Pressure Gradient Response of Prosthetic Insert Materials

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INTRODUCTION

Elevated pressures between an amputee's residual limb and prosthetic socket can lead to discomfort, skin abrasion, and even skin breakdown (Mak et al., 2001). In addition, large pressure gradients (changes in pressure over distance) can lead to acute pain and irritation. To mitigate these high pressure regions, specific areas of the socket are often inset with softer materials, patients wear whole-limb gel-liners or socks, or patients receive a combination of gel-liner and insert. Pressure values in the literature range from as low as 121 kPa to as high as 400 kPa (Mak et al., 2001; Sanders et al., 1993). However, the pressure gradients at these locations were not reported. The purpose of this study was to compare the peak and gradient pressures of typical prosthetic materials and gel liner materials under standardized loading and geometric indenter conditions (simulating a bony-prominence).

METHOD

Five different prosthetic insert materials, Pelite® (P), medium density Plastazote® (PZ), a Solflex® soft crepe material (SC), Aliplast 4E® (A4), and Aliplast XPE® (AX), were prepared in square samples with dimensions of 50 cm by 50 cm and a thickness of at least 6 mm. Two different 3 mm gel liner materials, silicone (gS) and urethane (gU), were prepared following the same methods. A simulated tissue+bony-prominence indenter was developed, consisting of a polymer sphere (ball with radius=27 mm, hardness of Shore OO 69.8), within which a spherical-tipped (radius=11.12 mm) oak dowel was imbedded, 12.7 mm from the contact surface. A one degree of freedom compression platen was used to apply a 64.5 N force and a pressure mapping system (I-Scan System, Tekscan, Inc., Boston, MA) with sensor resolution of 62 sensel/cm^2 was used to capture pressure maps.

RESULTS

Average peak pressure and average pressure gradients were calculated using a custom program. Pressure gradients are represented as a change in pressure from the center of the pressure map to the outermost point of the pressure map (reported as kPa/mm). Average peak pressure values ranged from 99 kPa (A4,gU) to 275.67 kPa (AX,gU). Observed pressure gradients ranged from 4.12 kPa/mm (A4,gU) to 13.74 kPa/mm (AX,no liner). The average contact area was determined from the pressure maps (Figures 1 and 2) and ranged from 6.13 cm^2 (SC,no liner) to 13.70 cm^2 (A4, gU). Total contact area increased as material hardness decreased (Figure 2) and with the addition of a gel liner (Figure 1). The magnitude of the peaks of the pressure maps shown in the figures corresponds to pressure magnitude. Higher 3D map peaks indicate higher pressures.

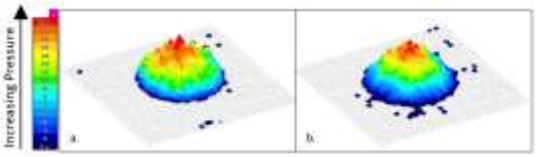

Figure 1.a) 3D pressure map, SC, No liner condition. b) 3D pressure map SC, sU condition 3D peak magnitude indicates pressure magnitude.

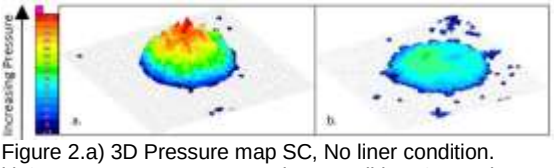

Figure 2.a) 3D Pressure map SC, No liner condition. b) 3D Pressure map PZ, No Liner condition. 3D peak magnitude indicates pressure magnitude.

DISCUSSION

Softer materials exhibited lower peak pressure, larger total contact areas, and thus lower pressure gradients. Softer materials were able to distribute the applied pressure over a larger contact area, reducing the peak pressure value. With the addition of a gel liner the increase in contact area is not as evident from the pressure maps, but for all materials the contact area increased by at least 1 cm^2 with the addition of a gel liner. Larger value pressure gradients and distinct gradient changes over the contact area are indicative of problem areas. High value pressure gradients could indicate the potential for pain or for surface blood flow occlusion leading to dermatological issues. The ability of the softer materials and the gel liners to distribute applied pressure over a greater contact area results in lower pressure gradients.

CONCLUSION

The addition of a gel liner on top of the traditional prosthetic insert materials increased the contact area and decreased the overall pressure gradient. As well, the gel liner reduced overall pressure gradient values and inter-contact area pressure gradient changes.

CLINICAL APPLICATIONS

Certain insert materials may not be suitable for all patient types. Understanding how each material distributes pressure can provide assistance to clinicians in achieving a successful prosthetic fit.

REFERENCES

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