Getting the Right Fit: Prosthetic Sockets and Engineering Principles

Why hydrostatic shape capture supports improved lower-limb prosthetic care

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INTRODUCTION

Prosthetic socket fit is about more than comfort – it is about how well the socket transfers forces from the prosthesis to the body. When wearing a prosthesis, forces pass from the socket through soft, flexible tissues like skin and muscle before reaching the bone. So, instead of judging fit only by feel, it is important to consider how forces are distributed, how tissues deform, and how stable the limb is during movement to prevent pain, skin problems, and injury.

HYDROSTATIC SHAPE CAPTURE WITH THE MAJICAST FOR SOFT TISSUE CONTROL

With the Majicast, the limb shape is captured under full load while carefully controlling the soft tissues, with the aim to achieve both surface and volume matching. This is realised by implementing the "stiffest path" principle - meaning the load is directed naturally through the firmest, most supportive structures. Forces can therefore be transferred more evenly from the skin, through the layered soft tissues of the residual limb, to the skeleton during shape capture. As a result, the connection between the body and the prosthesis is stronger, tissues are better protected, and overall function is improved.

"LET NATURE DICTATE SOFT TISSUE DEFORMATION UNDER A UNIFORM LOADING CONDITION"

RATIONALE FOR SOCKET FIT CRITERIA

The socket, liner, and remaining limb work together to support the user's body weight. This load doesn't follow a single path; skin, muscle, and fat are compressed, stretched, and slide against each other, depending on how stiff, flexible and strong they are. However, each tissue has limits: if the pressure or stretch is too high, the tissue might be damaged, leading to pain or injury. Because these actions happen at the same time, it is difficult to predict exactly how forces are shared - and what the risk for injury is - just from the socket shape. Instead, it also depends on the properties of each part, how well the surfaces stay in contact, and how this changes during movement.

A practical definition of "good socket fit" therefore requires balancing three interdependent criteria:

- **Mechanical coupling performance:** maximising stiffness and minimising unwanted movement (e.g. pistoning, rotation) to improve stability and control
- **Tissue safety:** limiting harmful mechanical conditions, including concentrated pressure in small areas, forces that cause layers of tissues to slide against each other (shear), and repeated loading over time that can damage the tissue
- **Functional usability:** ensuring the prosthesis enables everyday activities with appropriate comfort, reliable performance, and user confidence

From an engineering standpoint, several governing principles emerge:

- Load is typically taken through the **stiffest path of a structure**, meaning even small differences in shape or material behaviour can create areas of high pressure, especially over bony prominences
- Pressure level on its own is not enough to assess risk; changes in pressure across an area and the resulting **internal shear stresses** are key factors in tissue damage
- Soft tissues exhibit **nonlinear, viscoelastic, and time-dependent behaviour**, so their response depends on how load is applied over time – it's history, rate, and duration – rather than just the immediate loading conditions.

APPLICATION TO SOCKET DESIGN AND FABRICATION

Two widely used conceptual models for socket design are **surface matching** (aligning the socket with the limb's external shape to distribute contact pressures) and **volume matching** (preserving the limb's volume under load to ensure forces are transmitted evenly throughout the tissues). In practice, both approaches depend on maintaining **socket shape and volume stability under load**, avoiding sharp pressure changes that can create local stress concentrations.

Current fabrication approaches, including manual casting and digital CAD/CAM workflows, primarily capture **geometry rather than mechanical behaviour under load**, which explains why truly uniform pressure distributions are rarely achieved in practice. As a result, socket fitting remains an iterative optimisation process, guided by clinical expertise, patient feedback, and observational assessment.

KEY IMPLICATIONS FOR SOCKET DESIGN

Advancing prosthetic socket design requires a clearer, more **mechanics-based design framework**, where clinical decisions are guided by how loads are transferred and supported by improved design, measurement and modelling techniques. This can help produce more consistent outcomes, make patient feedback easier to interpret, and ultimately lead to more effective and longer-lasting prosthetic rehabilitation.

Related References:
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