

DESIGN FEATURES OF STUMP SOCKETS FOR PROSTHESES IN TRANSFEMORAL AMPUTEES

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Abstract. The paper discusses the design features of the main types of stump-receiving sockets for lower limb prosthetics in transfemoral amputations, which provide individual selection of the optimal type of socket based on the characteristics of the stump of a particular patient.

Key words: prosthesis design, stump socket, lower limb prosthetics, transfemoral amputation

Introduction

Patients with lower limb amputations face the problem of complete or partial loss of mobility and the ability to move independently, which is defined as loss of mobility according to the International Classification of Functioning [1]. The amputated part of the limb is replaced by a prosthesis, an important part of which is the stump socket, an element designed to ensure contact between the stump of the lower limb and the prosthesis. For this reason, the socket is subject to not only structural, but also ergonomic requirements to ensure the maximum possible comfort and convenience when using the prosthesis. For the purposes of designing and manufacturing stem sockets, it is necessary to determine their design features related to the biomechanical aspects of the interaction between the biological element (stump) and the technical element (prosthetic socket).

Results of the study

Lower limb prosthetics has a very long history, because as long as humanity has existed, there have been people with lost limbs or amputations. Thus, the field of prosthetics has been developing to ensure the manufacture of the most comfortable stump socket for a person. Today, there are a large number of designs and technologies for its manufacture. In this paper, we will discuss the most common technologies for the manufacture of stump sockets for transfemoral amputations, i.e. amputations at the level of the thigh.

Quadrolateral socket

The quadrolateral socket (fig. 1) is made in such a way that the back wall provides the main support for the body weight through direct contact with the distal border of the ischial tuberosity

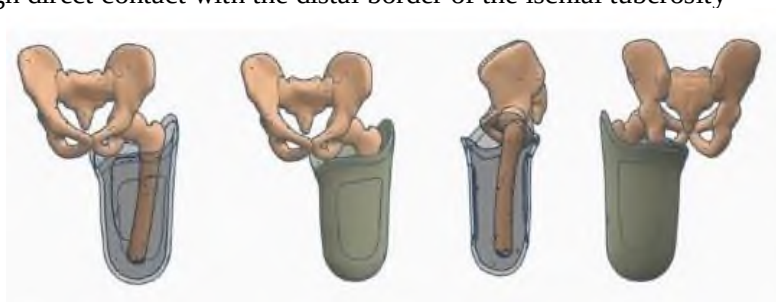


Fig. 1. A socket made using the quadrolateral method.

The medial wall provides stability, minimizes lateral movement, and aligns with the line of progression (fig. 2). The lateral wall maintains the alignment of the femur to optimize movement based on the laws of biomechanics [2]. The anterior wall includes an area to soften contact with soft tissues and creates counter pressure to ensure proper limb position.

The quadriateral socket contours can achieve a better pressure distribution.

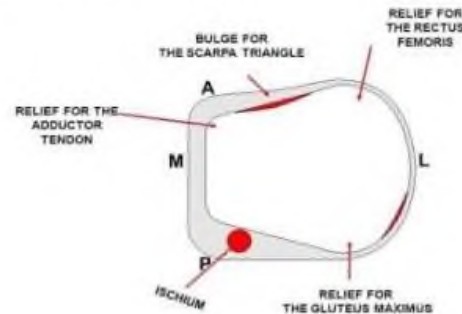


Fig. 2. Lines of progression and permissible areas of pressure on the stump during the manufacture of a stump receiver using the quadrolateral method.

The advantages of the quadrolateral socket are:

- Special design features ensure the functioning of the stump muscles.
- The main load is transferred mainly to the proximal part, not to the distal end of the femur.
- Well-established design - many years of experience in using this type of socket has allowed us to form an optimal socket design that has been tested in practice.
- Easy fitting for patients with clearly defined weight bearing zones.

The disadvantages include:

- Due to the support on the ischial bone, instability may occur during weight-bearing activities.
- Release of the lateral wall:
Causes unwanted movement inside the socket.
- Uneven weight distribution, in particular in the gluteal tuberosity and perineum.
- Limitation of movement - the design of the socket limits the range of motion of the limb.
- Limited ability to compensate for changes in limb volume.
- Asymmetrical posture in the sitting position - the back wall of the socket contacts the seat surface, causing the pelvis to move in the proximal direction.

The socket with ischial retention (ischial containment, IC)

The main design difference of this type of socket is the retention of the ischium (fig. 3). This type of socket provides a more natural shape of the stump.

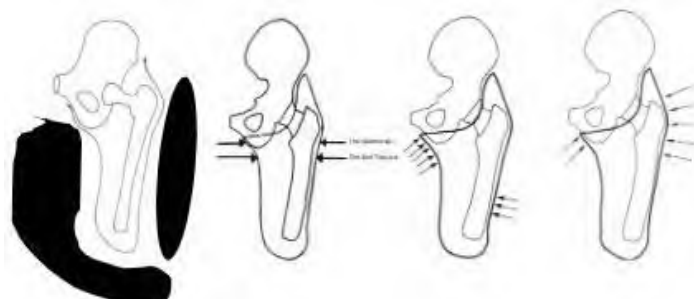


Fig. 3. The socket is made with the retention of the ischial bone

This method of socket is made by applying pressure to the medial side of the stump and holding the ischium, which allows for a more oval and natural shape of the human stump (fig. 4). This type of stump socket improves the fit of the stump to the socket and avoids deformities of the stump in the future [3].

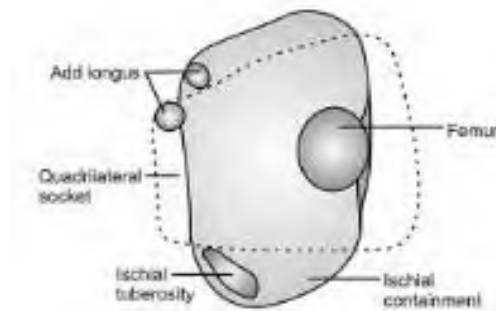


Fig. 4. Progression lines and permissible areas of pressure on the stump during manufacturing hip resurfacing with retention of the ischial bone

Advantages:

- Improved mediolateral stability due to bone locking through the encapsulation of the ischial bone.
- Increased comfort in the inguinal area due to the lower medial wall.
- Better control of the pelvis and torso due to stability during weight-bearing activities.
- Preservation of normal hip adduction due to the narrow mediolateral shape.
- Improved load distribution due to more efficient weight distribution along the femoral diaphysis.
- Increased comfort in the sitting position due to the lowered edges of the coccyx receiver and flexible design.
- Preservation of muscle functionality by taking into account muscle movements in the socket.
- Improved vacuum suspension, which is ensured by conforming the design of the socket to the natural shape of the stump, preventing vacuum loss.
- Increased functional performance due to improved connection between the residual limb and the prosthesis.

Disadvantages:

- The fitting process is complicated due to the need for accurate anthropometric measurements.
- Increased manufacturing cost compared to traditional quadrilateral sockets.
- Less adaptive capacity for significant changes in the volume of soft tissues of the stump due to increased tissue encapsulation.
- Reduced ability to compensate for volume fluctuations, because under the influence of significant forces, the limb can be pushed out of the socket (from the hold of the ischium).
- Increased pressure on the ischium and pubic bone branch, resulting in reduced comfort for shorter limbs.
- Asymmetrical posture in the sitting position due to the fact that the socket encapsulates the back of the buttock bone, which results in contact with the seat surface.

Marlo anatomical socket (M.A.S.)

Structurally, this socket is the closest to the shape of the human stump (fig. 5). Its main features are the complete retention of the ischium and the ischial-pubic branch (medially). Anterior, posterior, and medial cuts are reduced [2]. Increased retention of the sciatic-pubic branch medially. Use of quasi-hydrostatic loading through the soft tissues of the thigh. The gluteus maximus and gluteus maximus are not included in the socket due to the lowered posterior edge.



Fig. 5. A socket made using the Marlowe method

Advantages:

- Improved comfort in the seated position, as the ischial tuberosity is in contact with the seat surface, not the socket.
- Enhanced range of motion, as the design provides a full range of motion that improves gait.
- The aesthetic characteristics are ensured by the absence of visible gaps or the contour of the cartridge case under clothing.
- Easy to put on - this prosthesis is easier to put on, which increases the patient's independence.
- Versatility ensured by successful fitting for all age groups.
- The ischial retention provides improved stability due to the effective encapsulation of the ischial tuberosity and part of the ischial-pubic branch.
- Improved weight distribution by redistributing the load from the medial side of the pubic bone branch to the anterolateral part of the socket.

Disadvantages:

- The need for precise measurements - the M.A.S. system requires accurate anatomical measurements and special training for proper implementation.
- Specialized training - prosthetists must obtain M.A.S. certification to use this technique correctly.
- Longer time - the unique design of the socket may require more time to manufacture and adapt to the socket for both the prosthetist and the patient.
- Difficult to use in patients with obesity, as this design cannot fully ensure the retention of the ischium and the ischial-pubic branch.
- Limited research - while initial results are encouraging, more research is needed to assess long-term effectiveness compared to other cartridge designs for reliable scientific data [3].
- The design does not provide significant levels of fit with significant changes in the volume of the stump.
- The M.A.S. system does not tolerate suspension variability.

The socket is without a rigid frame.

Stump sockets without a rigid frame (fig. 6) provide a soft or semi-rigid structure due to the use of elastic materials, while the structure is usually not solid, which provides wide adaptability of the liner. Users experience up to more even weight distribution. The liner without a rigid frame is 2.6 times cooler than traditional liner [1]. Users report a improvement in sitting comfort. There is a reduction in skin problems. Users of the nonrigid frame socket report a increase in stability and confidence while walking. Dependence on a walker is reduced by . Users are 3.6 times more likely to walk independently than users of traditional sockets.



Fig. 6. Socket without a rigid frame

Today, the constructional type of the liner without a rigid frame is still being studied, so the advantages and disadvantages are difficult to describe.

Conclusions.

The reviewed design features of different types of stump sockets for transfemoral amputation prosthetics showed that each type has its advantages and disadvantages, with traditional designs being more studied and reliable, but the search for design types to improve patient comfort continues. Based on the analysis, it is possible to individually and reasonably select the most comfortable type of stump socket for the patient, taking into account the biomechanical and ergonomic features of the stump.

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