Case Report

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Improved maternal bonding with the use of 3D-printed models in the setting of a facial cleft

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Aim: Case presentation of the effects of 3D-printed models on the maternal bonding of two fetuses with facial clefts. **Method:** In one case the Maternal Antenatal Attachment Scale was used to score maternal bonding before and after viewing of 3D-printed images. In the other case, the effect of the 3D-printed image was witnessed anecdotally. Both 3D prints were created using polylactic acid on an Ultramaker 2+ printer. **Result:** In both cases maternal bonding appeared to be improved. Increased global bonding and quality of attachment was quantifiably measured in the second case. **Conclusion:** 3D-printed models can be a useful addition to patient education and can positively impact maternal–fetal bonding. Further study is required to evaluate how 3D printing can affect maternal bonding in a larger setting.

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3D printing has been used to assist antenatal assessment and perinatal planning for abnormal facial anatomy in the fetus [1]. However, as printing capabilities improve and applications are explored [2–4], there may be advantages for parents to visualize and touch 3D-printed facial models to understand the anticipated appearance of their child, interventions and expected outcomes of antenatally diagnosed fetal facial clefts. Facial clefts as a clinical entity have important and unique psychosocial dimensions for parents and family members [5,6]. For those facial clefts diagnosed in the antenatal period, the impact on parental psychosocial well-being includes reduced reproductive self value, concerns about disadvantaged status of affected offspring and anxiety related to insufficient information about facial clefts. Recent studies demonstrate the importance of the use of 3D ultrasound during high-risk pregnancies and its implications in increasing antenatal maternal–fetal bonding, but the use of 3D printing in such cases has not been greatly documented [7]. Currently, we report two cases in which 3D printing impacted familial bonding and attachment to fetuses with cleft lip anomalies. Case number one involves the use of 3D printing to facilitate understanding between family members of a fetus diagnosed with Opitz G/BBB syndrome, a condition characterized by midline anomalies [8]. During case number two, assessment of 3D printing's effect on attachment and bonding was evaluated using the Maternal Antenatal Attachment Scale (MAAS) [9–11]. This scale showed an increased level of bonding and attachment when comparing the patient's scores after initial 3D ultrasound revealed a cleft lip anomaly and then after presentation of the 3D model.

Case report

Case number one

Case number one concerns a 27-year-old primigravid woman whose fetus demonstrated the presence of a single umbilical artery, Dandy–Walker malformation, and a bilateral cleft lip and cleft palate during her 20-week ultrasound (Figure 1). Amniocentesis and microarray analysis demonstrated the presence of a microdeletion at *Xp22.2*, and Opitz G/BBB syndrome was diagnosed. The possibility of producing a 3D print of the fetus' facial defect and possible outcome with correction was discussed with the patient and she accepted. A 3D image was made at 28 weeks (Figure 2) and the 3D-printed images were presented to the patient at 30 weeks gestation (Figure 3).

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Figure 1. 2D image of the cleft lip at 20 weeks.

When compared with images seen on ultrasound, the patient stated that the 3D prints tactile qualities enhanced her understanding of the defect as well as reduced her concerns that the defect might confer a decreased quality of life for her child. Furthermore, the patient's extended family voiced greater acceptance of the printed models compared with traditional ultrasound images. The positive impact made on the family by the 3D print was interacting with the 3D print. One family member seemed distraught by the baby's appearance upon delivery, and this individual was the only one who did not interact with the print (Figure 4).

Engineering of the 3D prints

The Data Imaging and Communications in Medicine data from a 3D ultrasound image (GE Voluson™ E8) of the defect was converted to standard tessellation language. Polylactic acid was used to print the original segmented image, as well as a corrected rendition of the defect on an Ultramaker 2+ 3D printer. The method described was utilized for construction of 3D prints in both cases.

Case number two

Case number two describes a 34-year old G4P3013 woman who presented for routine prenatal care at 8 weeks gestation. The pregnancy was complicated by chronic hypertension, and conception for this pregnancy was assisted by the use of Clomid® (clomiphene citrate). The patient had a history significant for a missed abortion treated by dilatation and curettage 11 years previously. Routine anatomic screening at 20 weeks showed a left unilateral cleft lip with no other abnormalities. Noninvasive prenatal testing (cfDNA) was also performed at this visit and demonstrated no aneuploidy. At this time, the patient was asked if she would like to view a 3D-printed model of the fetus and to take a questionnaire evaluating antenatal attachment, the MAAS.

Figure 2. 3D image of the cleft lip at 28 weeks.

Scoring the Maternal Antenatal Attachment Scale

The MAAS used during case two evaluated qualities of bond and duration via 19 items, each answered on a five-point scale. The patient completed the first MAAS at her 24-week appointment, earning a global score of 79 out of 95, a quality of attachment score of 47 and a score of 27 for time spent in attachment. The 3D print was constructed in similar fashion as described in the first case above. During the patient's next scheduled appointment at 28 weeks, the 3D print was presented to her and the patient was allowed to take it home. The second MAAS was completed by the patient 2 days later. The scores were as follows: global score of 80, quality of attachment of 48 and time spent in attachment mode of 27.

Discussion

There have been few reports describing how 3D printing of an anatomically anomalous fetus can be used to supplement the educational value of 2D or 3D ultrasound images. The accuracy and reproducibility of 3D-printed medical models have not been thoroughly investigated. Inaccuracies occur during imaging, segmentation, post processing and 3D printing itself [2]. Recent studies have explored x-ray microtomography as a commercial solution to reduce structural imperfections [4]. Additionally, optimization in additive manufacturing may help improve future attempts of translating the 3D ultrasound images into a more accurate representation of fetuses facial features [3]. We present two examples in which 3D printing provided visual and tactile information to the mother about her fetus in a manner not possible with ultrasound alone. Despite our current limitations, the results in these cases resemble findings from previous research which have shown that 3D ultrasound images improve mothers' perception of their babies to a greater degree than 2D ultrasounds [7]. In the first case, we found that the model appeared to have a positive effect on the interaction between the mother and her newborn, which contrasted with the reaction of the family member who had not seen the 3D model prior to the child's birth. In the second case, we demonstrated that there was an increase in MAAS score from 79 to 80 after presentation of the 3D-printed model. Quality of attachment was also seen to increase from 47 to 48. Since the first survey followed the diagnosis and the patients viewing of the initial 3D ultrasound image and the second survey followed the presentation of the 3D print, it appeared as though the 3D print improved the bonding score compared with the 3D ultrasound alone. Taken together, these two examples provide preliminary evidence that 3D printing could offer distinct benefits to

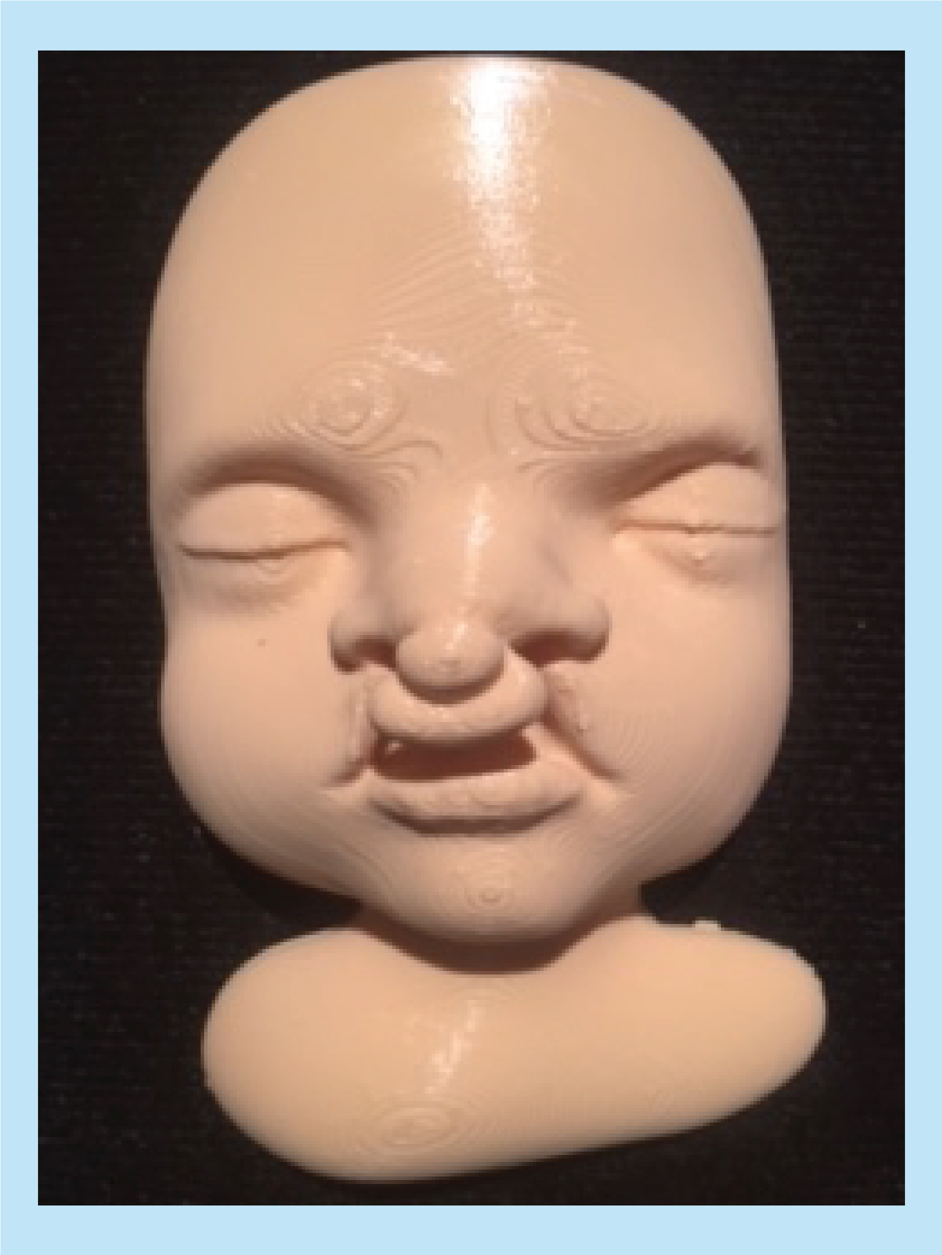

Figure 3. 3D print presented to the patient produced from the 3D image at 28 weeks.

patient education not currently available via 2D and 3D ultrasound by allowing the mother to feel a representation of her baby's face and interacting with it in real time. While these findings do not constitute definitive proof of the benefits of 3D printing with regards to maternal–fetal bonding, they do suggest that a significant increase in MAAS score may be found in a controlled study with a sufficient number of participants. A study testing whether or not there is a significant increase in MAAS scores after the presentation of 3D models would be useful because antenatal maternal–infant bonding predicts postnatal bonding, which is inversely associated with maternal-risk behaviors such as alcohol and tobacco use, poor healthcare and poor diet [12]. Furthermore, results of future studies that analyze the effect of 3D prints on maternal–fetal attachment and the occurrence of aforementioned risky behaviors during pregnancy could lead to indication for use of 3D printing in routine antenatal care to prevent adverse fetal outcomes, such as fetal alcohol syndrome, cocaine-induced abruption of the placenta and many others. A larger

Figure 4. Image of the infant after delivery.

sample size with adequate statistical power should be undertaken prior to implementing this technology in clinical practice.

Conclusion

In these two examples, the 3D printed models appeared to be a useful addition to the education of the patients. The 3D prints also appear to have positively affected maternal–fetal bonding.

Executive summary

- 3D prints aided in patient education and improved maternal fetal bonding in these two case examples.
- Further investigations using randomized, prospective studies are required to evaluate the value of 3D-printed models.

Financial & competing interests disclosure

J Coté has an affiliation with Image to Life, a 3D printing company, as a consultant. The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed.

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Informed consent disclosure

Informed consent had been obtained from the participants involved in accordance with Creighton University IRB.

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