Question list experts

- I know two different methods for *trans*-femoral amputations, do you know more techniques?
- Do you always amputate with the same technique?
  - Yes, which technique?
    - Why do you choose for this technique?
  - No, why differ between different techniques?
- Could you describe the technique(s)?
  - What are you doing with the muscles? How exactly?
    - Difference between deep and superficial muscles?
- Are there any advantages/ disadvantages of one technique against the other technique?
  - How do you know? Literature, experience, thoughts?
  - If method is myodesis → A myodesis is a longer operation than a myoplastic (drill holes), why do you choose for this method?
- And the protection of the femur, how to make sure the femur is not going to stich through the skin?

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