はじめに】

義足ソケットの選択は下肢切断者のリハビリテーションにおいて極めて重要な課題であり、切断者の身体的および社会的因子を総合的に考慮し決定される。中でも切断原因や断端長、断端周径（形状）といった因子が最も重要であるが、これらの情報は採型時に必須項目として記録されるものの、一般に知られることはなく、我が国ではこれらに関する基礎資料はない。

演者らは、「これまで義肢装具士はどのような切断者にどのような義肢をつくってきたか」をテーマに当研究所・補装具製作部における切断者と製作した義肢に関する詳細な調査を進めている。今回、義足ソケットの選択に関わる重要な因子である切断原因、断端長および断端周径変化の傾向および選択したソケット形式との関係について調査したので報告する。

【方法と結果】

参考文献に記載の方法により作成したデータベースを基に、切断者ごとの切断部位、切断原因、断端長、周径データおよびソケット形式を抽出・集計し、統計的解析を行った。対象者は下肢切断者 640 名である。紙面の都合上、ここでは断端長の分布とその傾向について述べる。

《断端長分布とその傾向》

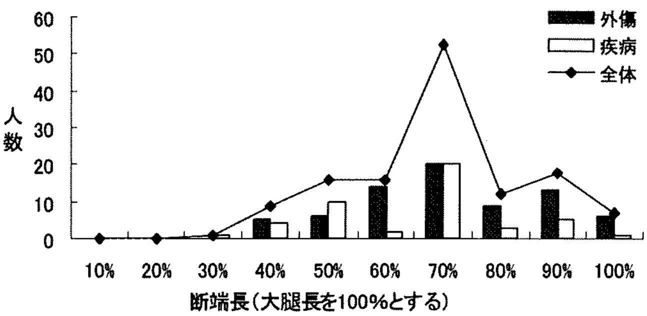
対象：片側下腿切断者 237 名および片側大腿切断者 212 名

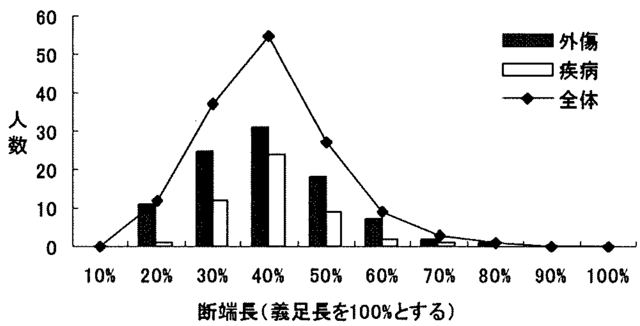
方法：切断者の初回製作時のデータより断端長を抽出し、切断原因別に比較した。なお、断端長は実務上、実際の長さで表記されることが多いが、個体差を考慮し、下腿切断者の断端長は下腿長（義足長）に占める割合、大腿切断者の断端長は大腿長（義足長－下腿長）に占める割合で表記した。また、得られたデータの統計的解析は Kruskal-Wallis 検定を行なった。

① 下腿切断

断端長分布を図 1 に示す。平均断端長は 35.2%±SD11.6%であった。切断原因別にみると

外傷性切断は平均値 34.8%±SD12.7%、疾病による切断は平均値 36.0%±SD9.4%であり有意な差は認められなかった。





平均断端長は 64.2%±SD17.0%であった。切断原因別にみると外傷性切断は平均値 66.7%±SD17.0%、疾病による切断は平均値 60.2%±SD16.5%であり有意な差を認めた（＜0.05）。特に疾病を原因とする切断では二峰性を示し、血行障害による切断は長断端側に偏在していた。

【おわりに】

本調査結果は経験のある義肢装具士が聞くと当たり前のことであるかもしれない。しかし、昨今の切断術では十分な断端長を有しても、断端の不整などソケットの適合と義肢製作に懸念を持つ事例も少なくない。現状における切断術はソケットの選択を含めた切断リハを十分に考慮しているとは言えず、これを改善するためには本調査で示すような基礎的情報を義肢装具士から提供し、共有化することが必要であると考えている。

口演ではこれに加え、断端周径変化の様子と切断原因および選択されたソケット形式との関係についても述べる。

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中村　隆．補装具製作部における切断者の調査とその傾向－義肢装具士の製作記録から－．国立身体障害者リハビリテーションセンター研究紀要．No.28，2007，p.93-103.

成果 2

非切断肢にも機能障害を伴う一側上肢切断者に対する筋電義手，作業用義手の有効性

上肢切断　筋電義手　作業用義手

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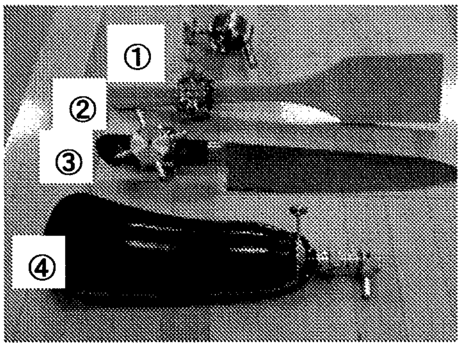
【はじめに】2008 度より労災保険による筋電義手支給対象が改訂された．これを受け当院に筋電義手製作目的で入院した，非切断肢にも機能障害を伴う一側上肢切断者に対し筋電義手，作業用義手を製作し訓練を実施した．その経過と結果を基に非切断肢にも機能障害を伴う者に対する筋電義手使用の効果をまとめたので報告する．

【症例】50 歳代男性．元シェフ．5 年前，仕事中に両手関節を切断．再接着術が施行されたが右は壊死し再切断（前腕切断 92%），左は生着するも手指は重度の ROM 制限，筋力低下（ピンチ力 500g）など機能低下をきたした．前医にて右前腕能動義手が製作されたが，手先具が上手く開かないこと，操作時に頸部～肩周囲に痛みが出現することなどから習得できず，能動義手への拒絶感も生じていた．ADL では，歯ブラシや髭剃り機は両手で挟み使用しなくてはならず，靴下着脱，ボタン留めなどには介助を要し，太柄スプーンでの食事以外に非切断肢を単独で使用できる場面はほとんど無く，在宅生活では家族の介助を受けていた．心理面では，「手がないから」と外出を控える面もあった．

【今回製作した義手と効果】①筋電義手：ADL 自立を目的に製作．ソケットは差し込み式とし，長断端であるためピンつきシリコンライナーによる懸垂を採用した．ハンドは手部切断用 DMC ハンドとした．その結果，筋電義手で歯磨き，髭剃りが，両手で靴下着脱が可能になった．またわずかに機能改善した左手指で，バネ付き箸やボタンエイド，ループ付きタオルなどの自助具を活用したり，財布から義手でお金を出す際に財布を掴んで保持するなどの両手動作が可能になり，昼間帯は常に筋電義手を装着し実用的に活用していた．義手使用中に頸部～肩周囲に痛みは出現しなかった．

②作業用義手：筋電義手での調理は，特に包丁を本人の思い通りに操作することは出来無かった．そのため作業用義手を製作した．ソケットは筋電義手と同様のライナー式ソケットとし，手先具に鎌持ち金具を採用して包丁・ヘラを取り付けた．鎌持ち金具は取り外しや回旋が容易になるようにレバーを取り付け改良した．その結果，目的に応じて自身で包丁やヘラ，義手を付け替えることにより調理が可能になった．



製作した作業用義手　①鎌持ち金具　②調理ヘラ(鎌持ち金具付)

③包丁(鎌持ち金具付)　④作業用義手(包丁⇔ヘラなどの付け替

心理面では積極的に外出する機会が増えたり，「期待以上のことができ，これまでの生活とは劇的に変わった」や「シェフの経験を活かして料理教室を開きたい」など意欲的な発言が聞かれるようになった．

【まとめ】非切断肢にも機能障害を伴う一側上肢切断者が筋電義手を使用することの効果として，①両手で行っていた活動が片手で，介助を受けていた活動が両手でできるようになる．②義手で主動作を行えるようになるため，非切断肢に要求される役割が主動作から補助動作に変わり，ROM 等のわずかな機能改善でも非切断肢を活用できる場面が格段に増える可能性がある．③ハーネスが不要であることは，義手の付け替えが容易となるだけでなく，身体的負担や心理的負担も軽減させる可能性があることが分かった．

【おわりに】義手は，身体機能，生活状況など個々に合わせた製作が可能である．今回，症例に適した義手を製作したことで，義手を活用し一人暮らしが可能になった．今後も個々のニード，生活スタイルに合わせた義手の製作が必要である．

成果 3

幼児筋電義手の公的支給：事例報告

筋電義手　幼児　公的支給

国立障害者リハビリテーションセンター[1)]
兵庫県立福祉のまちづくり研究所[2)]

三田　友記[1)]、山崎　伸也[1)]、赤居　正美[1)]
松原　裕幸[2]

【はじめに】 幼児筋電義手装着の利点には以下の点がある[1)]。①両親の心理的ケアに役立つ。②義手をボディイメージの中に統合し、義手の受入れを容易にする。③両手動作を促進する。④ボディバランスを改善する。

当センターでも上記の利点を踏まえた上での積極的なアプローチの必要性を認識しており、これまでに数名の幼・小児への試用評価を行ったが、いずれも実使用には至っていない。今回、平成19年に幼児1名へのアプローチを開始し、翌年に公的支給に至ったので、その経過について報告する。

【対象】

H17/12/5生　男児

横断性欠損（右手根骨）

両親との3人家族、

都内在住

【義手の仕様】

・装飾義手:顆上支持ソケット、パッシブハンド(旧Centri製)

・筋電義手（主な部品）: Electrohand 2000 8E51=5 1/2, 4in1 Controller LS 9E370, Coding Plug 13E184=2(Digital) 後に13E184=4(DMC), 以上Otto Bock製

【経過】　H18/5（生後5ヶ月）：都内大学付属病院を受診。医師を介して同病院担当POから兵庫リハを勧められたが、遠方により断念。その後、父親が情報収集を行う。

H19/10/5（1歳10ヶ月）：当センター病院受診

H19/12/5（2歳0ヶ月）：装飾義手試用評価開始

H20/1/8（2歳2ヶ月）：筋電検出開始

H20/1/22（2歳2ヶ月）：自宅にて装飾義手の試用状況記録

H20/2/14（2歳3ヶ月）：筋電検出・電極位置の決定

H20/2/21（2歳3ヶ月）：2電極にて筋電義手試用評価開始

H20/3/7（2歳4ヶ月）：自宅にて筋電義手試用状況記録

H20/4/4（2歳4ヶ月）：成長に伴うソケット交換

H20/5/16（2歳5ヶ月）：プラグをDigitalからDMCに変更

H20/6/24：意見書、見積書、説明書と共に区へ支給申請

H20/7/18（2歳6ヶ月）：成長に伴うソケット交換

H20/7/27：補足意見書を求められPOから区へ提出

H20/10/3：区の担当職員が自宅にて試用状況を視察

H20/10/22：自立支援法による補装具費支給決定

H21/4/3（3歳3ヶ月）：ソケット交換　　　現在に至る

【アプローチと考察】 装飾義手の受入れが良好であったため、筋電義手への移行がスムースであった。MyoBoy での筋電導出の際には、まず母親の筋電導出を行って児の模倣を促し、次いで児の健側、対象側の順に行った。当初、屈筋側の随意的な信号出力は確認したが、伸筋側には再現性が見られず、分離状況は不良であった。しかし、重量への適応を図る目的で筋電義手の貸出を開始したところ、翌日からリリース動作が定着した。その後の訪問では言語での指示に沿った開閉操作や、玩具で遊ぶ際の的確な開閉操作を確認した。

支給に関しては筋電義手の必要性と年間の製作修理にかかる費用等に関する補足意見書を求められ提出した。その後、区の担当者3名が自宅訪問にて試用状況を視察し（PO立会い）、その3週間後に支給が決定された。区の担当者によると都では幼児筋電義手の公的支給は前例が無かった。

現在、プリスクールと呼ばれる英語環境での保育施設に通園しており、スクールでのアクティビティの他、自転車、鉄棒など両手動作を要する様々な活動を行い、幼児筋電義手装着の利点が現れている。実使用に至った要因として、切断レベルおよび開始年齢と装着率との相関[1]が挙げられる。また、兵庫リハPOとの情報交換を密に行い、効率的なアプローチが可能となったことも一因である。今後、当センターでの取組み体制、およびOTとの連携について検討する。

【参考文献】

1) 陳隆明：義手の現在－上肢リハビリテーションの今後－

日本義肢装具学会誌，20：37-41，2004

成果4

NEUROCASE

2009, *iFirst*, 1–7

http://www.psypress.com/neurocase DOI: 10.1080/13554790902950442

Metal bar prevents phantom limb motion: Case study of an amputation patient who showed a profound change in the awareness of his phantom limb

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This case report describes an amputee (patient A.S., a 60-year-old male forelimb amputee) who had an extraordinary experience with a phantom limb. He complained that he could not move the wrist of his phantom limb because a metal bar was perceived to be grasped by the hand. As a solution for removing the metal bar, we invited the patient to undergo mirror reflection-induced visual feedback therapy. The patient reported that the metal bar previously grasped by his hand was successfully removed from the phantom during the course of therapy. Interestingly, this experience was accompanied by profound changes in the EMG modulation in the residual wrist muscles. In this article, the possible mechanisms underlying this interesting phenomenon will be discussed.

Keywords: Phantom limb; Kinesthesia; Mirror; Visual feedback; Electromyography.

INTRODUCTION

A phantom limb is the sensation that an amputated limb is still attached to the body and is moving together with other body parts (Hunter, Katz, & Davis, 2003; Melzack, 1992; Ramachandran & Hirstein, 1998). This sensation is reported by almost all amputees, and is usually accompanied by pain (Flor, Nikolajsen, & Staehelin Jensen, 2006). It is now well recognized that amputation results in reorganization of the sensorimotor cortex: with the area previously innervated by the amputated limb now occupied by the adjacent region (Flor et al., 1998; Ramachandran, Rogers-Ramachandran, & Stewart, 1992). Researchers believe that this reorganization may partly explain phantom limb sensation and pain (Flor et al., 1995; Willoch et al., 2000).

While some amputees have a vivid kinesthesia for their phantom limb, previous studies have described others as having an awareness of the missing limb as clenched and paralyzed in a specific position (Hunter et al., 2003; Ramachandran & Rogers-Ramachandran 1996; Reilly, Mercier, Schieber, & Sirigu, 2006). One possible interpretation for the latter case is that the amputee cannot send motor commands to the missing limb. This interpretation can work under the premise that the patient does not have a motor representation of the phantom limb anymore. However, given previous findings showing that the awareness of the phantom limb can be enhanced with viewing an image of their intact hand, which can create a visual illusion of their missing hand (i.e., the 'mirror box') (Hunter et al., 2003; Ramachandran & Rogers-Ramachandran 1996), it is reasonable to consider

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that the patients still possess the ability to send motor commands to the missing part. With regard to this point, Mercier, Reilly, Vargas, Aballea, and Sirigu (2006) have recently reported an interesting result that the sense of motion in the phantom limb can be re-awakened through transcranial magnetic stimulation of the motor cortex, even when the patient has a 'paralyzed' phantom limb.

The patient in this case study, A.S., is a forearm amputee who had an extraordinary experience with the phantom limb. He complained that the wrist flexion motion of his phantom limb was prevented by a metal bar grasped in his hand. He also said that his experience of the phantom limb involved severe pain. Based on the above-mentioned recent findings, we speculated that A.S. might still have been able to send motor commands to the missing limb, but that the presence of the metal bar and/or pain prevented the neural circuit from functioning properly. In order to reactivate motor commands to the phantom limb, we decided to utilize a 'mirror box', which is based on the concept that the mirror-induced artificial visual feedback of the missing limb can enhance awareness of the phantom limb (Hunter et al., 2003; Ramachandran & Rogers-Ramachandran, 1996). Although direct evidence is still limited, the effects of the mirror therapy on the phantom limb pain have been described in some case reports (MacLachlan, McDonald, & Waloch, 2004; Ramachandran, Rogers Ramachandran, & Cobb, 1995) and have been observed in some recent clinical trials (Brodie, Whyte, & Niven, 2007; Chan et al., 2007). We therefore hypothesized that the mirror therapy would be an effective method for allowing A.S. to release the metal bar and thus relieve the phantom limb pain.

In order to evaluate the phantom limb motion, we recorded muscle electromyographic (EMG) activity of the residual wrist flexor and extensor muscles near the amputation stump. With regard to EMG measurements, Reilly et al. (2006) have recently recorded the EMG activities of the residual muscles in the upper amputees and reported that different intention of the phantom limb movements are associated with distinct muscle EMG activity in the residual stump muscles. Also, in a preliminary experiment with six forearm amputees, we confirmed that the forearm stump muscles demonstrated clear EMG activities that correlated with the phase of phantom wrist motion. We therefore assumed that changes in phantom limb motion can be quantitatively evaluated by EMG recordings. The purpose of this study was twofold: first, to describe A.S.'s unique phantom limb condition, and second, to examine the changes in the phantom limb condition due to the therapy via EMG recordings of the stump muscles.

METHODS

The patient (A.S.) was a 60-year-old man amputated at the left forearm. A.S. suffered an injury in which his hand was crushed by a machine at his workplace. Although the injured forearm was almost completely separated from the body and completely paralyzed, it was preserved for 4 days. However, because of severe pain and no sign of recovery, the paralyzed forearm was surgically amputated. The amputation position was 9 cm distal to the lateral epicondyle. The first time A.S. came to the laboratory, 2 months after the amputation, one author (T.M.) conducted an interview with A.S. about his missing limb. During the interview, A.S. was first asked whether he felt any sensation of the missing limb. When he replied that he still felt sensation of the limb accompanied by pain, T.M. asked him to move his phantom limb. However, he said that he could not move it well. Surprisingly, when A.S. tried to move the wrist joint of his phantom forearm, he said 'I cannot move it because the metal bar is preventing wrist flexion'. According to him, the metal bar was massive, cold, and approximately 10 cm long. He felt the metal bar more as an artificial object than as a part of his body. He also said that the extent of the feeling of the metal bar changed somewhat day by day, but that the bar was continuously grasped in the phantom hand. To gain a better understanding of this phantom limb condition, we asked A.S. to replicate the condition of the phantom limb using the intact hand. As shown in Figure 1A, wrist motion was prevented by the bar that was placed on the wrist joint. We also made a projection drawing to facilitate the visualization of the phantom limb's condition in accordance with his verbal comments (see the figures shown at the bottom of Figure 1A). As shown in this figure, the phantom limb was shorter than the intact limb. The phantom limb pain was perceived as being like an electric shock, and lameness around wrist and became much more pronounced on cold and humid days. A feeling of sweating around the base of the fingers was perceived when he tried to move the phantom hand.

Mirror therapy

Before participating in the therapy, A.S. gave informed consent which was approved by the ethics committee of the National Rehabilitation Center for Persons with Disabilities. The mirror therapy utilizes a simple method in which a mirror provides reflection-induced visual feedback of the phantom limb. A.S. placed his intact arm on one side of the mirror, which was positioned in such a way that he could see the reflection of the intact hand as another side of the hand (Figure 1B). A.S. was instructed to perform synchronous and periodic (flexion to extension and vice versa) wrist motions using both intact and phantom limbs with the visual feedback. We asked him to carry out the motion as smoothly and in as large a range as he could without a specific prescription regarding the magnitude and speed of the wrist motion. He performed the therapy for 1 h per week during 3 months of hospitalization.

Measurements

In order to record the changes in phantom limb motion, we conducted the following experiments at the beginning of therapy, the end of therapy, and at a 6-month follow-up evaluation. Similar to the therapy sessions, the experiment also consisted of synchronous and periodic wrist motions using both intact and phantom limbs. During the experiment, however, A.S. performed the wrist motion without a mirror. A.S. was asked to describe the difficulty of phantom limb motion using a visual analog scale (VAS: ranging from 0 (hard) to 10 (easy)). He was also questioned regarding the degree and type of pain from his phantom limb.

The patient was instructed to conduct the motion for 30 s at a comfortable speed. During the movement, bilateral muscle EMG activity was obtained from the extensor digitorum longus (EDL) and flexor carpi radialis muscles (FCR) with bipolar electrodes. As mentioned above, the patient underwent amputation at the left forearm 9 cm distal to the lateral epicondyle, so he still had his EDL and FCR muscles. The EMG signal was amplified and band-pass filtered between 20 and 450 Hz (The Bagnoli-8 EMG System, DELSYS, USA). In order to measure changes in wrist angle, an electrogoniometer (Goniometer System, Biometrics Ltd, Ladysmith, VA, USA) was attached to the wrist joint on the intact side. In the present study, we assumed that the wrist motion of the intact side might reflect the phantom limb motion because A.S. was asked to move both wrists synchronously. Since the EMG data were obtained on different days, we should be careful in comparing these data. We used bipolar electrodes (DE-2.3, DelSys, Inc., Boston, MA, USA) with a constant interelectrode distance (1 cm apart), and tried to place the electrodes at the same locations among the three testing sessions. Also, in order to reduce the

Figure 1. (A) A reproduction of the condition of the phantom limb using the intact hand. A.S. said that wrist motion was prevented when the bar was placed on the wrist joint. The drawings in the bottom picture, which were drawn by one of the authors (T.M.) based on comments provided by A.S., represent the conditions of the phantom limb. (B) Mirror therapy. A.S. was asked to participate in mirror therapy, which consists of visual feedback of the phantom limb by way of a mirror reflection of the intact

hand.

impedance between electrode and muscle, skin preparation (abrasion, cleaning with alcohol) was carried out carefully before recording. During the testing session, all data were continuously monitored by Power Lab software (Chart ver. 5, AD Instruments, USA) and were digitized at 1 kHz for later analysis.

Statistics

All values are given as the mean ± *SD*. One-way ANOVA with repeated measure was used to test the effects of therapy on wrist motion and EMG size among three data sets. If the results of ANOVA were statistically significant, a multiple comparison (LSD) was applied to identify differences between data points. Significance was accepted at $p < .05$.

RESULTS

Figure 2A shows the waveform of the wrist joint angle recorded from the intact side and the EMG activity of the FCR and EDL muscles in both arms. The quantified wrist motion frequency, range of motion (ROM), and EMG levels of each muscle are summarized in Figure 2B. As mentioned in the Methods section, we assumed that the wrist motion of the intact side might reflect the phantom limb motion when A.S. conducted bilateral synchronous wrist motions. As clearly shown in Figure 2A,B, the wrist motion frequency and ROM obtained from the intact side were consistent