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Hand Transplantation versus Prosthetic Substitution in Upper Extremity Amputees: Current Practice and Future Prospects

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Abstract

Hand transplantation and prosthetic substitution are the only two concepts available to restore hand function after hand loss. However, the indication for either technique must be carefully weighed for each patient. Recent investigations have shown no significant difference between transplanted and prosthetic hands in below elbow amputees. Thus, treatment should be guided by what is most beneficial for the patient with the least risk of harm. Due to frequently encountered side effects of immunosuppression the indication for allotransplantation must still be restrictive, the best being bilateral hand loss.

Keywords: Hand amputation; Hand transplantation; Hand prosthesis; Upper extremity; Reconstruction

Introduction

About 1.7 million people are currently living with limb amputations in the United States whereas this number is expected to double in the year 2050 [1]. The estimated prevalence of major upper limb amputations ranges from 11.6-13.9 per 100.000 in studies conducted in Norway and the USA, respectively [1,2]. Since trauma is the leading cause especially young people are affected of upper limb amputations and suffer from potential impairments of their working status and independence in daily life [3,4].

Attempts to replace the human hand have been developing over the past 70 years [5,6]. Hand transplantation and improvements in prosthetic systems have opened new frontiers in restoring hand function after loss of hands or limbs. Vascularized composite allotransplantation (VCA) is a rising field establishing new treatment strategies for patients missing various parts of their body. Although VCA necessitates life-long immunosuppression with all known side effects, hand transplantation has the unique potential to fulfill Sir Harold Gillies principle of "replacing like with like" as such restoring a functional sensate hand [7-9]. Beside hand and face transplantation, recently, even successful uterine and penile transplantation have been reported [10,11]. Since 2013 hand and face allografts are recognized as organs and therefore listed in transplantation networks [12]. Still, hand transplantation does not represent a live-saving procedure, therefore, the risk-benefit ratio must be weighed carefully and patient selection is crucial [11,13].

Since the first successful hand transplantation in Lyon in 1998 over 100 upper extremity transplantations have been performed in 26 centers worldwide listed in the international registry on hand and composite tissue transplantation [14]. However, there were 24 known re-amputations due to non-compliance, bacterial infection or arterial ischemia and almost every single patient experienced single or multiple episodes of rejection [14,15]. Moreover, immunosuppression increases the risk of systemic infection, neoplasia, organ failure or metabolic disorders [8]. Additionally, combined procedures of face and hand transplantation had to accept fatalities as a direct consequence of immunosuppressive medication [12].

Alternatively, prosthetic hand replacement is able to restore useful hand function without the need of immunosuppression. The first electronically-driven hand prostheses were developed as a consequence of World War II [16]. Cosmetic features and technical components have improved over time and prosthetic fitting with myoelectric devices has been established as the standard of care in upper limb amputees [17]. Conventional myoelectric hands are controlled by a minimum of two individual muscle groups within the stump [16]. Prosthetic fitting can take place soon after amputation and requires short hospitalization and rehabilitation.

Some reports state that hand function is superior after hand transplantation compared to prosthetic substitution; however, these claims were without sufficient outcome evidence, since none of these directly compared the two methods [7,18-20]. The largest trial comparing prosthetic outcomes with biological alternatives has been done with replanted hands only and enrolled different prosthetic devices including body-powered tools as well as different levels of amputation [21]. Although recently transplanted hands have been compared to the outcome scores of replanted and prosthetic hands within a review using the data from Graham et al published in 1998, the literature was lacking direct comparison with up-to-date prosthetic devices [22]. To guide future treatment strategies and patient selection in extremity reconstruction the specialist community highlighted the urgency of a direct comparison of hand transplantation and prosthetic substitution [23].

Therefore we have established a multicentre study enrolling transplanted patients from centres at the Medical University of

Innsbruck, Austria and the Hand Trauma Centre at St. Hedwig's Hospital in Trzebnica, Poland to compare the functional outcome with amputees fitted with prosthetic devices at the Medical University of Vienna, Austria [13]. Altogether this study comprises seven transplanted and seven prosthetic hands at below elbow level from five transplanted (two bilateral) and seven unilateral prosthetic users. The global upper extremity function was evaluated with standard outcome measurements (Action Research Arm Test (ARAT), Southampton Hand Assessment Procedure (SHAP), Disabilities of the Arm, Shoulder and Hand measure (DASH)). These assessments monitor hand function closely related to activities of daily life. Additionally, the quality of life was evaluated with the Short-Form 36 (SF-36).

This direct comparison could not show any significant differences in functional outcome measurements between transplanted and prosthetic hands. Both groups showed very good results managing a great variety of daily-life activities reflecting their high level of independence. However, the transplanted patients showed superior outcomes in four out of eight sub scores of the SF-36 compared to the prosthetic cohort, even superior to an age-equivalent male norm sample. This observation displays satisfying physical functioning and good general health of the transplanted patients. The confounding effects of including uni- as well as bilateral transplanted or prosthetic patients may account for the encountered differences, although significances do not change when only unilateral patients are considered [13].

Concluding, we could show that there is no significant difference on functional outcomes between hand transplantation and prosthetic substitution when considering motor skills only [13]. Given these findings, patient selection should be dependent on what is most beneficial with the least risks for the patient. Hence, hand transplantation and prosthetic fitting are complementary but not competitive methods for functional reconstruction in upper limb amputees. Both procedures have their advantages and limitations. Since limb transplantation will not prolong life but may improve its quality, the risk-benefit ratio becomes far more delicate, subjective and hence, controversial.

On the other hand, estimated 20% or more of upper-limb amputees reportedly do not use their prosthetic devices [24]. This may be due to wearing discomfort, lack of functional benefit, weight, repetitive need for repair and service as well as lack of sensory feedback [25]. However, prosthetic substitution has no systemic side-effects and does not need additional surgery or medical treatment [9].

Considering the immense sensory capacity of the hand, clearly a transplanted hand is the far superior choice compared to any available myoelectric hand prosthesis. However, in unilateral hand loss, the remaining sound hand will always have far superior functional capacities and therefore will become dominant. Usually, unilateral amputees are able to perform up to 90% of the activities of daily living without any functional reconstruction [26]. Therefore, the reconstructed hand, regardless of transplanted or prosthetic, will at best be a helping hand in unilateral amputees [27-29]. However, in patients with bilateral hand loss, all sensory feedback has been lost. Thus, it may simply not be sufficient to solely replace motor skills. In these cases, the benefit of restoring some sensation, proprioception, and natural movement may outweigh the risk of life-long immunosuppression, tilting the decision making process in favour of hand allotransplantation in bilateral amputees.

Within the next years, hand transplantation as well as prosthetic technology will most definitely further improve. Interesting and promising approaches in achieving immunotolerance have been reported in animal models [30]. Not only the possible induction of donor-specific tolerance, but also sensitization and more sensitive monitoring strategies of rejection will result in a safer transfer of vascularized composite tissue [28,31]. Prosthetic control algorithms such as pattern-recognition and proprioceptive tactile feedback will enhance function and will help control complex mechatronic devices [5,16,32]. The man-machine interface will be further enhanced by the use of implantable sensors to transmit myoelectric signals to the prosthetic device [33]. Different muscle and also direct nerve interfaces are subject of current investigations with first clinical applications [33,34]. Thus, future developments in prosthetic technology will have substantial impact on the indications for hand transplantation [9,35].

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References

1. Ziegler-Graham K, MacKenzie EJ, Ephraim PL, Travison TG, Brookmeyer R (2008) Estimating the prevalence of limb loss in the United States: 2005 to 2050. Arch Phys Med Rehabil 89: 422-429.
2. Østlie K, Skjeldal OH, Garfelt B, Magnus P (2011) Adult acquired major upper limb amputation in Norway: prevalence, demographic features and amputation specific features. A population-based survey. Disabil Rehabil 33: 1636-1649.
3. Luff R, Forrest J, Huntley J (2016) The Amputee Statistical Database for the United Kingdom.
4. Salminger S, Roche AD, Hruby LA, Sturma A, Riedl O, et al. (2015) Prosthetic reconstruction to restore function in transcarpal amputees. J Plast Reconstr Aesthet Surg 69: 305-310.
5. Farina D, Aszmann O (2015) Bionic Limbs: Clinical Reality and Academic Promises. Sci Transl Med 6: 257ps12.
6. Vilkki SK, Kotkansalo T (2007) Present technique and long-term results of toe-to-antebrachial stump transplantation. J Plast Reconstr Aesthet Surg 60: 835-848.
7. Simmons PD (2000) Ethical considerations in composite tissue allotransplantation. Microsurgery 20: 458-465.
8. Brenner MJ, Tung TH, Jensen JN, Mackinnon SE (2000) The spectrum of complications of immunosuppression: is the time right for hand transplantation? J Bone Joint Surg Am 84: 1861-1870.
9. Salminger S, Roche AD, Sturma A, Mayer JA, Aszmannet OC, et al. (2016) Hand Transplantation Versus Hand Prosthetics: Pros and Cons. Curr Surg Reports 4: 8.
10. Johannesson L, Kvarnström N, Mölne J, Dahm-Kähler P, Enskog A, et al. (2015) Uterus transplantation trial: 1-year outcome. Fertil Steril 103: 199-204.
11. Jowsey-Gregoire S, Kumnig M (2016) Standardizing psychosocial assessment for vascularized composite allotransplantation. Curr Opin Organ Transplant 21: 530-535.
12. Siemionow M, Gharb BB, Rampazzo A (2013) Successes and lessons learned after more than a decade of upper extremity and face transplantation. Curr Opin Organ Transplant 18: 633-639.
13. Salminger S, Sturma A, Roche AD, Hruby LA, Paternostro-Sluga T, et al. (2016) Functional and Psychosocial Outcomes of Hand Transplantation Compared with Prosthetic Fitting in Below-Elbow Amputees: A Multicenter Cohort Study. PLoS One 11: e0162507.

14. Shores JT, Brandacher G, Lee WP (2015) Hand and upper extremity transplantation: an update of outcomes in the worldwide experience. Plast Reconstr Surg 135: 351e-60e.
15. Hautz T, Engelhardt TO, Weissenbacher A, Kumnig M, Zelger B, et al. (2011) World experience after more than a decade of clinical hand transplantation: update on the Innsbruck program. Hand Clin 27: 423-431.
16. Roche AD, Rehbaum H, Farina D, Aszmann OC (2014) Prosthetic Myoelectric Control Strategies: A Clinical Perspective. Curr Surg Reports 2: 44.
17. Salminger S, Sturma A, Herceg M, Riedl O, Bergmeister K, et al. (2015) Prosthetic reconstruction in high amputations of the upper extremity. Orthopade 44: 413-418.
18. Carty MJ, Bueno E, Lehmann LS, Pomahac B (2011) A position paper in support of hand transplantation in the blind. Plast Reconstr Surg 128: 510e-515e.
19. Schneeberger S, Ninkovic M, Gabl M, Ninkovic M, Hussl H, et al. (2007) First forearm transplantation: outcome at 3 years. Am J Transplant 7: 1753-1762.
20. Agnew SP, Ko J, De La Garza M, Kuiken T, Dumanian G, et al. (2012) Limb transplantation and targeted reinnervation: a practical comparison. J Reconstr Microsurg; 28: 63-68.
21. Graham B, Adkins P, Tsai TM, Firrell J, Breidenbach WC (1998) Major replantation versus revision amputation and prosthetic fitting in the upper extremity: a late functional outcomes study. J Hand Surg Am 23: 783-791.
22. Breidenbach WC, Meister EA, Becker GW, Turker T, Gorantla VS, et al. (2016) A statistical comparative assessment of face and hand transplantation outcomes to determine whether either meets the standard of care threshold. Plast Reconstr Surg 137: 214e-222e.
23. Kay S, Wilks D (2013) Invited comment: Vascularized composite allotransplantation: an update on medical and surgical progress and remaining challenges. J Plast Reconstr Aesthet Surg 66: 1456-1457.
24. Biddiss EA, Chau TT (2007) Upper limb prosthesis use and abandonment: a survey of the last 25 years. Prosthet Orthot Int 31: 236-257.
25. Biddiss E, Chau T (2007) Upper-limb prosthetics: critical factors in device abandonment. Am J Phys Med Rehabil 86: 977-987.
26. Bhaskaranand K, Bhat AK, Acharya KN (2003) Prosthetic rehabilitation in traumatic upper limb amputees (an Indian perspective). Arch Orthop Trauma Surg 123: 363-366.
27. Schuind F, Abramowicz D, Schneeberger S (2007) Hand transplantation: the state-of-the-art. J Hand Surg Eur 32: 2-17.
28. Piza-Katzer H, Wechselberger G, Estermann D, Gabl M, Arora R, et al. (2009) Ten years of hand transplantation experiment or routine. Handchir Mikrochir Plast Chir 41: 210-216.
29. Aszmann OC, Roche AD, Salminger S, Paternostro-Sluga T, Herceg M, et al. (2015) Bionic reconstruction to restore hand function after brachial plexus injury: a case series of three patients. Lancet 385: 2183-2189.
30. Kueckelhaus M, Fischer S, Seyda M, Bueno EM, Aycart MA, et al. (2016) Vascularized composite allotransplantation: current standards and novel approaches to prevent acute rejection and chronic allograft deterioration. Transpl Int 29: 655-662.
31. Szajerka T, Klimczak A, Jablecki J (2011) Chimerism in hand transplantation. Ann Transplant 16: 83-89.
32. Antfolk C, D'Alonzo M, Rosén B, Lundborg G, Sebelius F, et al. (2017) Sensory feedback in upper limb prosthetics. Expert Rev Med Devices 10: 45-54.
33. Pasquina PF, Evangelista M, Carvalho AJ, Lockhart J, Griffin S, et al. (2014) First-in-man demonstration of a fully implanted myoelectric sensors system to control an advanced electromechanical prosthetic hand. J Neurosci Methods 244: 85-93.
34. Urbanchek MG, Kung TA, Frost CM, Martin DC, Larkin LM, et al. (2016) Development of a Regenerative Peripheral Nerve Interface for Control of a Neuroprosthetic Limb. Biomed Res Int 2016: 5726730.
35. Jones NF (2002) Concerns about human hand transplantation in the 21st century. J Hand Surg Am 27: 771-787.