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PROSTHETICS AND ORTHOTICS

Current rates of prosthetic usage in upper-limb amputees – have innovations had an impact on device acceptance?

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ABSTRACT

Purpose: There is a large body of evidence demonstrating high rates of prosthesis abandonment in the upper extremity. However, these surveys were conducted years ago, thus the influence of recent refinements in prosthetic technology on acceptance is unknown. This study aims to gather current data on prosthetic usage, to assess the effects of these advancements.

Materials and methods: A questionnaire was sent to 68 traumatic upper limb amputees treated within the Austrian Trauma Insurance Agency between the years 1996 and 2016. Responses were grouped by the year of amputation to assess the effect of time.

Results: The rejection rate at all levels of amputation was 44%. There was no significant difference in acceptance between responders amputated before or after 2006 ($p = 0.939$). Among users, 92.86% ($n = 13$) used a myoelectric, while only one amputee (7.14%, $n = 1$) used a body-powered device. Most responders complained about the comfort (60.87%, $n = 14$) as well as the weight of the device (52.17%, $n = 12$).

Conclusions: The advancements of the last decade in the arena of upper limb prosthetics have not yet achieved a significant change in prosthetic abandonment within this study cohort. Although academic solutions have been presented to tackle patient's complaints, clinical reality still shows high rejection rates of cost-intensive prosthetic devices.

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➤ IMPLICATIONS FOR REHABILITATION

- Abandonment rates in prosthetic rehabilitation after upper limb amputation have shown to be 50% and higher.
- The advancements of the last decade in the arena of upper limb prosthetics have not yet achieved a significant change in prosthetic abandonment.
- Well-structured and patient-tailored prosthetic training as well as ensuring the amputee's active participation in the decision making process will most likely improve prosthetic acceptance.

Introduction

The loss of a hand or an arm poses a severe challenge to the amputee, often permanently impairing working status as well as independence and quality of life [1]. Prosthetic reconstruction is an important goal to facilitate a reintegration into social and working life for these individuals, who are generally young and otherwise healthy [2,3]. However, the percentage of long-term prosthesis users is limited, varying substantially among different reports [4–7]. Depending on the level of amputation, prosthetic usage rates in upper extremity amputees ranging from 9 to 81% can be found in literature [4,5,7–9]. This wide variance may be due to the heterogeneity of investigated cohorts, regarding factors such as level of amputation and type of terminal device [4]. The largest review on upper-limb prosthesis use and abandonment has shown, that on average one of every five individuals rejects their device [4]. In general, distal amputations have higher prosthetic acceptance rates, while rejection is seen in 60% and higher in above-elbow amputees [4,7].

Over the last decades, a great variety of functional outcome measurements have been established to evaluate overall capability and manual dexterity after prosthetic rehabilitation [10–12]. It is important to take these functional aspects into account when assessing outcomes, as patients may use their myoelectric prostheses for cosmetic purposes only [13,14]. Thus, success of prosthetic rehabilitation in upper limb amputees cannot be defined just by frequency of use or abandonment rate [15]. Still, the rate of non-users is of utmost importance, in particular when considering that prosthetic rehabilitation with myoelectric devices represents a highly cost intensive endeavor for service providers.

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

Several surveys have been conducted investigating the reasons for use or non-use of prosthetic hands, as well as factors related to a successful prosthetic rehabilitation and patients' concerns about different prosthetic features [16–20]. Satisfaction with device function and comfort have been shown to be the most important predicators for successful prosthetic rehabilitation among upper limb amputees [21–23]. Thus, numerous advancements within the last decade have aimed to improve on these areas, addressing the well-known concerns users have about their prostheses. Such developments include lightweight lithium batteries, life-like silicone gloving material, customized silicone sockets, multiarticulating hands, optimized control strategies through nerve transfers or advanced signal processing techniques, osseointegration for improved mechanical attachment or implanted interfacing sensors, just to name a few [4,24–28]. While many of these advances have reached routine clinical application, there is no evidence that they truly had an impact on prosthetic acceptance in upper limb amputees [29].

Most of the existing surveys and studies were carried out more than 10 years ago, therefore, not considering the mentioned advances in prosthetic technology and amputation surgery. Furthermore, surveys were largely performed either at the treating and limb-fitting facility or in other pre-selected scenarios, where possible non-users and patients who had broken ties with the respective facility may not be accounted for. Thus, the aim of this study was to gather unbiased, up-to-date information on prosthetic use from all major upper limb amputees of the last 20 years in Austria, who were registered within the Austrian Trauma Insurance Agency.

Materials and methods

Questionnaire

An interdisciplinary group consisting of plastic-reconstructive surgeons, a physiotherapist, an orthopedic technician and clinical statistician designed the questionnaire. The questionnaire collected data on current prosthetic use and on demographic, amputation-related and prosthesis-related factors. General demographic facts of interest were age, gender, marital status, and profession. Amputation-related factors were age at amputation, reason for amputation, level as well as side of amputation and prior dominant hand. Prosthesis-related factors were time of first prosthetic fitting in relation to the amputation, number and type(s) of prosthetic fitting, prosthesis wearing time, amount of prosthetic training, perceived prosthetic usefulness, prosthetic satisfaction, and pain levels.

The questionnaire was evaluated and distributed during a short pilot phase to five upper limb prosthetic users who routinely visited our outpatient clinic. Two questions were considered to be imprecise and thus were modified after discussion among the authors. The survey was accessible online on the webpage of our institute between September and December 2018. The link to the website was distributed with an invitation letter where interested patients could choose either completing the questionnaire online or returning it by pre-paid mail. All questionnaires with a minimum of 50% completed answers were used. Inclusion criteria for the questionnaire study were traumatic major upper limb loss through or proximal to the radiocarpal joint, age of 18 years or older and registration within the Austrian Trauma Insurance Agency, who treat working as well as non-working accidents. If a question was not answered by all patients, the number of responders was separately included into the results. The study was approved by the institutional review board of the Austrian Trauma Insurance Agency (approval number 8/2016).

Patients

We identified 68 eligible amputees who have suffered a traumatic amputation at the wrist or proximal to the wrist in the years from 1996 to 2016 and were treated in one of the seven hospitals of the Austrian Trauma Insurance Agency. Patients were identified using ICD-10 codes and candidates who met all inclusion criteria were contacted with a postal invitation letter containing the link to the online questionnaire.

Statistical analysis

Data were processed using IBM SPSS Version 21 (IBM Corp., Armonk, NY). A two-tailed Mann–Whitney *U*-test, Chi square test as well as Cramer's *V* correlation test were used for the analysis, with an alpha level of 0.05. Equality of variances was not assumed.

Results

Patient demographics

Out of the 68 identified individuals with a major upper limb amputation, 25 responded (36.76% response rate). The mean age at the time of survey was 50.24 ± 16.36 years. All responders were unilateral upper limb amputees. Twenty-eight percent ($n = 7$) had suffered a below-elbow amputation, 64% ($n = 16$) an above-elbow, and 8% ($n = 2$) a shoulder level amputation. Seventy-two percent of responders had lost their dominant hand due to the amputation. Patient demographics are documented in Table 1. There were no relevant differences in distribution between the questionnaire responders and non-responders for the variables level of amputation, gender, or age.

Table 1. Patient demographics.

Variable	Responders
Age at survey (years)	50.24 (SD 16.36)
Gender (% men)	80
Marital status at survey (%)	72
Married or cohabitant	72
Separated, divorced, single, or widowed	28
Educational level (%)	
Compulsory school	16.67
Apprenticeship	54.17
Comprehensive school (4 years)	20.83
College or university	8.33
Occupational status at survey (%)	
In paid employment	52
Self-employed	4
Not in paid employment	44
Age at amputation (years)	35.92 (SD 17.17)
Reason for amputation (%)	
Work-related	72
Non work-related	28
Unilateral amputation (%)	100
Level of amputation (%)	
Wrist	0
Forearm	28
Through or above-elbow	64
Shoulder	8
Amputation of dominant hand (%)	72
Prosthetic device of users (%)	
Myoelectric	92.86
Body-powered	7.14

Rates of prosthesis use and rejection

Only 14 out of 25 (56%) responders stated using a prosthetic device at the time of the survey. This results in a rejection rate of 44%. When responders were categorized in below- and above elbow amputees, the difference of 71.4% acceptance rate in below-elbow compared to 50% in above-elbow amputees was not statistically significant ($p = 0.407$).

Five amputees who did not use a prosthetic device at the time of survey reported that they had initially been fitted and subsequently used the device for a mean of 10.2 ± 22.25 months. However, four out of these five amputees stopped using their device after less than a month, indicating that rejection mainly occurs early on. Out of all responders, only one above-elbow amputee was not fitted with a prosthetic device after amputation due to absent muscle function.

The prosthetic users ($n = 10$) reported a mean daily wearing time of 8.7 ± 4.35 h (range 2–15 h) and a mean prosthetic experience of 14.56 ± 9.63 years ($n = 11$). The majority of amputees (92.86%, $n = 13$) used a myoelectric device, only one (7.14%, $n = 1$) used a body-powered device. The fitting was carried out on average 21.43 ± 51.35 months (range 2–198 months, $n = 14$) after the amputation. Responders who had lost their dominant hand showed a higher rejection rate (55.5%) compared to non-dominant hand loss (14.3%). However, this trend is not significant ($p = 0.062$).

Responders were also categorized according to the time of amputation, i.e., before 1996 ($n = 5$), between 1996 and 2006 ($n = 8$) and after 2006 ($n = 11$). The prosthetic acceptance rate in these groups was 60%, 50%, and 54.5%, respectively. There was no significant difference in acceptance rates between responders amputated before or after 2006 ($p = 0.939$). Furthermore, there was no significant correlation between gender ($p = 0.623$), age ($p = 0.705$), cause of amputation ($p = 0.068$), prosthetic experience ($p = 0.122$), type of device ($p = 0.914$), or time from amputation to fitting ($p = 0.711$) and prosthetic acceptance. However, six amputees reported that one or more operations have been performed prior to prosthetic fitting, five out of these responders were above-elbow amputees. All of these five responders reported active prosthetic use which shows a significant difference compared to the other amputees without additional surgery ($p = 0.020$).

Prosthetic devices were mostly used by the participants while being in society (71.43, $n = 10$) or during leisure time (71.43, $n = 10$), while only 42.86% ($n = 6$) reported frequent use during work or when performing household tasks. The results are summarized in Table 2.

Table 2. Prosthetic use.

Variable	Responders
Response rate (%)	29.1
Rejection rate (%)	44
Below-elbow	71.4
Above-elbow	50
Daily wearing-time (hours)	8.7 (SD 4.35)
Time from amputation to fitting (months)	21.43 (SD 51.35)
Prosthetic use (%)	
In society	71.43
Leisure time	71.43
Work	42.86
Areas for improvement (%)	
Comfort	60.87
Weight	52.17
Function	43.48
Aesthetic appearance	26.09
VAS score	4.77 (SD 1.73)

Prosthetic training

90.91% of patients ($n = 20$) received prosthetic training to a variable extent. A quarter of the amputees had either 1–5 or 6–10 h of training, respectively, while 16.7% received 16–20 h and 33.3% more than 20 h of prosthetic training. The amount of prosthetic training however, did not exhibit a significant ($p = 0.091$) influence on prosthetic acceptance. Additionally, the questionnaire asked if the prosthetic training was perceived as useful, whereas 70% answered with yes. If this was the case, prosthetic acceptance was significantly higher ($p = 0.003$). Still, the amount of prosthetic training showed no influence on the subjective attitude to its usefulness ($p = 0.222$). The two amputees who received no prosthetic training both do not use a prosthetic device.

Complaints about prostheses

Most responders complained about the comfort (60.87%, $n = 14$) as well as the weight of the prosthetic device (52.17%, $n = 12$). Ten responders (43.48%) mentioned that the function of the prosthesis should be improved. The aesthetic appearance was only an issue for few patients (26.09%, $n = 6$). Among prosthesis rejectors, most (70%, $n = 7$) mentioned the lack of comfort as the reason for abandonment, followed by weight (70%, $n = 7$) and function (50%, $n = 5$).

Phantom pain

Twelve percent of amputees ($n = 3$) reported not suffering from phantom pain sensation. Responders who had phantom pain ($n = 22$) showed mean VAS scores of 4.77 ± 1.73, with 31.82% ($n = 7$) reporting pain of VAS 6 or higher. Still, there was no significant correlation between VAS score and prosthetic rejection ($p = 0.229$). However, there was a significant correlation between the level of amputation and the frequency of phantom pain ($p = 0.019$), revealing that proximal amputees suffered from phantom pain more frequently. Still, only 34.78% ($n = 8$) rely on regular pain medication.

Working status

The majority of responders (86%) were able to return to an employed or self-employed status, of which 50% were able to re-enter their former job with or without retraining. These patients regained their employment after a mean time of 8.33 ± 5.95 months ($n = 15$). Sixteen percent of responders had either been sent to premature pension or were not employed at the time of the survey. There was no significant correlation between the working status and prosthetic acceptance ($p = 0.153$).

Discussion

Prosthetic abandonment was found in 44% of upper limb amputees within this study, with 29.6% for below-elbow amputees, and 50% in amputations proximal to the elbow joint. This is in contrast to most of the present literature where the rejection of all prostheses could be observed in approximately one of every five (20%) individuals with upper limb deficiency [4]. However, the majority of the previous studies were conducted on pre-selected or biased patient populations, at treating orthopedic technician or rehabilitation centers [4]. Therefore, possible non-users or patients who had broken ties with these facilities are not accounted for within these studies. Thus, to eliminate this bias, the upper limb amputees included in this study were recruited out of the register of the Austrian Trauma Insurance Agency (seven hospitals in Austria) where they have been treated for primary medical care. The first author was not affiliated with this institution.

In contrast to most of the studies of the present literature, the patient population of this study is very homogenous. Only adults with traumatic major upper limb amputations were included. The predominance of males participating in this survey is congruent with other studies [4]. However, the patient population in the present study differs from those of other surveys to the extent that the majority of patients are above-elbow amputees, which was also the case for non-responders. As expected, rejection rates have shown to be higher in above-elbow compared to below-elbow amputees, although this difference was not significant. However, other studies have shown that even in highly selected patient cohorts after TMR surgery, up to a third of the patients are non-users [29]. Nevertheless, within this cohort, patients who had undergone additional surgery prior to prosthetic fitting (most probably TMR or osseointegration) have a significantly higher acceptance rate. Interestingly, responders who have lost their dominant hand showed a higher rejection rate (55.5%) compared to non-dominant hand loss (14.3%). Although we know that after dominant hand loss the other hand will take on this role, the higher rejection rate reinforces the fact that a prosthesis can more easily replace an assisting hand instead of a highly dexterous dominant one [30].

Among our cohort, only one patient (4%) was not fitted with a prosthetic device, as prosthetic rehabilitation is fully covered by the publicly funded healthcare system in Austria. This is in contrast to the USA, where up to 48% of non-wearers reported personal costs as an influential factor for prosthetic abandonment [31]. Thus, lack of reimbursement is not a reason for device rejection in Austria. Interestingly, Roeschlein and Domholdt noted an association between users' perceived cost of the prosthesis and its subsequent use, with higher usage rates of devices thought to be more costly [32].

According to the data of this survey, a targeted and individualized prosthetic training may have a positive impact on device acceptance. The two responders who did not receive any prosthetic training were both not using a prosthesis. However, if patients received training and perceived it as useful, the rate of acceptance was significantly higher ($p = 0.003$). Still, the amount of training alone did not show an influence on prosthetic acceptance, indicating that the quality of the training seems to be the relevant factor. The desire for customized prosthetic training meeting the individual needs has also been noted elsewhere [33]. The fact that most of the prosthesis rejectors used the device only for less than a month, shows that the initial guidance and training are particularly important. As soon as the device is used for a certain time, the likelihood of abandonment seems to decrease. The time between amputation and prosthetic fitting however showed no influence on acceptance within this cohort. Along these lines, the relatively late prosthetic fitting in this cohort (mean of 21.43 ± 51.35 months), might also have contributed to the high rejection rates. Literature suggests that fittings within the first six months after amputation lead to a much higher acceptance [34]. This can be explained by individuals getting used to one-handed activities, making it harder to introduce an artificial hand to regain bimanuallity.

Comfort, weight, and function have been listed as the most critical factors for prosthetic abandonment by the responders of this study. This is consistent with previous studies [4,21,23,35]. Numerous advancements of the last decade have tried to solve user concerns in these areas, including life-like silicone gloving and socket materials, lightweight lithium batteries [36], osseointegration [26], increased speed of motion, and substantial changes in control algorithms like targeted muscle reinnervation (TMR) [37] or pattern recognition-based control [38]. In 2007, Biddiss and Chau [4] listed numerous advancements of prosthetic technology which would "pave the way for a new generation of more functional, comfortable, and aesthetically pleasing powered prostheses". More than 10 years later, most of these refinements are clinically available for many years, however, without major changes on prosthetic abandonment, according to the data of this survey. There was no detectable difference regarding prosthetic acceptance if responders suffered the amputation before or after the year 2006 ($p = 0.939$). Pylatiuk et al. [13] reported that almost all upper limb amputees would like to be able to feel the force their prosthetic hand is grasping with. Twelve years later, even such a simple feedback mechanism has not reached clinical reality. Certainly, some innovations like osseointegration [26] or implanted myoelectric sensors [27] are too recent and still have too limited patient numbers, to exhibit an impact on the data of this survey. In our experience with implantable sensors for improved myoelectric control, we have observed distinct functional benefits for our patients when compared to current surface electrodes. We believe that a combination of such an approach together with osseointegration and ideally also natural feedback will lead to major improvements in function as well as comfort, which will then also be reflected in acceptance rates when applied on a larger scale. However, it might take decades until all these techniques have reached routine clinical application.

The response rate of 29.1% was lower compared to other studies, however, this may be explained by the nature of the study as patients were selected out of a register without personal interference [4]. Additionally, the sample size limits statistical interpretation, although the number of responders is comparable to most of the present literature [4].

Numerous advancements of the last decade within the constantly changing arena of upper limb prosthetics have not yet achieved a significant change in prosthetic abandonment within this study cohort. Although solutions for improved wearing comfort, weight, and function have been presented within the last decades, the rejection rates of cost-intensive prosthetic limb replacements are still very high. However, recent invasive methods like TMR or osseointegration seem to have a positive impact on device acceptance. Thus, a combination of future technologies including osseointegration, implanted interfaces, and in particular prosthetic feedback will hopefully enhance prosthetic function in a way that is more useful for the amputee and leads to overall increased acceptance. Additionally, as well-tailored prosthetic training has been shown to be a major factor improving prosthetic acceptance, and is further expected to get additional importance for the more complex future solutions [39], ensuring high standards of training by qualified therapists, seems a cost-effective way to tackle this problem.

Finally, given the amount of new technologies entering clinical practice, it seems more important than ever to fully integrate the patient in the decision-making process to avoid expensive solutions not being used.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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