

A cosmetic functional hand incorporating a silicone rubber cosmetic glove

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Abstract

A body powered hand prosthesis has been developed with a view to meeting some of the more common criticisms made against currently available designs i.e. weight and cosmetic appearance. An overall weight reduction of about 30 per cent has been achieved and the use of silicone rubber as the cosmetic glove material has resulted in greatly improved cosmesis and stain resistance. The prosthesis also incorporates a new style of prehension that is felt to give improved visibility when picking up small objects.

The hand has been produced in conjunction with the endoskeletal arm system also under development at the Orthopaedic Bio-Engineering Unit, Edinburgh.

Introduction

The hand prosthesis described was developed initially for use in conjunction with the body powered modular arm system being designed at the Orthopaedic Bio-Engineering Unit, Edinburgh, but it is also compatible with the standard wrist socket fitted to artificial arms supplied in the United Kingdom.

There were several reasons for choosing to develop a new type of hand rather than use an existing prosthesis. Firstly, the prostheses available at present generally have limited functional capacity, using simple criteria such as maximum opening and the ability to pick up and hold commonly used objects. They also tend to be rather heavy. These judgements are based partly on clinical experience but also on the performance specifications that have been laid down by several groups, an excellent example being that of Peizer *et al* (1969). These criteria can be applied to both the

externally powered and body powered hands that are available, although the various experimental multi-degree of freedom prostheses which are currently being developed do not really qualify for comparison because they could not at present be fitted routinely in the clinic. The second reason for development of the hand is the production of new types of silicone rubber with a sufficiently high tear strength to be suitable for cosmetic gloves. These materials, with their ease of processing and inherent non-staining characteristics, have considerable potential for improving cosmetic appearance. The excellent results of Dr. J. Pillet, Chef du Centre Prothèse Plastique et Restauratrice de L'Hôpital St. Antoine, 76 Avenue Marceau, Paris V111^e demonstrate the point. A significant objection has always been the high cost of such material but this has now fallen to the point where, although still expensive compared with polyvinyl chloride (PVC), it accounts for a relatively small proportion of the cost of the prosthesis as a whole. Whilst it might be argued that existing prostheses could equally well be fitted with silicone rubber gloves, it was felt that in the interests of cosmesis the mechanism of the hand should be shaped to fit the cosmetic glove rather than *vice versa*. The results seem to bear out this point of view although it has necessitated the development of new techniques for the design and construction of the hand mechanism. Fortunately, these new techniques have also led to a significant weight reduction, the overall weight saving being around 30 per cent compared with currently available prostheses.

The gripping geometry of the hand which has been developed is also different from the usual arrangement of thumb moving in opposition to the first and second fingers in a "pincer" action (Figure 1). It has often been pointed out that a single degree of freedom artificial hand will, of necessity, be a compromise when faced

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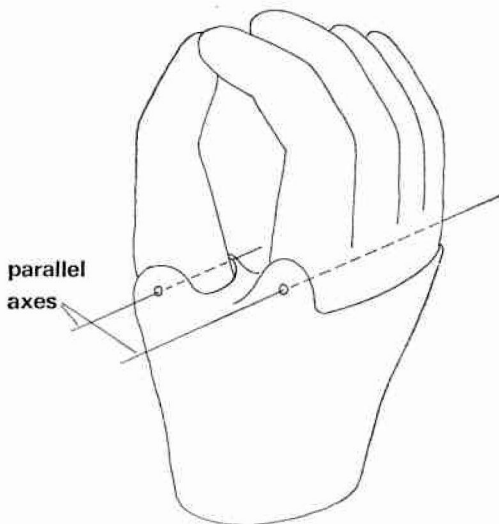


Fig. 1. Geometry of typical "pincer" action hand.

with the enormous variety of tasks that it will be asked to perform. Thus the gripping geometry used will reflect the designer's idea of the correct compromise to achieve a satisfactory engineering solution to the problem of prehension. The fact that the "pincer" action hand is virtually universal in routinely fitted prostheses would indicate that it might be a reasonable choice, although the fact that both it and the covering glove are easy to make probably plays a considerable part in contributing to its popularity. The geometry of the new hand is basically a modification of a "pincer" action combined with a lateral grip in order to improve visibility when picking up an object. It also appears to offer a more stable grip in most situations, helped by the use of the "powder grip" technique first developed by Simpson (1971).

The detailed description of the hand that follows is divided under three headings: Cosmetic glove, gripping geometry, and hand mechanism.

Cosmetic glove

Although the stain resistance of silicone rubber has always made it attractive as a cosmetic glove material, its high cost and poor tear strength in any easily processable form have been fundamental drawbacks. Fortunately, the last few years have seen the development of new higher tear strength types of room tem-

perature vulcanising (RTV) silicone rubbers and, with their increased use, the cost has fallen. The RTV used in the development of this cosmetic glove was supplied by Chas. F. Thackray Ltd.

The glove making process itself is essentially a slush moulding technique using a flexible female mould also made from RTV. The flexibility of the mould allows gloves with any degree of finger flexure to be made. Briefly, the mould is made by taking a cast of an appropriate hand using another quick setting type of RTV (Silcoset ICI Ltd.) into which has been mixed a liquid paraffin as a release agent, a technique described by Barrachina (1972). The cast is then used to slush mould a rigid replica of the hand in polyester resin. This replica of the hand is then coated with the high tear strength RTV which, when cured and removed, becomes the finished (female) mould. After applying a release agent (paraffin wax dissolved in xylene) the slush moulding of the finished glove can begin, having first dispersed the RTV in a suitable solvent to a pourable consistency. The solvent subsequently evaporates leaving a thin layer of RTV behind. About six to eight coats are needed for 1.5 mm build up of thickness. By the use of different coloured layers, very realistic skin simulation can be achieved, and the reproduction of skin physical detail is virtually perfect. The glove is produced with moulded recesses for acrylic finger nails which are attached with silicone adhesive.

It is intended to develop the glove making technique further into the area of partial hand replacements where it is felt that the very soft, elastic nature of this particular RTV will enable maximum use to be made of any remaining movements in the stump.

Gripping geometry

As mentioned above, the diversity of situations in which a prosthetic substitute for a human hand may be used is so great that any "solution" arrived at will necessarily be a compromise. Thus a reasonable policy is to try to achieve a design that functions well in those situations in which the lack of ability to accomplish the task is a serious inconvenience to the majority of amputees. It must also be said that the functional requirements of unilateral and bilateral amputees are different. For the unilateral amputee the natural hand

will almost always be dominant, with the prosthetic hand being used in a supporting role. The act of picking up an object is relatively less important than the ability to hold it securely because picking up and manipulation will be done by the natural hand, followed by transfer to the prosthetic hand. This is not to say that the ability to pick up should be ignored, on the contrary this should be made as easy as possible in the hope that a genuine bimanual ability will develop.

By comparison, a bilateral amputee makes far greater demands on the prosthesis. Picking up now becomes very important and it is unfortunately true that in this situation the lack of degrees of freedom and sensory feedbacks compared to the human hand make any prosthetic replacement a very poor substitute. It can be argued that the approach to, and picking up of, an object now uses two main sources of information. Firstly, knowledge of the position of the stump leads to a knowledge of the position of the prosthesis as an extension of the stump (Simpson, 1976). The second source is a visual appreciation of the position of the prosthesis relative to the object. Whilst knowledge of the position of the stump itself may often be quite accurate, movement of the fingers or any play in the socket leads to a loss of proprioceptive accuracy, a situation which worsens as the amputation site changes from below to above elbow. Vision, on the other hand, is independent of amputation site and it is argued that during the final approach to an object visibility of the gripping area is of primary importance. The same conclusion was reached by Kenworthy (1974) in his design of a side pinch type of hand for use with the CO₂ powered extended physiological proprioception arms (Simpson, 1973) currently being fitted in this centre. The geometry of this hand is shown in Figure 2.

Thus, considering the conventional "pincer" grip type of prosthesis from this point of view, some experimentation shows that although it is easy to pick up tall objects (greater than about 25 mm above the surface), the only way that low objects (25 mm high or less) can be grasped is by approaching the object from above with the forearm axis at a relatively large angle to the horizontal as the above-elbow amputee demonstrates in Figure 3. Thus, whilst not impossible, such tasks are made considerably

more difficult, the degree of difficulty increasing with the height of amputation because of the greater amount of abduction required of the upper arm.

It was with this difficulty in mind that the geometry of the new hand has been developed, whilst hopefully not compromising performance

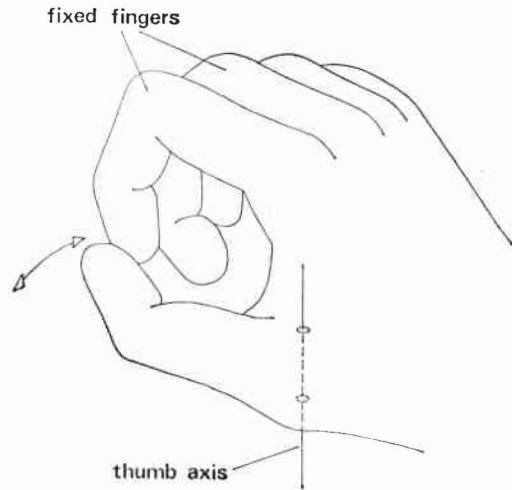


Fig. 2. Geometry of Kenworthy hand.



Fig. 3. Above-elbow amputee using "pincer" action hand.

in other areas such as the maximum width of grip. Further advantages have since become apparent, particularly the ability to hold a long thin object such as a pencil in a stable grip, an activity in which "pincer" type hands are only marginally successful.

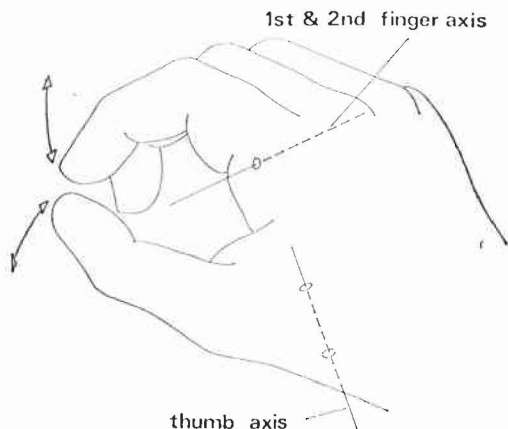


Fig. 4. Geometry of OBEU hand.

The basic geometry is shown in Figure 4. It is, in a sense, a compromise between the "pincer" type and the Kenworthy hand in trying to achieve the wide opening of the former and the good visibility of the latter. The rigid first and second fingers move together about an axis corresponding to the positions of the metacarpal phalangeal joints of the natural hand, the second finger being flexed slightly more than the first. The thumb moves about an axis approximately midway between the positions of the carpal metacarpal and metacarpal phalangeal joints and inclined at an angle of about 60 degrees to the first/second finger axis when viewed along the wrist centre line. This arrangement allows the loci of the tips of the thumb and first and second fingers to move approximately in a horizontal plane when the wrist axis is at about 25 degrees to the horizontal. In other words they will "sweep" the surface. Figure 5 shows the new hand in this situation and illustrates the reduction in upper arm abduction required compared to the "pincer" hand shown in the same situation in Figure 3.

To increase the stability of grip, "powder grip" conformable padding has been included in the gripping surfaces. This consists of tiny spherical plastic beads, enclosed by an inextensible bag, that conform to the shape of an

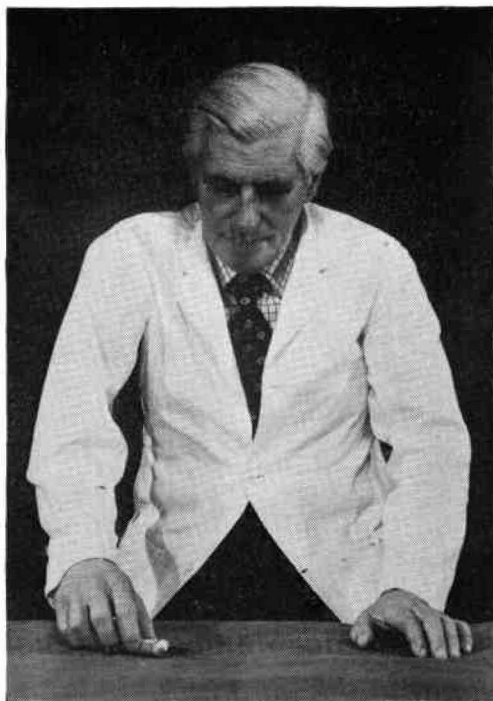


Fig. 5. Above-elbow amputee using OBEU hand.

object thus increasing the contact area. At the same time they do not store any elastic energy which would otherwise contribute to an unstable equilibrium situation. The overall result is that a stable grip can often be attained with significantly lower gripping force, an asset in a body powered device where operating forces are often low.

Hand mechanism

The method of construction of the hand mechanism had to fulfill several requirements. Firstly, since for cosmetic reasons it was to be made to fit the inside of a specific cosmetic glove, the external shape of the mechanism had to be made using this glove as a pattern. Secondly, it had to be capable of coping with the type of gripping geometry adopted, the axes of which make fabrication techniques using cartesian or polar co-ordinates difficult. Thirdly, as this was a development project it had to lend itself to quick production of small numbers of prototypes with the capacity for allowing changes to be made at short notice, while at the same time having the potential for being produced in relatively large numbers (in prosthetic terms). Finally, it had to have

a good strength to weight ratio bearing in mind that the silicone cosmetic glove is slightly heavier than its PVC counterpart.

The technique finally employed consists essentially of a brazed skeleton of steel rods constructed using brazing jigs originally derived from a moulding taken of the inside of the cosmetic glove. This moulding is also used to produce the moulds for the polyurethane foam padding. By this means the shape of the mechanism matches the cosmetic glove.

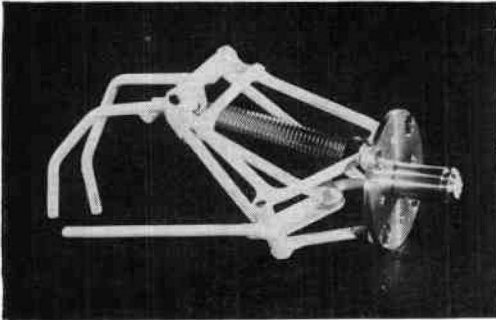


Fig. 6. Skeleton of OBEU hand.

The steel skeleton, shown in Figure 6 is mounted on an aluminium base plate which also incorporates the bayonet fixing for the wrist. The fingers and thumb are joined by a radius arm and rod linkage and operation of the hand is by a pushrod system operated through the centre of the bayonet (a pull cord version is also planned). For corrosion resistance the steel parts are nickel plated and those of aluminium are anodised.

The fingers and thumb are produced by moulding the polyurethane foam in place around the steel rods. The mould is sealed and the high pressure resulting produces a dense

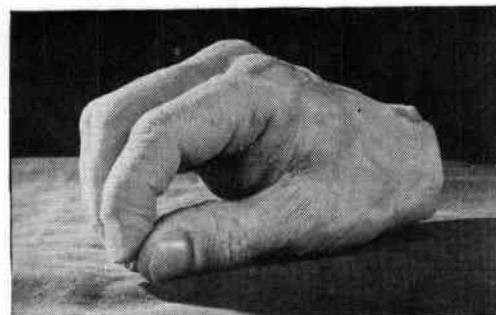


Fig. 7. OBEU hand.

foam of good structural properties. The palm and back padding are produced separately and "clip" on to the skeleton, the texture of the foam for these being made softer and less dense by allowing controlled pressure relief from the mould.

A completed adult male hand is shown in Figure 7. The weight of this hand is 285g (10 oz.).

Conclusion

A functional cosmetic hand prosthesis has been presented which shows improvements in cosmesis, weight, and function over those currently available. A clinical evaluation involving about 24 prostheses is currently being undertaken, following which it is intended to produce a range of sizes suitable for the majority of amputees.

Acknowledgements

The authors are grateful for the support and encouragement of Professor D. C. Simpson, Executive Dean, Faculty of Medicine, University of Edinburgh. Thanks are also due to Mr. A. C. Roberts of St. Luke's Hospital, Bradford for valuable advice regarding materials for the cosmetic gloves, and also to Mr. W. Barnett, Arm Training Instructor, Princess Margaret Rose Orthopaedic Hospital, for his willing co-operation as a "guinea pig". The development of both this hand prosthesis and the closely related modular arm system have been financed by a grant from the Scottish Home and Health Department.

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