Evidence Based Design of Facemasks for Children Using Computerized 3D Face Analysis

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Introduction

- Current pediatric masks are miniaturized versions of those empirically developed for adults; not designed with children specifically in mind[1].
- Mask dimensions, contour, adequate seal and dead space volume are a problem in this age group since faces, from birth to 3 years, undergo rapid and marked developmental change.

Aim

To design masks that optimize alignment, improve seal, and minimize dead space by obtaining anthropometric data from faces of infants and young children.

Methods

- Key face mask features: coronal dimensions and rim contour.
- Vertical height, *H*, from the bridge of the nose to the most protuberant point of the chin was quantified in 271 children, ages 0-4 years (Figs. 1 & 2).
- 3D geometric topographies were obtained by structured light technology (Fig. 3). This method has sub-millimeter accuracy with texture-less surfaces like faces[2,3].
- Data from light patterns produced with a home cinema projector and computer are converted into a triangular surface mesh. Noise is removed, and the surface 'holes' filled (Fig. 4).

Fig. 1

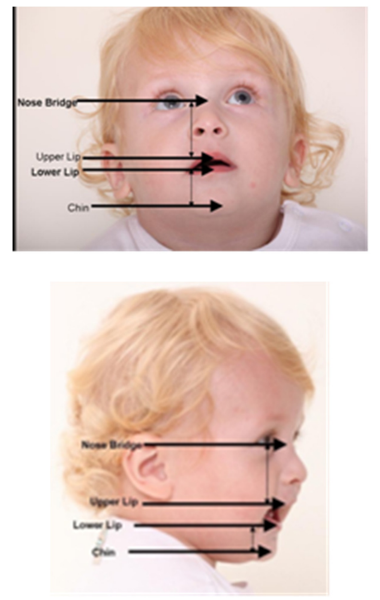


Fig. 2

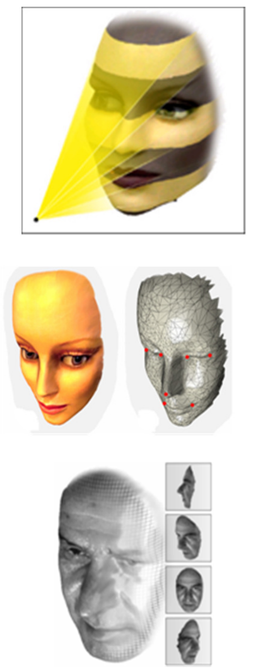


Fig. 3

Fig. 4

Results

Height

- *H* vs. age showed great variability (Fig. 5), indicating that age cannot be used as predictor of infants' facial dimensions for mask design.
- *H* and the horizontal closed mouth aperture provided much more reliable and reproducible indices from which the scans could be divided into small, medium and large clusters (Fig. 6).

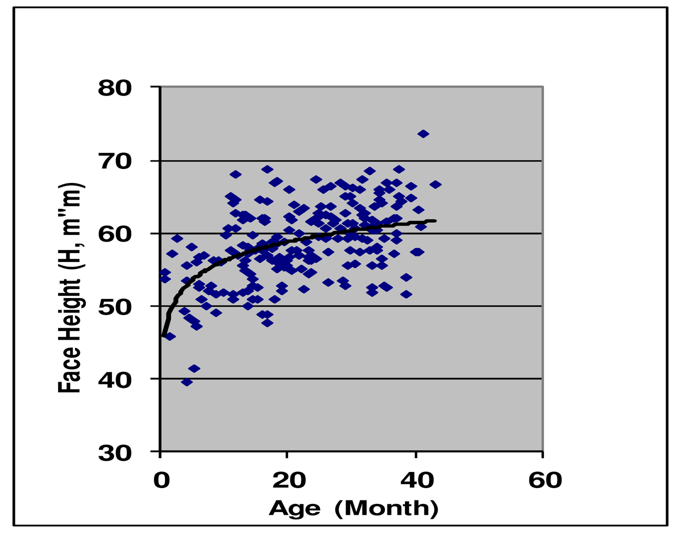


Fig. 5

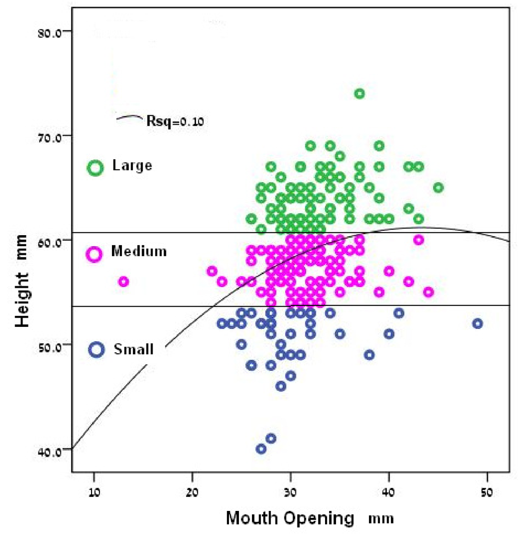


Fig. 6

Contour

- All faces within each cluster were aligned to develop an "average" (representative) face model using the iterative closest point (ICP) numerical algorithm.
- Each 3D image provided thousands of points in 3D space, serving as triangular vertices that, when combined, formed a triangulated mesh surface (Fig. 7). The ICP method starts with an initial 'guesstimate' relating the position of one surface with respect to the other and iteratively rotates and translates the surface for improving the alignment between the shapes.
- Two unaligned faces are shown on the left of Fig. 8, where one face is represented as a smooth template, while the second is represented as a triangulated mesh surface. Alignment of these two faces, using the ICP numerical algorithm, is shown on the right.
- A representative face was thus constructed by averaging the location of corresponding points for each cluster (Fig. 9).

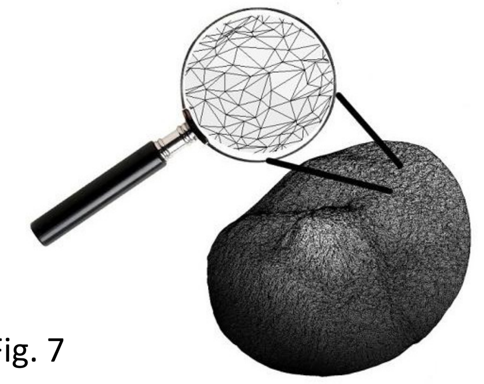


Fig. 7

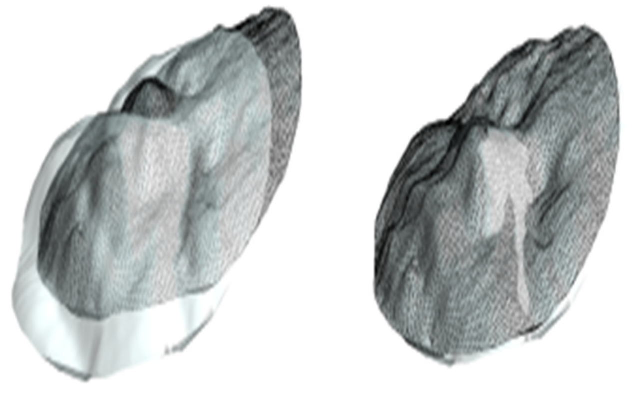


Fig. 8

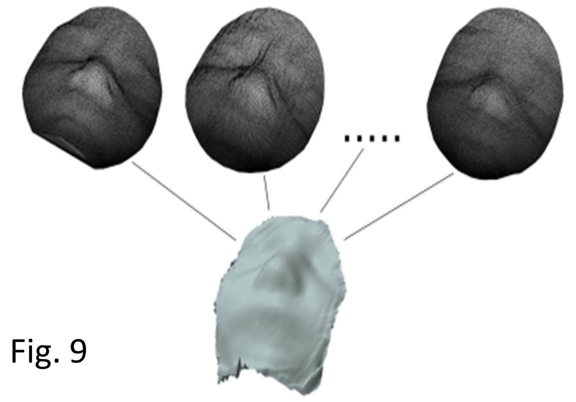
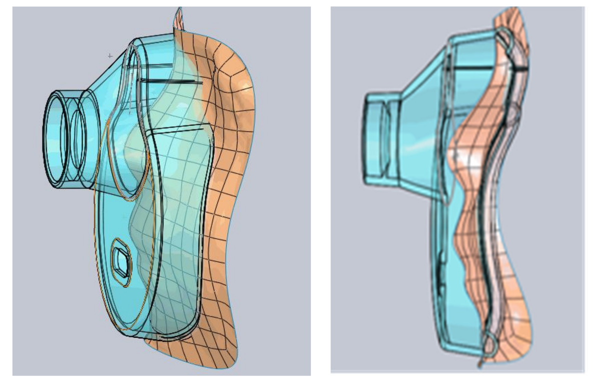
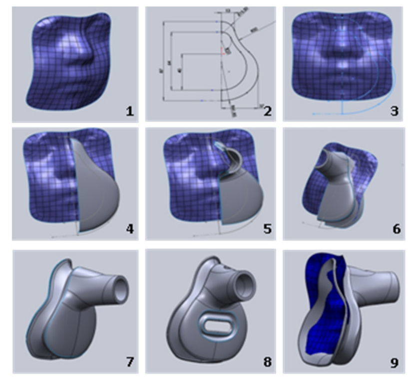


Fig. 9

Final Design

- A software engine aligned masks to each of the average faces resulting in an optimally sealing range of small, medium, and large sizes with minimal dead space.
- SootherMask® allows children to use their pacifier by inserting it through a slot in the front of the mask.
- An effective and gentle seal is established by atmospheric pressure as children suck on their pacifier with little additional force by caregivers.
- The same dimensions are used in the InspiraMask™, designed for children that do not use pacifiers.





Conclusions

Small, medium and large masks have been developed for delivering aerosols to children from birth to 4 years using unique, evidence-based anthropometric analysis. These masks follow facial contours to improve seal and reduce medication leakage while minimizing dead space. Further studies are underway to confirm the effectiveness of these masks in clinical practice.

References

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3. Heike CL, Upson K, Stuhaug E, Weinberg SM. 3D digital stereophotogrammetry: a practical guide to facial image acquisition. Head & Face Medicine 2010; 6:18.