MATERIALS ENGINEERING FOR COMFORT: ELASTIC MODULUS AND VISCOELASTICITY

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INTRODUCTION

A prosthetic socket interfaces the human limb with distal componentry and functions to transfer biomechanical forces resulting from gait and other movements as well as weight bearing forces. Limbs are soft while distal componentry is hard. Thus, the socket must transition from hard distal componentry to soft tissue in a way that is effective at counteracting biomechanical and weight-bearing forces, avoids skin breakdown, and is comfortable. The ability for a socket to function in this way is dependent on how the socket is configured or shaped to engage with the limb and the materials that comprise the socket. Outside of geometry, we believe that elastic modulus and viscoelasticity (also referred to as cold flow, pack-out, and creep) are the most important factors affecting socket comfort; elastic modulus for the instantaneous fit and viscoelasticity for the long term fit.

METHOD

Materials within three types of conventional laminated sockets (CLS), two types of patented sockets, and two types of adjustable sockets were investigated for tensile and flexural elastic moduli. Tests were performed on a mechanical testing system. The tensile elastic modulus was determined using the tensile test (ASTM D638), and the flexural modulus was tested using the 3-point bend test methods (ASTM D790). Tested materials included various carbon fibers, thermoplastics, textiles, foams, and gels. The viscoelastic response to a tensile load was measured as per ASTM D2990.

RESULTS

The tensile and flexural moduli were determined for most materials. The flexural moduli of the textiles were immeasurable, since there was no inherent rigidity.

The carbon fiber composites of each socket had the highest elastic moduli. Of the sockets tested, the patented socket type had the highest stiffness. The foams and textiles had the lowest moduli, while the thermoplastics varied in between the two.

The patented socket type without flexible inner liner and the CLS without flexible inner liner had the fewest materials, and thus the fewest discrete values of elastic moduli, sockets with a flexible inner liner and adjustable socket #2 had several more discrete values of elastic moduli, and socket type #1 had the most discrete values of elastic moduli as well as the widest range of elastic moduli.

A wide range of viscoelastic deformation was observed across the sample set. The largest single factor affecting the amount of viscoelastic deformation was the comprising polymer type. Thermosetting polymers exhibited substantially less deformation than thermoplastic polymers. Other factors affecting the amount of deformation seen were molecular weight, and material strength. There was also a correlation to elastic modulus.

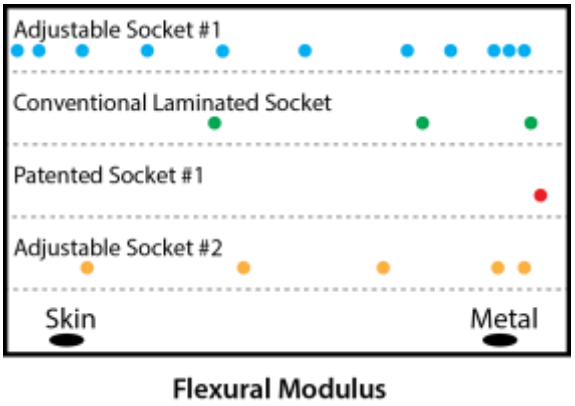

Figure 1: Range over which Flexural Modulus varies within Different Prosthetic Sockets

DISCUSSION

It is postulated that sockets with the fewest discrete moduli of elasticity rely heavily on being configured or shaped to avoid high peak pressures that can lead to discomfort and reduced function. Conversely, sockets with the highest discrete moduli of elasticity rely less on being configured or shaped to avoid high peak pressures.

Additional material properties data was collected for textile aspects of the socket since textiles exhibit different properties than structural components. This data is discussed but not directly correlated to the structural components and materials in other sockets since these tests do not apply to plastics and metals.

CONCLUSION

Socket types differ greatly with respect to various materials properties found within. We believe that sockets with less materials variability rely great on socket shape to achieve comfort.

CLINICAL APPLICATIONS

Choosing the appropriate materials combination can be used in addition to socket shape, to improve socket comfort in the short and long term.

REFERENCES

ASTM testing standard D638
ASTM testing standard D790
ASTM testing standard D2990

American Academy of Orthotists & Prosthetists
43rd Academy Annual Meeting & Scientific Symposium
March 1-4, 2017