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Silicone sockets for functional prosthesis of the hand

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Purpose Develop a technology of manufacturing silicone sockets for functional hand prosthesis. **Methods** The technology of fabricating sockets for functional hand prosthesis made of high temperature vulcanization (HTV) silicone was developed and tested for the first time in the practice of domestic prosthetics, including the traditional stages of molding, positive reproduction, and manufacturing of sockets. However, there are technological peculiarities in each of the stages that enable to manufacture a comfortable individual full-contact socket for hand prosthesis made of silicone that was successfully used in active and functional prostheses and prostheses with external power in patients with congenital and amputation hand defects. **Results** The technology has a number of advantages over traditional ones, as it provides comfortable conditions for full contact and partial loading of the residual segment of a club-shaped hand stump in the liner socket of the prosthesis. These properties of the liner socket allow the production of the most skeletonized carrying socket made of composite material for reliable attachment of the components of functional hand prostheses to it. **Conclusion** Successful trials of the liner sockets of the hand prosthesis made from HTV silicone created the conditions for a wider application of this silicone brand in the manufacture of a new generation of sockets for upper and lower limb prosthesis.
Keywords: hand defect, prosthetics, hand prosthesis, liner socket, HTV silicone, active prosthesis of the hand, working prosthesis, hand prosthesis with external power

INTRODUCTION

The stump of the hand is club-shaped, which makes it difficult for prosthetic fitting. Experts always face with the problem of how to ensure the comfort of the stump in the receiving glove socket, as well as easily remove and put on the prosthesis, and at the same time, how securely and aesthetically fasten the functional elements of the hand prostheses in the receiving socket [1, 2]. At present, this problem is solved by producing two types of sockets – a carrying socket made from a composite or rigid thermoplastic material, as well as a loose socket from a soft thermoplastic material, for example, polyethylene foam. However, the liner socket made from polyethylene foam has a number of shortcomings. It has low strength and damping properties. The stump in it may slip and sweats. In this case, it is necessary to manufacture a carrying socket from a composite material which is uncomfortable when the prosthesis is put on due to the stump shape and the rigidity of the material. These inconveniences can be corrected by prosthetists with deep cuts in the socket which decrease fixation stability of the prosthesis on the patient's stump and require cumbersome tape fastenings. Thus, to date, an optimal material has not been found for the manufacture of a liner socket of a hand prosthesis, which, on the one hand, would ensure stump comfort and cosmetics of the carrying socket, would have partial load bearing capacity as well as properties for reliable attachment fastening elements to the rigid carrying socket of the prosthetic hand [3, 4]. Therefore, the search for new materials for sockets of functional hand prostheses is a relevant issue.

METHODS

The technology of fabricating inner sockets for functional hand prosthesis made of high temperature vulcanization (HTV) silicone was developed and tested for the first time in the practice of domestic prosthetics that includes the traditional stages of molding, positive impression, and manufacturing of a receiving socket. Nevertheless, there are technological peculiarities in the manufacture of a full-contact inner socket for hand prosthesis made of HTV silicone. We would show them using the sample of an obliquely truncated hand stump with a preserved fifth ray and transplanted index finger that was transferred to the little finger position. Making an imprint for the manufacture of a plaster positive reproduction can be done in the classical and

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well-known way with plaster bandages. However, this method has disadvantages associated with the complex shape of the stump and underdevelopment of the hand. Therefore, we introduced a new in the domestic prosthetics method for taking imprints using alginate which is a safe and hypoallergenic material obtained from seaweed and widely used in cosmetology and dentistry. Its dry powder, mixed with water in exact proportions, becomes thick fast and acquires the properties of a dense jelly, while changing color as it hardens. Before the process of hardening begins, the patient's hand is immerged in such a substance, and then carefully removed 2–3 minutes later after the substance reaches the optimum density. Thus, an exact negative reproduction imprint of the defective limb of the patient is made (**Fig. 1, a**). Liquid plaster is poured into the alginate negative mold (**Fig. 1, b**), and the positive reproduction is removed after hardening. The resulting positive plaster model is processed according to general rules accepted in prosthetics. For greater stability of the receiving socket on the forearm, two pelottes should be selected in the projection of the lateral surfaces of the radial and ulna bones distanced 2 or 3 cm proximal to the axis of the wrist joint, with a depth of no more than 2 mm (**Fig. 1, c**). Once the positive plaster model has been dried, the surface is checked and, if necessary, aligned further. Next, the surface of the plaster is treated with a special liquid separator (**Fig. 1, d**). Subsequently, marking is applied to the positive plaster model with a chemical pencil for the edge of the socket, the axis of the wrist joint, the location points of the metal fasteners and zipper (**Fig. 1, e, f**).

HTV silicone is a two-component material, mixed using a special machine, a two-roll mill; in Russia this device is called “rollers” **(Fig. 1, g**). The components of the silicone are weighed and mixed (1:1 by weight); during mixing, a coloring agent is added to the silicone according to the patient’s choice. After tuning for color, the required thickness is set on the rollers and a sheet of not yet hardened silicone is rolled out **(Fig. 2, a**).

Fig. 1 Technological steps for production of a silicone socket for a functional prosthesis: **a** – damaged limb mold making with alginate; **b** – pouring liquid plaster into the alginate mold; **c** – processing of the positive plaster reproduction, drying; pelottes are marked red; **d** – application of a separating agent; **e**, **f** – marking of positive plaster reproduction; **g** – machine for mixing HTV silicone (rollers)

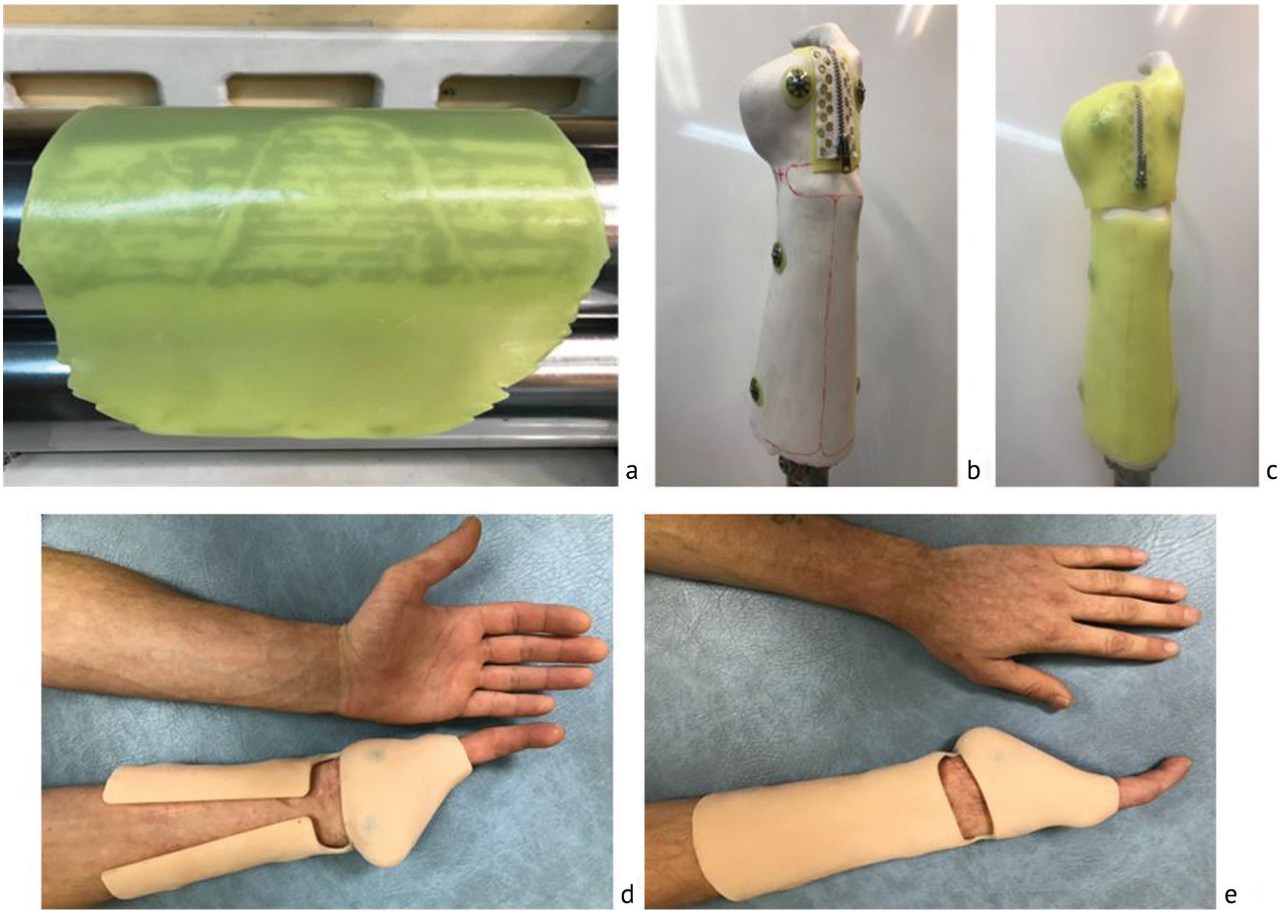

Fig. 2 Further technological steps for production of a silicone socket for a functional prosthesis: **a** – mixing and rolling HTV silicone; **b** – laying of elements on fragments of silicone; **c** – application of the main layer of silicone, vacuuming and drying; **d**, **e** – mechanical treating and fitting

For active hand prostheses, wall thickness of 2–3 mm is sufficient for the necessary strength and wear resistance of the liner socket. According to the markup, the embedded elements are laid out on the positive plaster model, so that they are in the bulk of the material after hardening and do not protrude either onto the outer or the inner surface (**Fig. 2, b**). These elements include perforated metal fasteners for fixing a silicone socket inside the carrying socket. As a rule, for reliable fixation, four fastening elements in the projection of the hand segment and four on the forearm are sufficient. The embedded elements on the forearm should be placed so that in the future, when assembling the prosthesis, the same elements can be used to install Velcro fasteners. An important element is the zipper for easier fitting of the prosthesis with a pronounced club-like stump. Then, the step of putting the silicone sheets on the mold with the embedded elements on it is performed. After the HTV silicone is laid out, it must be checked for vacuum with complete elimination of air bubbles from silicone and air pockets between the plaster and silicone. In addition, it is necessary to homogenize the silicone in the places of embedded elements and the junctions of the materials. The next stage is drying the silicone in the oven (**Fig. 2, c**). Before this, the bag and the knitted sleeves used for the vacuumizing process are removed; the nylon is carefully peeled off from the silicone, which, if necessary, is further aligned. Depending on the grade of HTV silicone, the oven polymerization takes one to two hours at a temperature of 90–110° C. As the silicone socket does not slide over the patient's skin, showing the properties of a silicone liner, it is recommended to apply it using a water-soluble gel that can be fully absorbed into the skin with little or no residue, such as Procomfort Gel (OttoBock). It is checked how tightly the socket fits the stump, whether there are air pockets, how comfortably the patient feels in it. The ideal result should be considered a glove socket that fits tightly the stump of the patient's hand without air pockets and without stretching (**Fig. 2, d, e**). When moving the stump, the socket should not slip. Patients who use this liner socket feel the comfort and reliable fixation of the functional prosthesis, which is proved by the functional bench tests (**Fig. 3**).

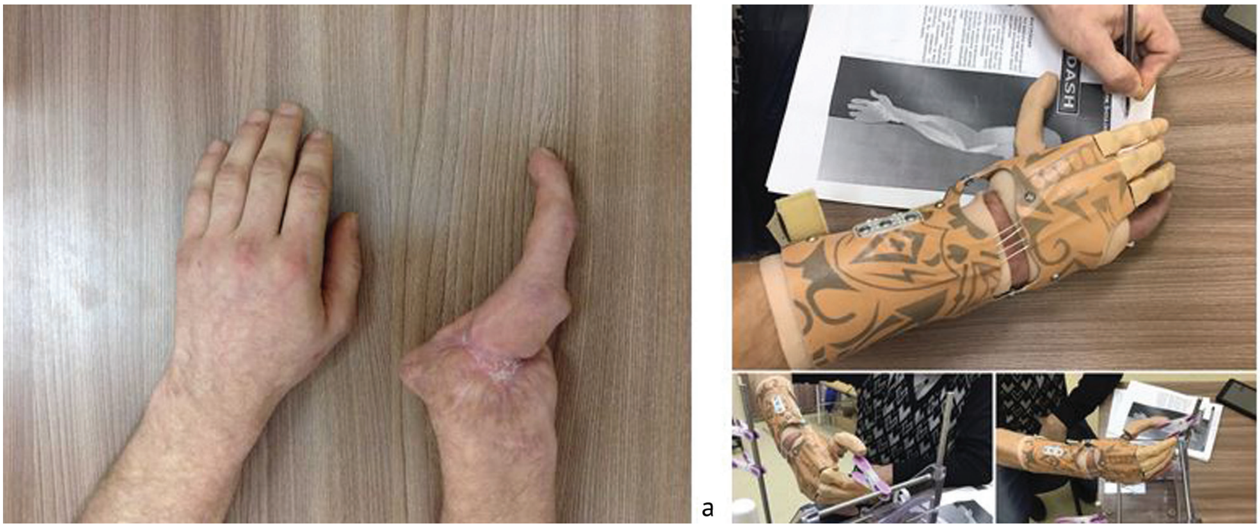

Fig. 3 Result of the prosthetics: **a** – type of oblique truncation of the hand with an intact fifth ray and the index finger transplanted to the little finger position; **b** – active prosthesis with an inserted silicone socket; functional bench tests

RESULTS

Practical testing of the technology in 45 patients with defects of the hand demonstrated its advantages over the available sockets made of other materials. All patients noted its sufficient strength and wear resistance, a decrease in piston-like and other free movements of the stump, and, at the same time, preservation of flexion and extension movements in the wrist joint, which is important for controlling active prostheses of the hand. This socket type can be successfully used in any functional prostheses such as active prostheses of the hand and fingers, working prostheses of the hand, and prostheses of the hand with external power. It has a very high rehabilitation effect and functional potential due to its comfort, combined with reliable fixation without significant limitation of mobility of the hand stump. So, the socket practically does not limit pronation or supination, as well as dorsal and palmar flexion of the hand in the prosthesis, allows use of the potential of a safe thumb. It provides the ability, if necessary, to be securely and simply attached to the supporting acrylic socket of the functional prosthesis due to the metal fastening elements. The acrylic carrying socket sleeve of the prosthesis, at the same time, can be made as skeletonized as possible (since the silicone socket itself is strong enough and carries a partial load). Moreover, it can include various modules, adapters, and fasteners of any functional hand prostheses. All this is combined with the compactness of the inserted socket (its thickness not exceeding 2–3 mm). These merits facilitate further work on the development of active prostheses of the hand and fingers, universal for any kind of defect of the hand.

Silicone sockets do not require additional softening and damping elements, and its manufacturing technology provides the possible local increase or decrease in the thickness, depending on the shape of the stump and other defects. In addition, it allows you to use the club shape of the hand stump as an attachment due to the elasticity and the possibility of installing zippers and other anchorages inside the socket.

CONCLUSION

Broad perspectives open in the use of the developed and tested technology, due to its merits, in the manufacture of individual silicone inserts for upper and lower limb prostheses.

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