Title: A Comparison of Post-Operative Recovery of Amputees that Undergo Two Different Lower Extremity Amputation Procedures: Traditional vs. Osteomyoplasty

Honors Thesis Prepared

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Abstract

Objective: The purpose of this project was to compare the post-operative recovery of patients undergoing lower extremity amputation following either a traditional or osteomyoplasty procedure.

Methods: Peer reviewed articles were extracted from six data bases and websites published from 1967 to 2017. Search terms included: “Ertl”, “lower-extremity amputations”, “complications”, “length of hospital stay”, “surgical technique”, “osteomyoplasty”, “traumatic”, “non-traumatic”, “prosthesis”, and “ambulation”. A series of questions was also developed for interviews with health care professionals working with amputees who have undergone the traditional or osteomyoplasty surgical amputations.

Results: The average length of hospital stay for the traditional technique was 12.8 days for the studies reviewed, but no studies reported for length of hospital stay following osteomyoplasty. Time to prosthesis and ambulation for the traditional procedure was 54 days (range of 24.8 to 126 days) and the osteomyoplasty procedure was 69.2 days (range of 32.2 to 156.8 days). For the traditional procedure, infection rates were 18% (range 1.9% to 34%) compared to 15% (range 0 to 35.1%) for the osteomyoplasty procedure. Stump revision rate for the traditional procedure had an un-weighted average of 25% (range 3.2 to 50%) compared to 14% (range 0 to 37.9%) for the osteomyoplasty. Following the traditional procedure, the ambulation rate was 65% (range 38.3% to 87.8%) compared to 97% (range 87.5 to 100%) for the osteomyoplasty procedure. Employment rate for the traditional procedure was 43% (range 10 to 96.7%) compared to 70% (range 21.6 to 100%) for the osteomyoplasty. Results of the interview revealed that health care professionals who work with amputees who have undergone the traditional vs. osteomyoplasty procedure believe there are advantages for the patient long-term with the osteomyoplasty technique.

Conclusions: Based on this research, the osteomyoplasty provides better functional outcomes than the traditional procedure for patients who are good candidates. More research is needed directly comparing the two surgical techniques and training of more surgeons in the osteomyoplasty procedure before it is likely to become more widely used.

Introduction:

Amputation of a limb can result from either traumatic or non-traumatic tissue injury. The leading causes are vascular disease (54%), trauma (~45%), and less than 2% due to cancer [1]. It has been estimated that approximately 1.6 million people in the United States are currently living with an amputated limb and another 185,000 amputations are performed each year [2]. The most common site of amputation is the lower-extremity with ~50% of all lower extremity amputations classified as transtibial [6] and ~18.5% of all amputations classified as transfemoral [7].

Traditional surgical techniques for amputation have not changed drastically over the years. Surgical teams have just learned to better control factors intraoperatively, including bleeding and infection risk, through the maintenance of a sterile environment [8]. The goal with any type of amputation procedure is to ensure that the patient has a functional limb, free of pain following recovery and a rehabilitation period. Amputations of limbs were first seen in Neolithic cave drawings in 1700 BC [8]. In 1529, Ambrose Pare began to advocate for controlling bleeding during amputation through the use of a tourniquet [9]. Another advance in patient post-surgical outcomes occurred when Lister, famous for the Theory of Germ Transmission, attempted to prevent infection through inhibiting and preventing the growth and spreading of germs at the time of the American Civil War by careful tourniquet placements and the use of chloroform when it was available [8]. Nonetheless, mortality rates were still high (~60%) despite these efforts [9]. By the time that World War I began in 1914, mortality rates had dropped to approximately 8% [10]. Survival rates improved to approximately 2.5% during and after World War I as blood transfusions and antibiotics were utilized. The Vietnam War brought an emphasis on the importance of early surgical intervention [10]. This allowed for better healing of the residual end of the limb by preventing infection, which allowed for earlier rehabilitation and the

return to a normal, active lifestyle [11]. Throughout history, scientific advances have improved the surgical technique of a traditional amputation and these changes have often occurred in accordance with major military events [8].

An alternative surgical technique to traditional amputation, osteomyoplasty, was developed in 1920 [12]. This technique involved the use of a section of cortical bone that is connected by a periosteal hinge. Osteomyoplasty is a surgical technique that was developed to restore the residual limb to a more normal physiological state. In other words, it would allow amputees to return to a more normal, active life with a more stable residual limb for better prosthesis fit and function [12]. Although the osteomyoplasty was developed in 1920, the procedure was never really widespread until 1949 when Ertl took the transtibial surgery a step further by creating a bone-bridge between the tibia and fibula [13]. Ertl believed that this technique would decrease a patient's post-operative pain and would also allow the residual limb to withstand a greater amount of force. This would be advantageous to patients, allowing for greater weight-bearing and promoting the maintenance of soft tissue at the distal end of the residual limb rather than tissue atrophy that often occurred over time [13]. Ertl also thought that it provided other advantages such as improved walking, prosthetic fit, and increased blood flow [13]. Although there are a number of potential advantages to the patient, the osteomyoplasty procedure also has drawbacks. Osteomyoplasty surgery is more time consuming than a traditional amputation [14]. The average time for the osteomyoplastic procedure is ~178.5 minutes, whereas the average surgery time for the traditional procedure is ~112.2 minutes [15]. This leads to additional costs to hospitals and surgeons because the increase in operating room (OR) time reduces the number of procedures that can be done in the average day. Another drawback highlighted by Mongon et al., [16] is the initial location of the wound cannot lie too

proximal to the tibia because it prevents the construction of an osteoperiosteal flap at the appropriate length. This is especially true in oncological and traumatic cases that require a wide surgical margin.

While some advantages and disadvantages to the osteomyoplasty procedure have been described in the literature, less information is available about post-operative recovery. The purpose of this project is to examine post-operative recovery variables (e.g., length of hospital stay, time to prosthesis/ambulation, and complications) in patients undergoing lower extremity amputation following traditional vs. osteomyoplasty procedures. The hypothesis to be tested is that the osteomyoplastic technique will result in a shorter length of hospital stay, reduced time to prosthesis and ambulation, and fewer complications than the traditional amputation procedure, making it the preferred method by patients and health care professionals. A secondary hypothesis is that these short and long-term benefits of osteomyoplasty will be more pronounced in transtibial whose injuries result from traumatic conditions. These hypotheses will be tested by accomplishing the following specific aims:

(Aim 1) To investigate the average length of hospital stay of lower extremity amputees following a traditional vs. osteomyoplasty surgical procedure, distinguishing amputation by lower extremity location (i.e., above and below the knee amputations) and cause (i.e., traumatic vs. non-traumatic).

(Aim 2) To investigate the average time to prosthesis and ambulation following a traditional vs. osteomyoplasty surgical procedure, distinguishing amputation by location and cause.

(Aim 3) To determine the short-term complications that affect time to prosthesis and ambulation following a traditional vs. osteomyoplasty surgical procedure, distinguishing amputation by location and cause.

(Aim 4) To determine the long-term complications that occur following a traditional vs. osteomyoplasty surgical procedure, distinguishing amputation by location and cause.

(Aim 5) To determine the attitudes and beliefs of health care professionals' (e.g., surgeons, physical therapists, prosthetists) who work with amputees who have undergone a traditional or osteomyoplasty surgical procedure.

Methods:

To accomplish these aims, the following databases and websites were used to find scholarly articles: PubMed, Google Scholar, MEDLINE, EBSCO, Oklahoma State BOSS, and google.com. The following search terms were used to identify published from 1967 to 2017: "osteomyoplasty", "Ertl", "lower-extremity amputations", "length of hospital stay", "surgical technique", "complications", "traumatic", "non-traumatic", "prosthesis", and "ambulation". All research articles were in English. For each article, the abstract was screened and the study was included if it addressed at least one of the specific aims**.**

In addition to reviewing the literature, a series of questions was developed to use in interviews of health care professionals working with amputees in a medical center that performs both osteomyoplasty and traditional surgical amputations (**Table 1**). The goal of these interviews was to gain a better understanding of the attitudes and beliefs of health care providers about the advantages and disadvantages of these two procedures.

Table 1. Interview Questions
How would you characterize your practice? a. In a typical year, approximately how many new amputees do you see? b. What proportion of amputees undergo a traditional amputation? Osteomyoplasty? c. What percentage of these patients require an amputation due to trauma? d. What is the typical duration of the rehabilitation process?
In your opinion, what are the advantages of the osteomyoplasty surgical procedure?
Do these advantages differ based on whether or not the amputation results from a traumatic vs. a non-traumatic tissue injury?
In your opinion, what are the disadvantages of the osteomyoplasty surgical procedure?
Which surgical procedure do you think provides the best functional outcomes in patients? Why?
Do you believe that osteomyoplasty should be used more widely? (If yes, what are the major challenges to wider acceptance of this procedure?)

In the sections that follow, the surgical methods of both procedures will be described followed by results organized around specific aims 1-5.

Results:

Amputation of a limb is usually the last option that any person or physician wants to turn. Undergoing amputation causes the patient to overcome a psychological stigma that society associates with limb loss [17]. Removing a diseased limb can be quite simple, but the care does not end there. Surgery must be performed in such a manner as to allow the patient to be able to wear a prosthetic limb comfortably. Amputation becomes the treatment of choice for diseased limbs in which attempts at reconstruction and salvage may be lengthy, costly, and provide negative functional outcomes. However, amputating the limb may allow the patient to have better functional results [17]

Osteomyoplasty Surgical Technique:

Once it is determined that an amputation is required and the osteomyoplasty procedure is to be performed, a tourniquet is placed on the thigh of the affected limb with an incision line drawn so that the distal limb will be removed (**Figure 1**). In traumatic cases, if the limb is already severed, the contralateral limb is used to measure length to allow for an accurate measurement of the residual limb. If both legs are not intact, surgeons attempt to maintain as much length to each limb as possible [4].

Figure 1: Incision line drawn so 9.5-10 inches of distal limb will be removed [4]

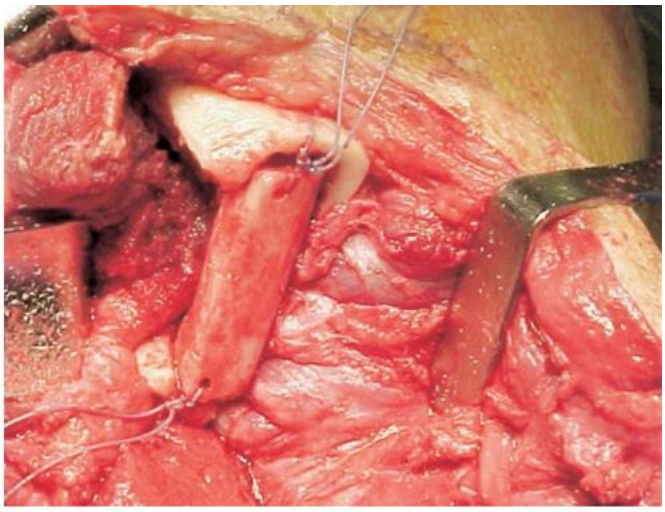

Figure 2: Bone bridge held in place with braided sutures through medial tibia and lateral fibula [4].

In order to perform a transtibial amputation, the skin is cut along the incision line while the bone is disarticulated approximately 2 cm above the skin incision to provide a long posterior skin flap that allows for a more symmetric closure. Next, periosteum of the bone is incised from top to bottom creating anteromedial and lateral flaps removing the cortical bone attached to the periosteum. This is repeated for the lateral tibial periosteum and the flaps are kept in moist sponges. The tibia and fibula are then cut perpendicular to the shaft with a

surgical saw at the same level. For a transtibial amputation, bone is grafted from the amputated fibula that is the length of the distance of the medial tibia to the lateral fibula. The bone graft is placed and anchored with a braided suture or screws (**Figure 2)**. Then the osteoperiosteal flaps are placed to cover the entire fibular graft and sutures the anterior fascia to the gastrocnemius fascia [4]

In a transfemoral amputation, the level of the amputation depends upon the length of the soft tissues. The soft tissue has to be long enough to be able to be stitched to one another. Skin is dissected and the muscles are separated from each other in a transverse cross. The adductor muscles are then stitched to the abductor muscles and iliotibial tract to allow the bone to be embedded. Sutures are placed both below and over the end of the bone in order to avoid slipping. This allows for a tight closing of the medullary cavity which will be able to maintain medullary pressure within the limb. The maintenance of this medullary pressure will establish efficient muscle connections between the antagonistic muscle groups. Skin is then fit into place and sewn up using suction drainage [18].

Traditional Surgical Technique:

To perform a traditional amputation, a tourniquet is applied to the limb with reference points for bone dissection being marked both medially and laterally on the leg [5]. A posterior and anterior flap line is drawn to make a half circle and this will allow for the elimination of a "dog ear" for a smooth close (**Figure 3**). Fascia

Figure 3: A posterior and anterior flap line drawn to make a half circle [5].

and subcutaneous tissue are cut in line with the skin incision and veins and nerves are ligated. The tibia (or femur) is stripped of the periosteum to help reduce the chances of osseous bone spur formation. The bone is then cut transversely with a surgical saw. If it is a transtibial amputation, the fibula is cut at the same level or just slightly shorter than the tibia. Deep calf muscles are then excised reducing posterior flap bulk and the wound is closed [5].

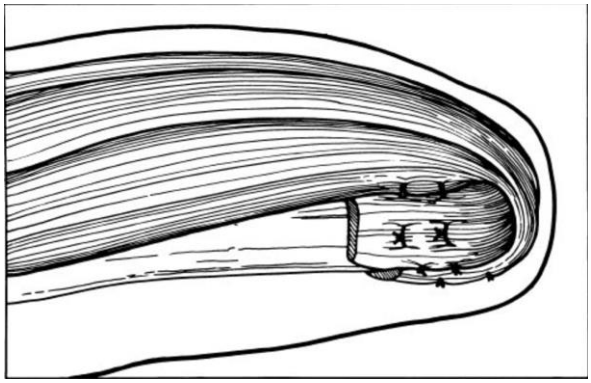

Figure 4: The quadriceps is sutured to the posterior aspect of the femur via drill [3].

If it is a transfemoral amputation, quadriceps are detached proximal to the patella in order to retain some of the tendinous section and the adductor magnus is detached from the adductor tubercle to expose the femoral shaft. Smaller muscles are transected about one to two inches longer than the bone in order to facilitate anchorage. The femur is then cut with a surgical saw and the adductor magnus tendon is sutured to the lateral aspect of the residual femur through drill holes. The adductor magnus is anchored and the quadriceps is sutured to the posterior aspect of the femur via drill holes (**Figure 4**). The fascia of the thigh is then sutured and dictated by the skin flaps [3].

Osteomyoplasty vs. Traditional Amputation on Length of Hospital Stay:

The first outcome measure assessed to compare traditional and osteomyoplasty procedures was the length of hospital stay. Length of stay is an important indicator to assess a patient's overall health status and post-operative recovery rate. A total of six studies were included that reported findings on the average length of hospital stay of patients that underwent the traditional amputation procedure. The average length of hospital stay following a traditional

Table 2: Osteomyoplasty vs. Traditional Amputation on Length of Hospital Stay

Reference	Population	Length of Stay	
		Traditional Procedure	Osteomyoplasty Procedure
Jindeel, et. al. (2013) [19]	Non-traumatic (n=847) Traumatic (n=66)	12.5 days	---
Ashrafi, et. al. (2017) [20]	Non-Traumatic (n=635)	14.4 days	---
Low et. al. (2017) [21]	Traumatic (n=2405) TT & TF	16.7 days	---
Seker, et. al. (2016) [22]	Non-traumatic (n=87) TT & TF	10.1 days	---
Wiessman et. al. (2015) [23]	Non-traumatic (n=316) TT & TF	10 days	---
Johannesson, et. al. (2004) [24]	Non-traumatic (n=174) TT, TF	13 days	---
TT = transtibial	TF = transfemoral		

surgical procedure ranged from 10-16.7 days with an un-weighted mean of 12.8 days (**Table 2**). Notably, no studies reported the length of hospital stay following the osteomyoplasty surgery. This represents a significant gap in the literature resulting in the inability for comparisons between the two procedures on this outcome.

Osteomyoplasty vs. Traditional Amputation on Average Time to Prosthesis and Ambulation:

In addition to length of hospital stay, time to prosthesis and ambulation is an important benchmark for amputees. The studies that reported the average time to prosthesis/ambulation following the traditional or osteomyoplasty surgical procedure that were included in this review are shown in **Table 3**. A total of ten studies were included when addressing this aim.

Two of the ten studies made direct comparisons between the traditional technique and the osteomyoplasty technique. Neither study reported a significant difference in the average time to

Table 3: Osteomyoplasty vs. Traditional Amputation on Average Time to Prosthesis and Ambulation

Reference	Population	Time to Prosthesis and Ambulation	
		Traditional Procedure	Osteomyoplasty Procedure
Taylor, et. al. (2010) [25]	Traumatic & Non-Traumatic (n=36) TT	126 days	72.8 days
Pinto, et. al. (2004) [26]	Traumatic (n=3) Non-Traumatic (n=12)	---	86 days
Mongon, et. al. (2013) [16]	Traumatic (n=7) Non-Traumatic (n=2)	---	49 days
Brown, et. al. (2014) [27]	Traumatic & Non-traumatic (n=293) TT	---	35 days
Bemden, et.al. (2017) [28]	Traumatic (n=8) TT	---	156.8 days
DeCoster, et. al. (2005-2006) [14]	Traumatic (n=1) Non-traumatic (n=4) TT	---	100.8 days
Johannesson, et. al. (2004) [24]	Non-traumatic (n=174) TT, TF	48 days	---
Woodburn, et. al. (2004) [29]	Non-Traumatic (n=154), TT	39 days	---
Wong, et. al. (2000) [30]	Non-traumatic (n=21), TT & TF	24.8 days	---
Dougherty (2001) [11]	Traumatic (n=72)	32.2 days	32.2 days
TT = transtibial	TF = transfemoral		

prosthesis/ambulation between the two procedures. A study by Taylor et al., [25] reported an average of 126 days to prosthesis/ambulation with the traditional technique and 72.8 days in the osteomyoplasty technique, but the differences were not statistically significantly different. Dougherty and colleagues [11] reported a mean time to prosthesis/ambulation of 32.2 days for both the traditional and osteomyoplasty technique. The remaining eight studies did not make direct comparisons between the two procedures. The time to prosthesis/ambulation ranged from

24.8 to 126 days for the traditional procedure and 32.2 to 156 days for the osteomyoplasty procedure. In these eight studies, the un-weighted average time to prosthesis/ambulation for the traditional procedure was 37.3 days and 85.4 days for the osteomyoplasty procedure, respectively. It was not possible to make distinctions between the cause of the procedure (i.e., traumatic vs. non-traumatic) or the site of the surgery (i.e., transtibial vs. transfemoral) as a result of the data presented in these studies.

Based on the review of literature that focused on the average time to prosthesis/ambulation in the two surgical procedures, the traditional technique requires less time to prosthesis/ambulation. These studies indicate that the overall un-weighted average time to prosthesis/ambulation following the traditional procedure was 54 days compared to 69.2 days following the osteomyoplasty procedure. The average time was not statistically significantly lower in the traditional technique compared to the osteomyoplasty technique, but it is numerically lower. An explanation for this discrepancy could be that the healing process required for the osteomyoplasty procedure is slower than that of the traditional procedure due to the time required for a bony bridge to create a union with the tibia and fibula. Nonetheless, time to prosthesis/ambulation in patients who undergo the osteomyoplasty procedure appears to be greater than the traditional procedure which could be a disadvantage for some patients.

Osteomyoplasty vs. Traditional Amputation on Short-Term Complications

The short term complications of the traditional surgical procedure and osteomyoplasty surgical procedure results are shown in **Table 4**. Fifteen studies were included in the literature review of these complications, which included infection and stump revision.

Thirteen studies reported findings on stump revisions and two of these thirteen studies

Table 4: Osteomyoplasty vs. Traditional Amputation on Short-Term Complications

Reference	Population	Short Term Complications			
		Traditional Procedure		Osteomyoplasty Procedure	
		Infection	Stump Revision	Infection	Stump Revision
Firth, et. al. (2011) [31]	Traumatic (n=2) Non-traumatic (n=3) TT	---	---	---	1/5 (20.0%)
Taylor, et. al. (2010) [25]	Traumatic (n=36) TT	---	5/10 (50.0%)	---	4/26 (15.4%)
Johannesson, et. al. (2004) [24]	Non-traumatic (n=174) TT, TF	20.7%	13.7%	---	---
Woodburn, et. al. (2004) [29]	Non-Traumatic (n=154), TT	22/154 (14.2%)	5/154 (3.2%)	---	---
Mongon, et. al. (2010) [32]	Traumatic (n=9) Non-traumatic (n= 7) TT	---	---	2/15 (13.3%)	1/15 (6.7%)
Fang, et. al. (2017) [33]	Non-traumatic (n=379) TT, TF	---	105 of 379 (27.7%)	---	---
Brown, et. al. (2014) [27]	Traumatic & Non-traumatic (n=293) TT	---	87/264 (33.0%)	---	11/29 (37.9%)
Tintle, et. al. (2011) [34]	Traumatic (n= 137) TT	34/100 (34.0%)	---	13/37 (35.1%)	---
Columbo, et. al. (2016) [35]	Non-traumatic (n=120) TT	---	9/120 (27.5%)	---	---
Low et. al. (2017) [21]	Traumatic (n=2405) TT & TF	---	807/2405 (33.6%)	---	---
Mongon, et. al. (2013) [16]	Traumatic (n=7) Non-Traumatic (n=2)	---	---	0/9 (0%)	0/9 (0%)
Pinto, et. al. (2004) [26]	Traumatic (n=3) Non-Traumatic (n=12)	---	---	---	1/15 (6.7%)
Bemden, et.al. (2017) [28]	Traumatic (n=8) TT	---	---	1/8 (12.5%)	---
Deol et. al. (2008) [8]	Traumatic (n=3) Non-traumatic (n=4) TT	---	---	1/7 (14.3%)	1/7 (14.3%)
Zivkovic, et. al. (2009) [36]	Traumatic (n=425) TT	8/425 (1.9%)	52/425 (12.2%)	---	---
TT = transtibial	TF = transfemoral				

directly compared the rate of stump revisions of the traditional and osteomyoplasty techniques. The study by Taylor, et. al. [25] reported a statistically significant difference between the two procedures. The traditional technique required 50% of their patients to get a stump revision while only 15.4% of osteomyoplasty patients required one. Brown and colleagues [27] directly compared the rate of stump revisions and did not report a statistically significant difference between the two procedures. Patients that had a traditional amputation had a 33% rate of stump revision and 37.3% of osteomyoplastic amputations requiring a stump revision. The discrepancy in these two studies may have resulted from the differences in patient population. The study by Taylor, et. al. [25] included patients that required an amputation due to traumatic incidences while the study by Brown, et. al. [27] included patient's that required an amputation from both traumatic and non-traumatic causes. Because individuals who experience a traumatic injury tend to be younger and healthier, this could account for the differences in the stump revision rates in the two studies. The remaining eleven studies did not make comparisons between the two surgical techniques. The un-weighted average rates of stump revision in traditional surgical technique in these eleven studies that did not make direct comparisons between the two procedure was ~20% (range 3.2-33.6%), while the rate of stump revision following the osteomyoplasty technique was ~10% (range 0-20%). These findings indicate that the rate of stump revisions following the osteomyoplasty procedure occurs ~50% less than traditional technique.

When considering post-operative infection rates, a total of nine studies reported findings on infection and only one of these nine studies directly compared the two surgical techniques on this outcome measure. The study by Tintle et al., [34] did not observe a statistically significant difference in the infection rates with a 34% and 35.1% rate of infection following the traditional

and osteomyoplasty technique, respectively. The remaining eight studies that were reviewed did not make direct comparisons on rates of infection. However, in these eight studies, the un-weighted average rates of infection in traditional surgical technique in these studies was ~12% (range 1.9-20.7%), while the rate of stump revision in the osteomyoplasty technique was ~10% (range 0-14.3%). This indicates that the rate of infection in the osteomyoplasty procedure does not differ from the traditional procedure.

Based on the review of these studies that focused on the short-term complications of stump revision and infection rates following traditional and osteomyoplasty procedures, the data indicates that the osteomyoplasty technique provides fewer complications and better results when it comes to stump revision rates, but not infection rates. When data from all of the studies was combined, the osteomyoplasty procedure stump revision rate was 14% on an un-weighted average, while the stump revision rate of the traditional technique was 25% unweighted. These rates are considerably lower in the osteomyoplasty group. In contrast, when it comes to infection rates, the un-weighted average was 18% for the traditional technique compared to an un-weighted average of 15% for the osteomyoplasty technique. This indicates that there is no real difference between the two procedures. Based on these findings related to short-term complications, the osteomyoplasty procedure can be considered to provide a significant advantage over the traditional procedure when it comes to stump revision.

Osteomyoplasty vs. Traditional Amputations on Long-Term Complications

The long-term complications of the traditional surgical procedure and osteomyoplasty surgical procedure results are shown in **Table 5**. The most common complications that were considered were ambulation and employment rates and a total of fifteen studies were included. A

Table 5: Osteomyoplasty vs. Traditional Amputations on Long-Term Complications

Reference	Population	Long Term Complications			
		Traditional Procedure		Osteomyoplasty Procedure	
		Ambulation Rates	Employment Rates	Ambulation Rates	Employment Rates
Wong, et. al. (2000) [30]	Non-traumatic (n=21), TT & TF	10/21 (47.6%)	---	---	---
DeCoster, et. al. (2005-2006) [14]	Traumatic (n=1) Non-traumatic (n=4) TT	---	---	5/5 (100%)	4/5 (80%)
Taylor, et. al. (2010) [25]	Traumatic & Non-Traumatic TT Total: (n=36)	---	1/10 (10%)	---	12/26 (46.2%)
Mongon, et. al. (2010) [32]	Traumatic (n=9) Non-traumatic (n= 7) TT	---	---	15/16 (93.8%)	---
Brown, et. al. (2014) [27]	Traumatic, Non-traumatic (n=293) TT	161/207 (77.8%)	---	29/29 (100%)	---
Tintle, et. al. (2011) [34]	Traumatic (n= 137) TT	94/100 (94%)	21/100 (21%)	35/37 (94.6%)	8/37 (21.6%)
Columbo, et. al. (2016) [35]	Non-traumatic TT (n=130 limbs; n=120 pts)	46/120 (38.3%)	---	---	---
Mongon, et. al. (2013) [16]	Traumatic (n=7) Non-Traumatic (n=2)	---	---	9/9 (100%)	---
Pinto, et. al. (2004) [26]	Traumatic (n=3) Non-Traumatic (n=12)	---	---	14/15 (93.3%)	---
Bemden, et.al. (2017) [28]	Traumatic (n=8) TT	---	---	7/8 (87.5%)	---
Pinzur et. al. (2008) [37]	Traumatic (n=8) TT	---	---	8/8 (100%)	8/8 (100%)
Deol et. al. (2008) [8]	Traumatic (n=3) Non-traumatic (n=4) TT	---	---	7/7 (100%)	---
Johannesson, et. al. (2004) [24]	Non-traumatic (n=174) TT, TF	80/174 (46%)	---	---	---
Dougherty, et. al. (2001) [11]	Traumatic (n=72)	---	29/30 (96.7%)	---	42/42 (100%)
Zivkovic, et. al. 2009 [36]	Traumatic (n=425) TT	373/425 (87.8%)	---	50/52 (96.2%)	---
TT = transtibial	TF = transfemoral				

total of thirteen studies reported findings on ambulation rates and three of these thirteen studies compared the rate of ambulation (i.e., the ability of a patient to move from place to place) following the traditional and osteomyoplasty techniques. The study by Tintle et al., [34] compared ambulation rates of patients undergoing traditional and osteomyoplasty procedures and did not observe a statistically significant difference between the two procedures. In this study, a 94% ambulation rate following traditional amputations was reported compared to a 94.6% rate of ambulation in amputees receiving an osteomyoplasty procedure. Brown et al., [27] compared the rate of ambulation in patients who had undergone traditional or osteomyoplasty amputation and reported a statistically significant increase between the two procedures. In this study, the traditional technique only had an ambulation rate of 77.8% while 100% of patients who had undergone the osteomyoplasty procedure were ambulatory. As observed with other outcome measures, the discrepancy in these two studies may have resulted from the differences in patient population. Because individuals who experience a traumatic injury tend to be younger and healthier, this could account for the lower ambulation rates in the Brown study compared to the Tintle study. The remaining ten studies did not make direct comparisons between the two surgical techniques. The un-weighted average rate of ambulation in traditional surgical technique in these ten studies was ~44% (range 38.3-47.6%), while the rate of ambulation following the osteomyoplasty technique was ~96% (range 87.5-100%). These findings suggest that the rate of ambulation following the osteomyoplasty procedure is about twice as high as the ambulation rate following the traditional procedure.

When considering post-operative and post-rehabilitative rates of employment, a total of five studies reported on employment rates and three of these five studies directly compared the two different surgical techniques on this outcome measure. Two of the three studies did not

report statistically significant differences between the two procedures. Dougherty et al., [11] reported a rate of employment for the traditional group of 96.7% while 100% employment was reported for the osteomyoplasty group. Tintle et al., [34] also did not report statistically significant differences between the two procedures with a 21% employment rate following a traditional amputation and 21.6% employment rate following the osteomyoplasty technique. Again, the differences between these two studies are most likely due to the differences in patient population and the type employment position. The patients in the study by Tintle et al., [34] were returning to active duty military duty while the patients in the study by Dougherty et al., [11] were not employed in the military. A study by Taylor et al., [25] reported statistically significant differences when comparing the two procedures. The traditional technique was associated a 10% employment rate while the osteomyoplasty technique was associated with an employment rate of 46.2%. These differences in rates compared to other studies could be due to the patient employment status before surgery. Only 50% of patients in the osteomyoplasty group were employed before amputation and 40% of patients in the traditional group were employed prior to amputation. The remaining two studies did not make direct comparisons between the two surgical procedures on employment rates and did not report any findings on the traditional procedure. However, the employment rate for the osteomyoplasty technique in these two studies ranged from 80-100% with a mean of 90%.

As a result of this review of literature that focused on the long-term complications of ambulation and employment rates, it was shown that following osteomyoplasty procedures fewer complications and better results than following the traditional procedure. Based on all of the studies reviewed, the un-weighted average of the osteomyoplasty procedure ambulation rate was 97% while the ambulation rate of the traditional technique was 65%. These rates are

considerably higher in the osteomyoplasty group compared to the traditional group. When it comes to employment rates, the un-weighted average of all of the studies included for the traditional technique was 43% compared to 70% indicating that employment rates are considerably higher following the osteomyoplasty procedure. Based on these findings the osteomyoplasty procedure can be considered to provide a significant advantage over the traditional procedure when it comes to long-term complications.

Attitudes and Beliefs of Health Care Professionals'

An interview was conducted by phone with Dr. Carole Dionne, PT, DPT, PhD, OCS, Cert MDT with The University of Oklahoma Health Sciences Center. She has been a practicing physical therapist for 40 years and has recently stopped seeing patients in order to see more patients in the motional analysis lab. Before the interview began she stated that she gave her answers based off of evidence-based facts for question unless specifically asked for an opinion. The interview questions and responses are provided in **Table 6**.

Dr. Dionne, primarily sees amputees that have undergone the osteomyoplasty procedure which is mainly due to the referring physician because he primarily performs this type of amputation procedure. She believed that the osteomyoplasty procedure provided more advantages over the traditional amputation procedure due to being able to allow full weight bearing on the residual limb in a prosthesis leading to better bone health, stump revision rates being considerably lower, and the gastrocnemius and tibialis muscles are able to co-contract with one another. She also stated that the advantages of the osteomyoplasty procedure will differ on whether or not the amputation has resulted from a traumatic or non-traumatic injury. Non-

Table 6: Osteomyoplasty vs. Traditional Amputation Interview

Interview Questions and Responses	
Questions	**Dr. Carol Dionne, PT, DPT, PhD, OCS, Cert MDT**
Would you please characterize your practice? 1) In a typical year, approximately how many new amputees do you see? 2) What proportion of amputees undergo a traditional amputation? Osteomyoplasty? 3) What percentage of these patients require an amputation due to trauma? 4) What is the typical duration of the rehabilitation process?	Practicing as a doctor of physical therapy for 40 years seeing patients that have more than one comorbidity relating to musculoskeletal diagnoses. 1) ~10 transtibial and 5-8 transfemoral 2) Less than 2% traditional amputation ~98% osteomyoplasty (primarily due to physician referral) 3) ~50% (unusual because OU is trauma 1 institution) 4) No more than 12 visits but usually takes about 6 ~3 months to prosthesis
In your opinion, what are the advantages of the osteomyoplasty surgical procedure?	Alignment is normal The prosthesis will load itself allowing the gastrocnemius and tibialis muscles to co-contract working in function with one another. Good bone health due to the allowance of direct weight bearing Stump revision rate is considerably lower
Do these advantages differ based on whether or not the amputation results from a traumatic vs. a non-traumatic tissue injury?	Yes Non-traumatic patients tend to have amputation due to comorbidities that can result in tissue injury—they have to be vigilant in keeping their skin and tissue healthy
In your opinion, what are the disadvantages of the osteomyoplasty surgical procedure?	Amputees with metabolic problems will have tissue problems If patients get sloppy then they will not benefit
Which surgical procedure do you think provides the best functional outcomes in patients? Why?	Osteomyoplasty Promotes better health outcomes but it is also up to the patient—patient has to take command of their rehabilitation
Do you believe that osteomyoplasty should be used more widely? (If yes, what are the major challenges to wider acceptance of this procedure?)	Yes Requires higher level of skill and more training by the health care providers Major challenges are that people do not have time or interest at this point

traumatic amputation patients tend to have comorbidities that have lead to tissue injury that have caused them to require an amputation due to tissue injury. They have to be very careful and vigilant in order to maintain good skin and tissue health as where traumatic amputation patients do not have comorbidities that have led to them requiring amputation. This could account for some of the differences found in the studies that were reviewed and included in addressing the specific aims.

Dr. Dionne expressed that she believed that the osteomyoplasty procedure should be more widely used due to the successes that she has seen in her practice and research. The major challenges to making the use of this procedure more widely spread are mainly due to the amount of time and the need for specialized training that it takes to be able to perform the procedure. A lot of surgeons do not have the time or interest in specializing in this specific procedure. All in all, Dr. Dionne expressed that in her opinion all parts of the osteomyoplasty procedure are more advantageous and provide better functional outcomes compared to the traditional procedure.

Discussion:

This review of literature was conducted to examine post-operative recovery variables (e.g., length of hospital stay, time to prosthesis/ambulation) as well as short-term and long-term complications in patients undergoing lower extremity amputation following traditional vs. osteomyoplasty procedures.

In terms of post-operative outcomes, comparisons between the traditional and osteomyoplasty procedure were unable to be made for length of hospital stay after a lower-extremity amputation. No studies reported on this aim for the osteomyoplasty procedure, which was also confirmed during the interview with Dr. Dionne. This notable gap in literature on the

osteomyoplasty procedure relating to length of hospital stay needs to be addressed. The present study also revealed the average time to prosthesis/ambulation for the traditional procedure is ~2 weeks shorter compared to patients who undergo the osteomyoplasty procedure. This could be disadvantageous to some patients and could be due to the fact that the bone bridge requires bone healing and time to create a union with the residual tibia and fibula.

The short-term complications that were considered were infection and stump revisions rates. The un-weighted average rate of infection for the traditional technique was 18% compared to 15% for the osteomyoplasty procedure. This indicated that there is no advantage in receiving one of the two procedures when it comes to rate of infection. The un-weighted average rate of stump revisions in this study for the traditional procedure was 25% compared to 14% for the osteomyoplasty procedure. These findings indicate that the osteomyoplasty can significantly reduce a patient's chances of requiring a stump revision. This would be advantageous to patients due to the fact that a second surgery could shorten their residual limb even more and result in greater challenges. The osteomyoplasty procedure had a substantially lower rate of stump revisions than the traditional technique providing a major advantage over the traditional procedure. However, no real differences in infection rates were observed between the two procedures.

The long-term complications considered in this review of the literature were post-operative employment and ambulation rates. The un-weighted average employment rates for the osteomyoplasty procedure was 70% compared to only 43% for the traditional procedure. The un-weighted average rate of ambulation for the osteomyoplasty procedure was 97% compared to 65% for the traditional procedure. These findings were expected and indicate that the

osteomyoplasty procedure provides a significant advantage in functional outcomes over the traditional procedure when it comes to these long-term complications.

Based on the interview with one health care professional who has extensive work with amputees following both the traditional and osteomyoplasty procedures, Dr. Carole Dionne, provided important insights. She expressed that the osteomyoplasty procedure provides better functional outcomes compared to the traditional procedure. She primarily sees osteomyoplasty patients due to the physician that is referring the patients to her. However, she noted that a patient's functional outcomes are ultimately left up to them and they must have the motivation and desire to rehabilitate to a normal, active lifestyle. For a surgeon to be able to perform the osteomyoplasty procedure they have to have a more specialized training in the procedure which takes up a lot of time, effort, and want to learn the procedure. This is part of the reason why it is not performed more often because there are a lot of surgeons that do not want to take the time or effort to gain this specialization.

In the osteomyoplasty procedure, creating a distal bone bridge requires additional surgical steps compared to a traditional amputation. This results in the osteomyoplasty surgical technique requiring a significantly longer surgery time compared to the traditional technique. When deciding which amputation procedure to use on patients, this should be taken into account because those who receive an osteomyoplasty have to be in good enough health to undergo a surgery that long [15]. Due to increased surgical steps and increased surgery time, this might limit the patients that can undergo the osteomyoplasty procedure because they have to be deemed healthy enough to be able to go through the procedure. This could be a reason as to why the osteomyoplasty procedure more than likely benefits young and active patients. In contrast, non-traumatic amputees tend to have other health co-morbidities and require an amputation due to

diabetic complications, vascular disease, cancer, etc. which is a reason that they might not be healthy enough to undergo the osteomyoplasty procedure. If patients are able to undergo the osteomyoplasty procedure it can restore the intraosseous pressure through the medullary canal and expand the terminal end of the residual limb through the bony bridge [16]. Expanding the terminal end of the residual limb decreased pain significantly and increases the ability to fully weight bear on the residual limb. This allows for better functional outcomes in patients that exert a lot of physical energy [16].

Although this research has provided important insights into the advantages and disadvantages of the osteomyoplasty technique, it is not without some limitations. First, many of the studies that were included in the literature review did not make direct comparisons between the traditional and osteomyoplasty procedures. Not a lot of research has been conducted that directly compare the outcomes of these two procedures so comparisons in the literature reviewed results were made more between each of the studies included rather than being able to directly compare the two procedures within each study. This is limiting because patient population in every study was different making it more difficult to make comparisons between the two procedures. Also, there was not a lot of research for certain aspects of each aim. For example, it was not possible to distinguish between the advantages and disadvantages of the two procedures based on the surgical site or location (i.e., transtibial vs. transfemoral) and cause (i.e., traumatic vs. non-traumatic) in all cases. Another limitation was that only one person was interviewed for their attitudes and beliefs about the traditional procedure compared to the osteomyoplasty procedure. All of the answers and attitudes and beliefs conclusions were made based off of one interview. In the future, the study could be strengthened by interviewing a larger number of health care professionals.

Future research is needed that makes more direct comparisons between the traditional and osteomyoplasty procedures. Also, studies should distinguish between traumatic and non-traumatic cases. This would provide additional insights since non-traumatic patients tend to not be as healthy overall compared to patients who experience a traumatic injury. Combining both traumatic and non-traumatic limits the conclusions that can be reached by reviewing the research.

In conclusion, we have noted some advantages to the osteomyoplasty procedure compared with the traditional procedure, including stump revision, employment, and ambulation. The major disadvantage of the osteomyoplasty procedure may be the average time to prosthesis/ambulation. While the osteomyoplasty procedure may have advantages over the traditional procedure because of better functional outcomes than the traditional procedure, further research is needed and training in the procedure before it is likely to be more widely used.

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