APPENDIX B.

APPENDIX B
Buechel-Pappas Ankle Contact Stress Calculation

Contact stress can be determined via analytical or experimental methods. One experimental technique is by the Fuji-Film Method. With this approach, a pressure sensitive film is placed between the articular surfaces. Next a static, compressive load is placed on the components resulting in rupture of the pressure sensitive beads in the film. The beads contain ink and break at different stresses. Therefore, after applying a load the film can then be analyzed to determine both the contact area patch as well as the contact stress by the variation in the color of the film.

This type of test is however impractical for use with the Buechel-Pappas ankle replacement system. This is due to the compound shape of the talar component, and the congruency of the articular surfaces. These factors will not allow the film to be controlled once placed between the components to produce the congruent contact needed in order to determine the appropriate contact stress. To expand on this statement, figure 1 displays a simple ball and socket congruent couple. In order for the two to be in congruent contact, the convex radii (R_1) has to be identical to that of the concave radii (R_2), as is shown. Figure 2 shows the couple with an object with a finite thickness introduced. In this situation, the components must first be displaced the thickness of the film. Next, in order for congruent contact to exist, the outside radius of the film must be different than the inside radius. Since this can not occur, congruent contact can not occur.

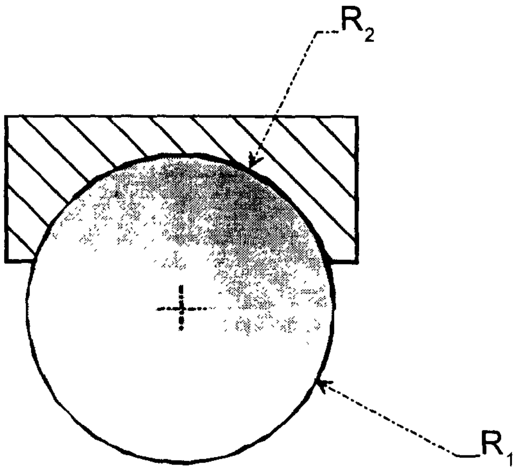

Figure 1.

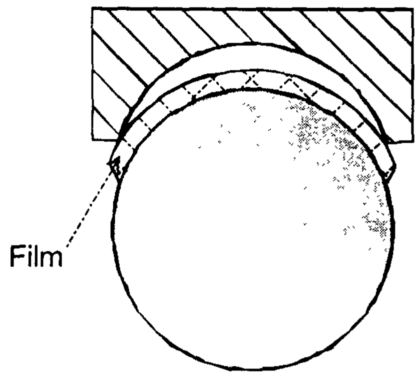

Figure 2.

Therefore, analytical methods are used here in order to calculate the contact stress. The equations for the contact stress of two curved surfaces of different radii pressing against each other (point contact) are well documented [36]. For congruent, shallow cup contact, it is reasonable to assume that the contact stress is uniform over the contact area. This result is,

$$\sigma = \frac{P}{A} \qquad (1)$$

where σ is the contact stress, P is the load applied, and A is the projected contact area in the plane perpendicular to the applied load.

CONTACT AREA

The projected contact area for the ankle device is shown in Figure 3.

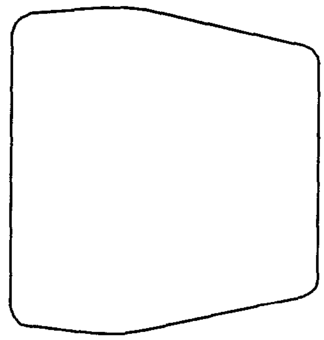

Figure 3.

In order to calculate the area, the above profile will be divided into a series of rectangles and triangles. As can be seen from Figure 4, if the bearing is divided in half, the resultant figure is broken into 2 triangles and 2 rectangles.

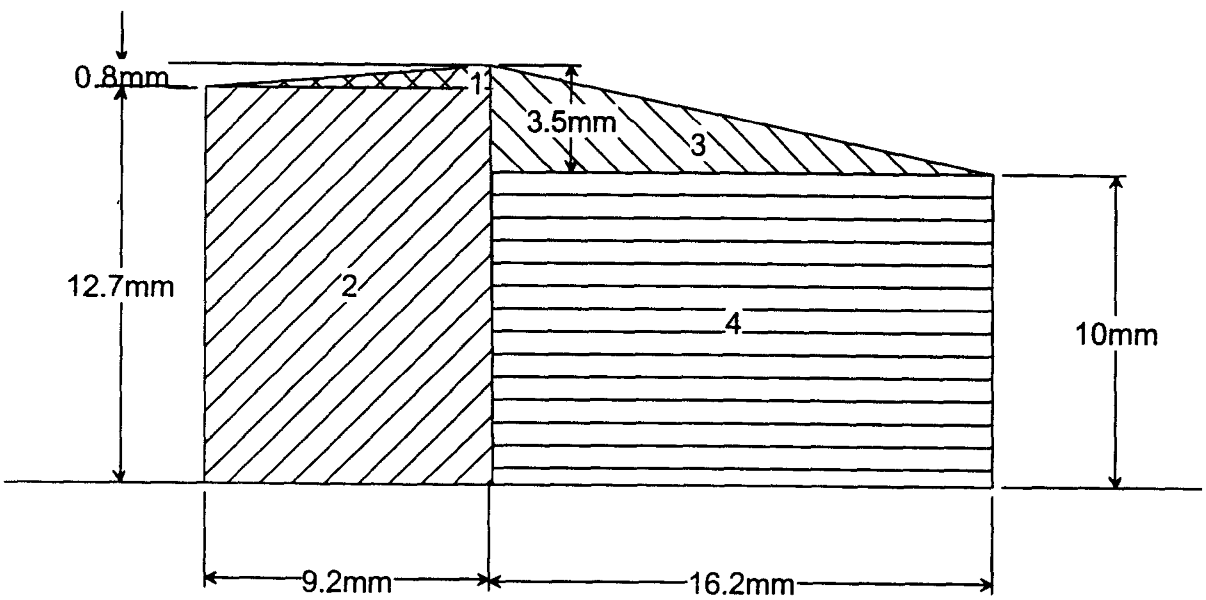

Figure 4.

From the above, the projected area becomes:

For area 1:

$$A_1 = \frac{1}{2}(b)(h) = \frac{1}{2}(9.2)(0.8) = 3.7mm^2 \qquad (2)$$

For area 2:

$$A_2 = (9.2)(12.7) = 116.8mm^2 \qquad (3)$$

For area 3:

$$A_3 = \frac{1}{2}(16.2)(3.5) = 28.4mm^2 \qquad (4)$$

For area 4:

$$A_4 = (16.2)(10) = 162mm^2 \qquad (5)$$

Therefore, the total projected area is:

$$A_{TOT} = 2(3.7 + 116.8 + 28.4 + 162) = 621.8mm^2 \qquad (6)$$

ANKLE FORCES

The tibiotalar compressive forces have been estimated to exceed four times body weight during normal walking, and the posterior shear forces approximately 80% of body weight.[18] (see figure 5).

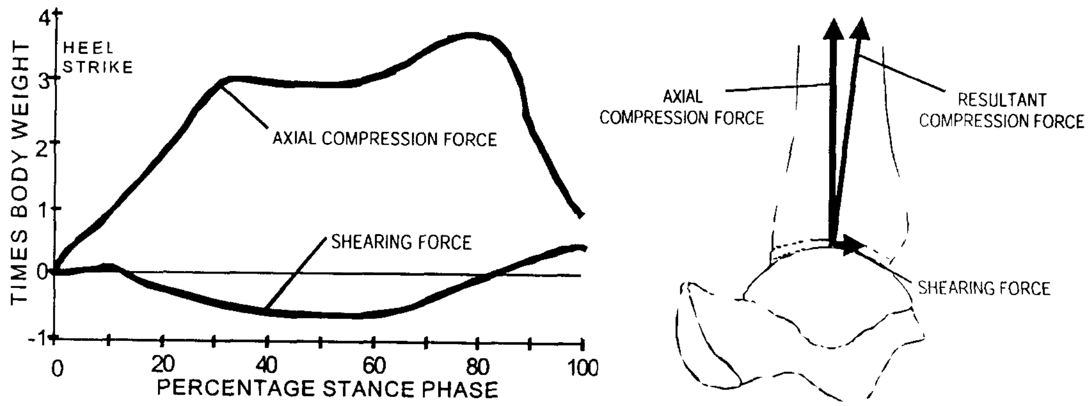

FIGURE 5.

For the standard size components used for the projected contact area, the body weight is assumed to be 190 lbs (86.3 kgs). Therefore, the resultant compressive forces is given from:

$$\begin{aligned} F_{compressive} &= \sqrt{(4 \cdot BW)^2 + (0.8 \cdot BW)^2} \\ &= \sqrt{(4 \cdot 86.3)^2 + (0.8 \cdot 86.3)^2} = 352kg \end{aligned} \qquad (7)$$

The compressive load is therefore 352kg or 3.45 kN. Using equation (1), yields a contact stress:

$$\sigma = \frac{3.45(10^3)}{6.22(10^{-4})} = 5.55MPa \qquad (8)$$

Figure 8 shows the computed contact stresses for the Buechel-Pappas Ankle and knee prosthesis (fixed and mobile bearings). The knee is used here as a comparison since the situation in the ankle is at least as serious as that in the knee. This is because the loads in the knee and ankle are comparable; however, the ankle is much smaller in size, and hence in articular surface. The chart below displays the computed contact stress for area, point, line and quasi-line contact of several knee designs [10]. The manufacture of the polyethylene states that the contact stress for polyethylene applications having a compressive fluctuating load is 10Mpa [37]. Therefore, it is clear that the B-P ankle contact stress is not only in the acceptable or safe range for contact stress, it is much less than that of fixed bearing knees and ankles currently cleared by the FDA to market.

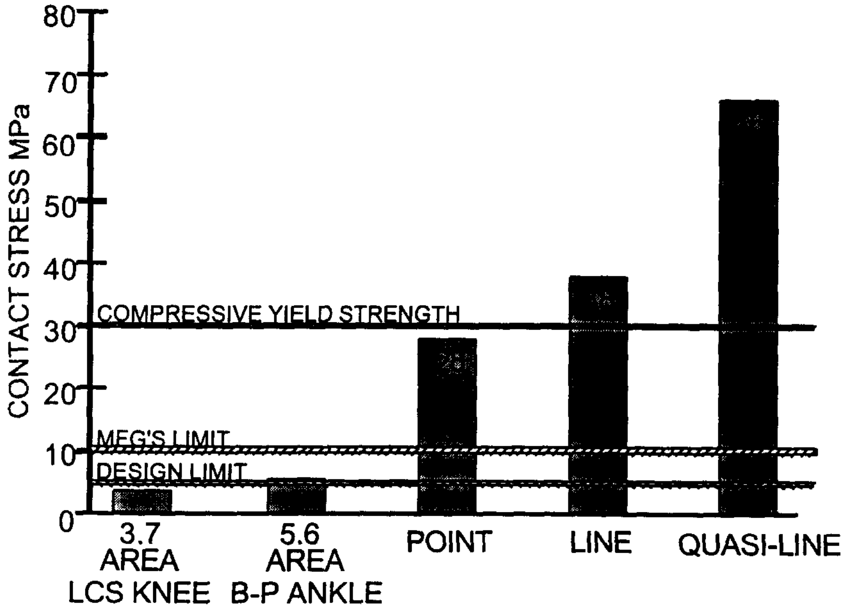

FIGURE 8.