Investigation of Potential Benefits of Clevamama® ClevaFoam™ Baby Pillow for the Prevention of Deformational Plagiocephaly

A Biomechanical Analysis of Contact Between an Infant Skull and Different Support Materials During Bed Rest

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Executive Summary

Deformational plagiocephaly is a medical condition, common for infants, describing local flattening of regions of the skull due to persistent localised pressure. Incidence has risen dramatically since the advent of recommendations to place sleeping infants on their backs as a preventative measure against sudden infant death syndrome. Although several treatment options exist there is scope for utilisation of passive devices during the early weeks and months after birth when infants are more prone to development of the condition due to relatively low levels of activity.

A study was undertaken to investigate the use of a polyurethane foam pillow (specifically a Clevamama® ClevaFoam Baby Pillow) as a means of reducing contact pressure to the occipital region of an infant skull during supine bed rest. Preliminary characterisations of (i) the foam used in the pillow and (ii) a generic infant mattress were carried out to define relevant support conditions for the desired analyses. A finite element model of an infant cranium was constructed, taking account of relevant structural features for the analysis of skull contact behavior. Simulations of the skull were performed for (i) normal bed rest on the generic mattress and (ii) resting on the foam pillow, which was in turn supported by the mattress from (i). The foam and mattress were successfully characterized for the purposes of the study.

Simulation of the two bed rest cases predicted that use of the pillow would reduce the mean contact pressure in the occipital region by increasing contact area and conformity. Furthermore, local tissue loading was also predicted to decrease with the use of a pillow. Predictions of the study were within range of values reported in the literature.

In conclusion, simulations of supine rest of an infant cranium in contact with (i) a generic infant mattress and (ii) a Clevamama® ClevaFoam Baby Pillow supported a hypothesis that use of the foam pillow can reduce mean contact pressure at the occiput by increasing contact area through greater conformant deformation.

Results

Analysis of the deformation of each model (Fig. 13) shows that the pillow model deformed more than the stiffer case of only the mattress. Furthermore, greater contact area between the cranium and its support was predicted for the pillow support condition (Fig. 14) — 2,959 mm2 for the mattress and 5,644 mm2 for the pillow. This increase in contact area for the pillow support leads to a reduction in the contact pressure (i.e. the contact force per unit area) since the force (i.e. the gravitational load, which was 8.55 N) is the same for each model. Thus the mattress support was predicted to apply an average contact pressure of 2.9 kPa to the skull while the pillow applied an average pressure of 1.5 kPa.

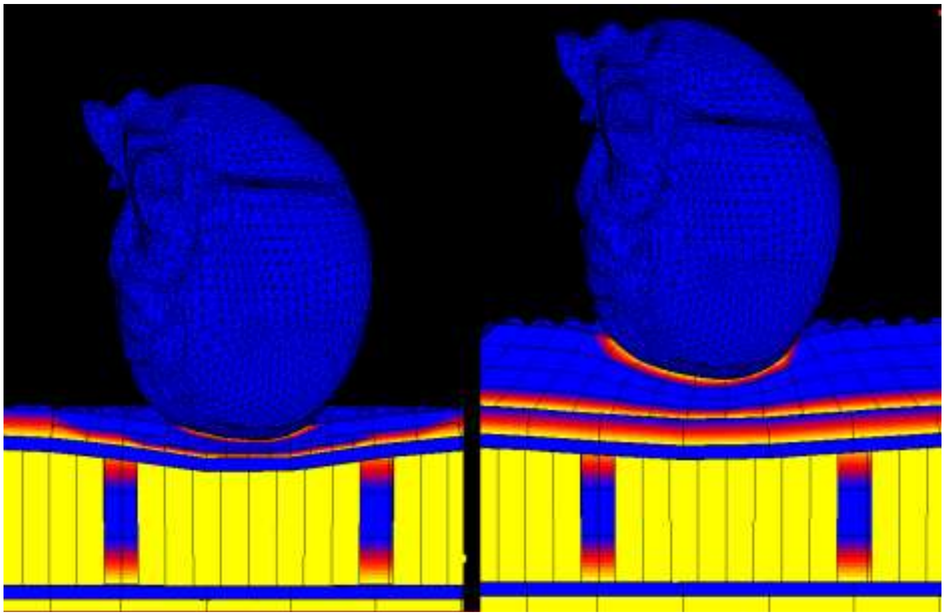

Figure 13: Cross-sectional view of contact areas between skull and each support material: (a) mattress and (b) foam pillow. Yellow regions indicate contact areas between the various bodies in the model.

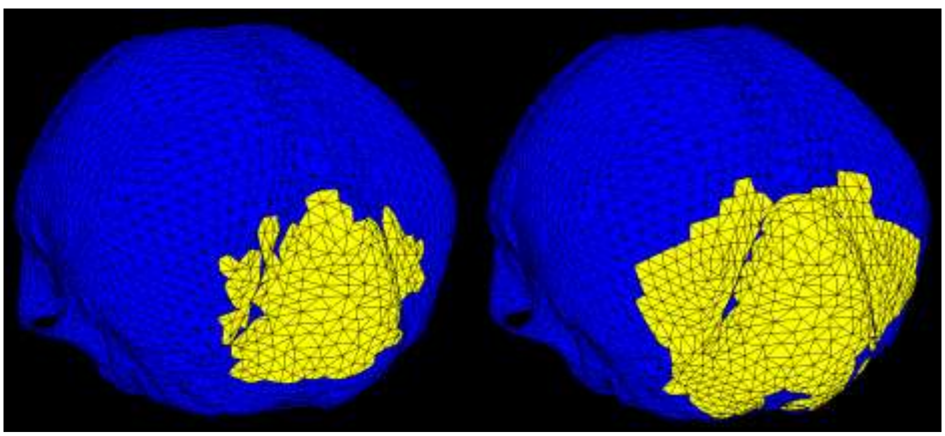

Figure 14: Oblique view of occipital contact areas (yellow regions) for (a) mattress and (b) foam pillow support condition. Greater contact area is apparent for the foam pillow model.

A benefit of using the finite element method is the ability to predict internal loading and deformation of the tissues. Two measures of loading were examined for the two models: von Mises stress (indicative of the forces generated within the tissue) and strain energy density (indicative of the energy of deformation). Contours of stress (Fig. 15) show that stress was not distributed uniformly within the contact region. Local concentrations were predicted around the suture regions for both models. In particular local stress in these regions was up to an order of magnitude higher than the man contact pressure. Furthermore, a larger region of highly loaded tissue was predicted for the occipital region of the mattress support. This trend was more pronounced when examining the strain energy density of the exterior cranial tissue (Fig. 16). Both stress and strain-energy density were more localized to the sutures for the pillow support condition. In general, stresses were relatively low (< 25 kPa) in the occipital region of both models.

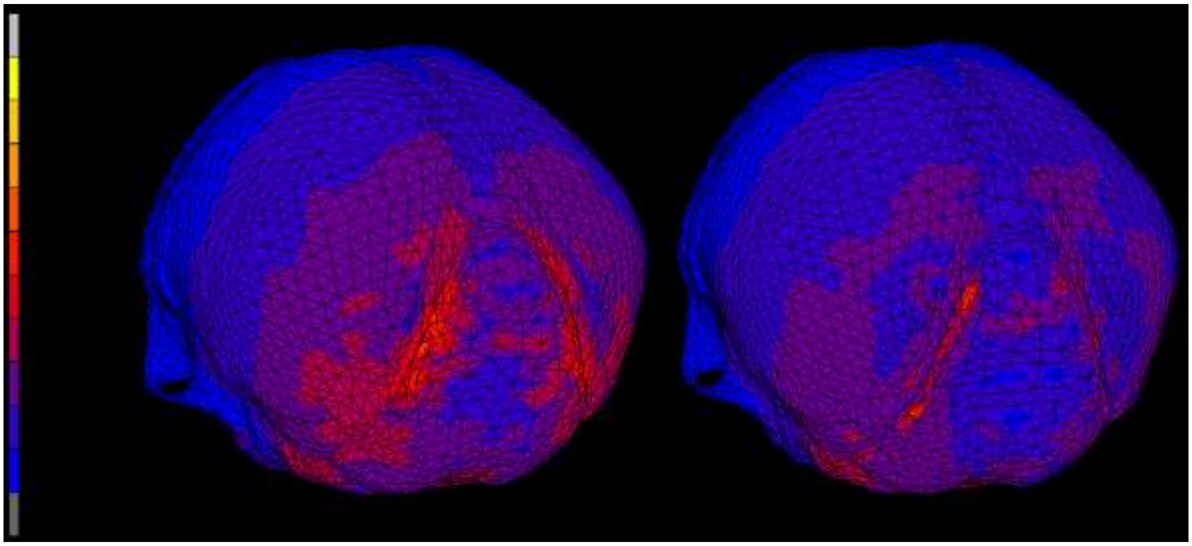

Figure 15: Von Mises stress distribution in occipital region of skull for each support type: (a) mattress and (b) foam pillow. Lower stresses were predicted for the foam pillow support condition.

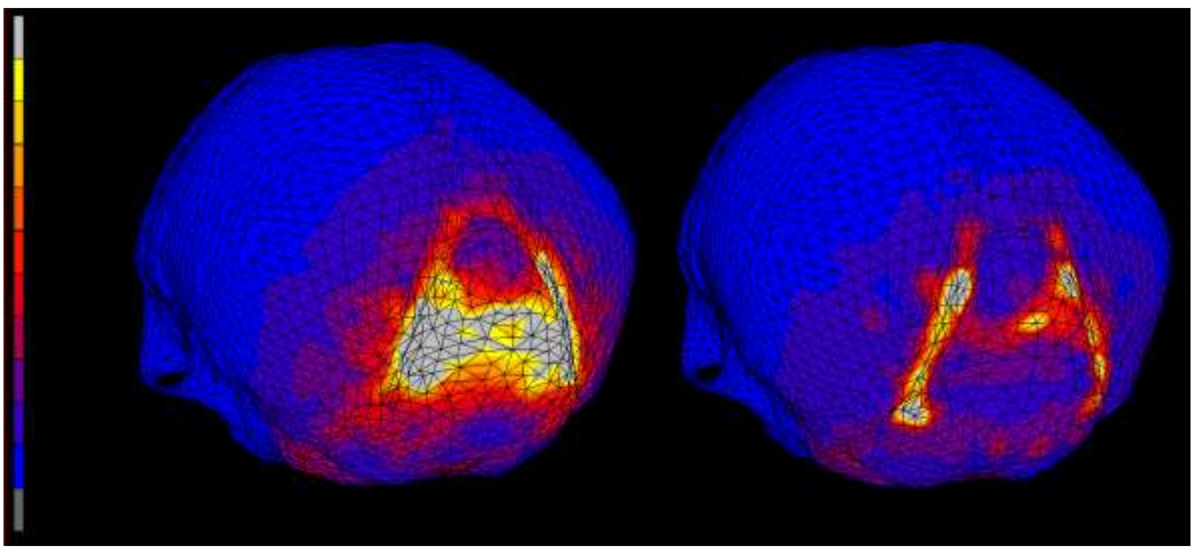

Figure 16: Strain energy density for occipital region of skull for each support type: (a) mattress and (b) pillow. Lower strain energy density was predicted for the foam pillow support condition.

Conclusions

In conclusion, simulations of supine rest of an infant cranium in contact with two different supporting materials, (i) a generic infant mattress and (ii) a Clevamama® ClevaFoam™ Baby Pillow, supported a hypothesis that use of the compliant polyurethane foam pillow can reduce mean contact pressure at the occiput by increasing contact area through greater conformant deformation. This study represents a first step in determining the local mechanical environment in the tissue of the contact region for an infant head resting in a supine position. The ability to study this mechanical environment opens the possibility of further study of the role of mechanical loading in the development of deformational plagiocephaly.