Using low-cost 3d-printed models of prenatal ultrasonography for visually-impaired expectant persons

Romain Nicot, Edwige Hurteloup, Sebastien Joachim, Charles Druelle, Jean-Marc Levaillant

To cite this version:

Romain Nicot, Edwige Hurteloup, Sebastien Joachim, Charles Druelle, Jean-Marc Levaillant. Using low-cost 3d-printed models of prenatal ultrasonography for visually-impaired expectant persons. Patient Education and Counseling, 2021, Patient Education and Counseling, 104, pp.2146-2151. 10.1016/j.pec.2021.02.033 . hal-04459092

HAL Id: hal-04459092
https://hal.univ-lille.fr/hal-04459092v1

Submitted on 22 Jul 2024

Version of Record: https://www.sciencedirect.com/science/article/pii/S0738399121001312
Manuscript_eb8a7e72f60bf6e3a985b44aa4c776f6

Using low-cost 3D-printed models of prenatal ultrasonography for visually-impaired expectant persons

Romain Nicot, Edwige Hurteloup, Sébastien Joachim, Charles Druelle, Jean-Marc Levaillant

Romain Nicot, MD, MSc, Senior Lecturer
- Univ. Lille, CHU Lille, INSERM, Oral and Maxillofacial Surgery Department, U1008 - Controlled Drug Delivery Systems and Biomaterial, F-59000 Lille, France; Center for Woman and Fetal Imaging, F-59000, France

Edwige Hurteloup,
- Hôpital Privé Armand Brillard, Groupe Ramsay Générale de Santé, F-94130, Nogent-sur-Marne, France; Center for Woman and Fetal Imaging, F-59000, France

Sébastien Joachim, President of Sébastien Joachim Kick Blindness Association
- SJKB association, 2 rue du Culbuteau, F-91330 Yerres

Charles Druelle, MD,
- Univ. Lille, CHU Lille, Oral and Maxillofacial Surgery Department, F-59000 Lille, France

Jean-Marc Levaillant, MD, PhD
- Hôpital Privé Armand Brillard, Groupe Ramsay Générale de Santé, F-94130, Nogent-sur-Marne, France; Center for Woman and Fetal Imaging, F-59000, France

Corresponding author at:

Dr. Romain Nicot
Service de Chirurgie Maxillo Faciale et Stomatologie Hôpital Roger Salengro - Bd du Prof Emile Laine – 59037 - Lille - Cedex - FRANCE;
Tel: 33 6 65 37 88 07
E-mail: romain.nicot@gmail.com

Keywords: Printing, three-dimensional; Ultrasonography; Visually Impaired Persons; Blindness; Education; Touch Perception

Abstract

Background: For visually impaired or blind patients, the experience of pregnancy sets them apart from nondisabled people for whom viewing of the first ultrasound has become a social and emotional milestone.

Objective: We proposed the use of 3D-printed models to allow the societal inclusion of visually impaired or blind expectant parents.

Patient Involvement: Visually impaired expectant parents were proposed to touch a 3D printed sensory vector of their prenatal classic ultrasonography.

Methods: After a classic ultrasound assessment was performed, selected volumes were processed and 3D-printed with acrylonitrile butadiene styrene. Patient satisfaction was recorded after they manipulated the models.

Results: A total of 42 prenatal 3D prints were for 12 expectant parents, used during 20 ultrasonographic sessions with visually impaired or blind expectant parents. During 13 of them (65%), it was the mother who was affected by a visual loss whereas the father was the parent affected by the disability during 7 sessions (35%). The parent affected by the disability was congenitally blind and Braille-reader in 9 ultrasonography sessions (45%). All expectant visually impaired or blind parents expressed very significant satisfaction with the use of 3D models for inclusive use.

Discussion: We have shown that acrylonitrile butadiene styrene-printed models improve the sonographic experience of visually impaired or blind expectant parents. They can thereby perform their own mental representation process by extrapolating sensory information obtained from the 3D tactile support.

Practical value: These low-cost 3D-printed models improve the inclusion of visually impaired or blind expectant parents, by offering them a sensory vector of information.

Funding: This work was supported by UNADEV for 3D printing funding.

1. Introduction

A vision impairment affects approximately 1.3 billion people in the world, and it is estimated that 36 million people are blind [1]. The World Health Organization describes individuals with low vision as having a best-corrected vision of 20/60 or worse, and blind as best corrected vision worse than 20/400, whereas legal blindness is identified as 20/200 in the United States and most Western countries [2]. Either degree of visual handicaps may cause difficulties with all normal daily activities, such as reading, moving, and many social activities.

For a pregnant woman, feeling a new life developing inside her body is an amazing experience, even though she may feel discomfort of varying degrees at times. But pregnancy is experienced differently from woman to woman according to their experience, their background, and their medical history. For visually impaired or blind patients, pregnancy may be a further situation of lack of access to experiences common to visually nondisabled people [3]. Vision loss can lead to difficulties for expectant parents, such as pregnancy embodiment, mental representation, dependency upon oral description by health care providers, and early fetal attachment. Specialized prenatal teams may use many options to solve these difficulties. To increase blind women's prenatal attachment, they may be helped to palpate their abdomen, feeling the fetus's position and movements, and to listen to its heart. In addition, the sonographer can let blind expectant parents touch the medical instruments or the sonographic probe before the examination in order to reduce a fear of the unknown.

3D-printing technology from surface-rendered prenatal sonographic views has recently allowed expectant parents to better apprehend fetal faces with cleft lip and palate or other craniofacial abnormalities, significantly improving their comprehension

[4–6]. It has also been shown that using fetal facial models resulted in greater increases in maternal-fetal attachment than the use of ultrasonography only [7]. While it is known that touch perception in visually impaired patients is significantly enhanced through several tactile assistance technologies, such as Braille reading, we suggest using 3D-printing technology as a sensorial vector to bridge the gap between blind and nonblind expectant parents [8].

Here we present a case series highlighting the use of 3D-printed models to allow the societal inclusion of visually impaired or blind expectant parents.

2. Methods

Included patients

This retrospective study examined all visually impaired patients who were given the opportunity to manipulate 3D-printed models after prenatal sonography from June 2019 to August 2020. Only pregnancies that ended in a normal liveborn neonate were included. Fetuses with a craniofacial abnormality of a syndromic condition were excluded from this study.

The ultrasonographic examinations, including 3D-printing of tactile models between 12 and 28 gestational weeks, were performed in all visually impaired or blind referred patients.

All study procedures were performed in accordance with the ethical standards of the Helsinki Declaration. Informed consent from all expectant parents has been obtained. Evaluation by an institutional review board was not required because of the retrospective nature of the study. All data were anonymized, and the "Commission Nationale de l'Informatique et des Libertés de France" (CNIL) declaration was performed in accordance with French law.

Sonographic view acquisition

Examination was performed using a Voluson E10 ultrasound machine fitted with 3D RM6C abdominal mechanical transducers (GE Healthcare, Velizy, France). A surface-rendered coronal view of the face using 3D ultrasonography was employed to complete the classical screening protocol. The analysis protocol was based on multiplanar reconstructions in the three traditional orthogonal planes and tomographic reconstructions.

Ideally, the fetal face should be in an anterior position facing the transducer, and the mouth should be open or half-open. To obtain better 3D-printed results, the presence of amniotic fluid is necessary around the fetal face, thereby allowing surface-rendered structures to be isolated. The axis of the transducer was set in a strict midsagittal plane, and the speed of the mechanical sweep was set for high quality (slow sweep). Artifacts or structures that interfered with reading the ultrasound volume were later removed using the electronic scalpel. The virtual lighting (HD Live) was focused on the frontal view of the volume.

From ultrasound to the 3D-printed tactile model

After conversion of the source file in an STL format with our own software, we used the Blender freeware to repair the STL file before 3D printing. 3D printing has been performed with a low-cost UP Plus 2 3D printer. The UP plus 2 3D printer (Beijing TierTime Technology Co. Ltd., Beijing, China) is a rapid prototyping machine based on a fused deposition modeling technique that uses acrylonitrile butadiene styrene (ABS) as a raw material. Up Studio is the software provided with UP Plus 2 3D printers. 3D models were created layer by layer with a 0.15-mm thickness, allowing to obtain a 3D model with a smooth to the touch surface. The created ABS models were printed in fine quality and with a lightweight filling modality with adapted dimensions, allowing to be easily held in one hand and handled with the other. The choice of the material used was oriented to the ABS, which seems to provide a better definition of printed models. On the other hand, plastic ABS models printed by the low-cost 3D UPplus2® printer provide dimensional accuracy that is comparable to other well-established high-cost professional rapid prototyping technologies [9].

Tactile procedure assessment

After we performed the classic ultrasound assessment, selected volumes were processed and 3D printed with ABS. The encounter between each blind pregnant woman and their own 3D tactile models was assisted by a psychologist specializing in support of visually impaired persons and included associative support. When necessary (i.e. for fetal face models), the 3D model was correctly oriented for tactile reading. Satisfaction was simply assessed by a satisfaction questionnaire in the form of a Likert scale performed orally at the end of reading the ABS-printed models (What is your level of satisfaction with the tactile ultrasound in order to compensate for your visual disability in ultrasonographic sessions? Low, intermediate, high, very high). Descriptive data were calculated for the variables of interest. Quantitative variables are expressed as medians (interquartile range Q1;Q3) because of their non-normal distribution. Categorical variables are expressed as numbers (percentage).

3. Results

12 expectant parents have been included. A total of 42 prenatal 3D prints were performed during 20 ultrasonography sessions with visually impaired expectant parents. During 13 of them (65%), it was the mother who was affected by a visual loss whereas the father was the parent affected by the disability during 7 sessions (35%). Median age of the visually impaired parent was 33 (28;45). The parent affected by the disability was congenitally blind and Braille-reader in 9

ultrasonography sessions (45%). In one case (5%), the printing concerned twins. 3D-printed model characteristics are listed in Table 1 and examples are showed in Figures 1-4.

Median weight of created ABS models was 52.5 (44.5;58.3) grams, median dimensions were 81.6 (77.8;105.8) centimeters in length, 66.3 (65.3;78.6) centimeters in width and 44.1 (36.0;46.6) centimeters in depth, and required 6.9 (5.8;12.6) hours to print in fine quality and with a lightweight filling modality.

All visually impaired or blind expectant parents expressed a very significant satisfaction with the use of 3D models for inclusive use.

4. Discussion and Conclusion

4.1 Discussion

Prenatal ultrasounds are emotionally salient moments in the parental journey of blind pregnant women. The first ultrasound is for many expectant mothers the moment when they will concretize their pregnancy by hearing the sounds of the heart or seeing the first profile of the fetus on the monitor of the ultrasound machine. Most of them have never felt their baby moving at this stage of the pregnancy. However, vision loss precludes having the same experience. Individuals who are blind must rely on other senses, such as their sense of touch or hearing, in order to understand the world around them. The practitioner must therefore use a particular protocol to reduce the gap between visually impaired pregnant women and their visually unimpaired peers. To increase prenatal attachment, he or she can help blind women to palpate their abdomen, feeling the fetus's position and movements, and to listen to its heart. During the ultrasound exam, he or she has to take care to describe all morphological details of the fetus with appropriates words, trying to compare the main anatomical elements to those of the father or the mother. For example, a doctor might say, “He has your nose.”

Werner et al. have previously reported the use of 3D-printed models from both ultrasonography and magnetic resonance imaging (MRI) to enhance maternal-fetal attachment of blind pregnant women [10]. While 3D-printing technology has previously been reserved for some hyperselected cases benefiting from prenatal computed tomography or MRI, it can now be performed from ultrasonography data alone. Therefore, we used this technology to produce 3D-printed models obtained from surface-rendered views of ultrasounds of the normal entire fetus between 12 and 28 weeks and gave visually impaired or blind expectant parents the opportunity to handle these models. Prenatal tactile three-dimensional ultrasonography therefore offers visually impaired people a sensory vector that is useful for bridging the disability-related gap, allowing for societal inclusion.

Whereas vision and audition are recognized for providing highly precise spatial and temporal information, the haptic system is especially effective at processing the material characteristics of surfaces and objects [11]. In general, blind adults outperform age- and sex-matched sighted controls on tasks involving the judgment of tactile grating orientation and haptic 3D shape discrimination [12–14]. These haptic tasks are performed using a different level of complexity. In a situation of lost vision, the first step consists in stereotyped manual exploration procedures, such lateral motion, pressure, or contour following [11]. But this sensory modality also has an affective component, allowing the understanding of emotional expression [11,15]. It has been shown that it is possible to tactually communicate culturally universal human emotions by haptically exploring emotional expressions depicted on live faces, 3D facemasks, and even 2D raised-line drawings [11]. Lederman et al. have indeed shown that with little or no training, humans are capable of haptically processing the facial identity of both live faces and facemasks and the common facial expressions of emotion at levels well above chance, suggesting that manual contact with the face constitutes a highly informative input channel [15]. It is therefore likely that 3D-printed models representing the fetal face can be recognized by the blind expectant parents and can represent a sensorial vector leading to parental emotions in response to the discovering of the unborn baby. This tactile experience can enable an emotionally richer aspect to the medical consultation, offering blind expectant parents an accommodation that allows the first ultrasound appointment to be refocused on the parents' encounter with their unborn child. Blind parents can thereby perform their own mental representation process by extrapolating sensory information obtained from 3D tactile support.

Otherwise, Norman et al. suggest that early visual experience may play a role in the blindness-related enhancement of solid shape discrimination [13]. They indeed suppose that because congenitally blind persons have had little or no visual experience, they cannot effectively generate the visual images needed for the visual mediation of tactile input. We did not experience differences between congenital and acquired blindness in how the patients in our series responded to the models. It is possible that this assertion is true for the discovery of new shapes yet that it is more moderate when congenitally blind people touch known forms, such as the human face. In addition, Wong et al. have shown that proficient Braille readers on their preferred reading index finger outperformed nonreaders, suggesting that tactile experience drives tactile acuity enhancement in blindness [14]. In our series, even if the number of participants was too low to assess this point, it appeared that all the congenitally blind patients were Braille readers, perhaps explaining why their tactile skill joined that of the patients with acquired blindness.

Finally, haptic understanding involves several material properties such as surface texture, compliance, and thermal quality. These material properties could also be involved in differences of haptic perception. Perceived surface texture might be characterized, for example, in terms of its roughness, stickiness, slipperiness, or friction. All these material parameters are capable of affecting the way people perceive an object through their haptic system. It is likely that they depend directly on the type of printed material used and printed-related parameters. 3D models of our case series have been printed in ABS material with 0.15 mm layers. We tried others 3D printing materials. When layers are of equal thickness, liquid photopolymer resin could offer a higher quality of tactile experience than ABS material (Figure 5). Specific studies comparing material-related tactile experience are mandatory to identify the optimal sensory vector. The haptic rendering of 3D printing will gradually become more and more realistic, offering visually impaired parents' a better quality of discovery of their unborn child.

4.2 Conclusion

Through this case series, we have shown that ABS-printed models improve the sonographic experience of visually impaired people. Different materials could be used to achieve these models. Prospective evaluation of 3D-printing-assisted prenatal diagnoses for visually impaired people is required.

4.3 Practice Implication

Offering 3D-print models to blind expectant parents can be easily achieved in everyday practice since these models can now be printed from ultrasound data only. In addition, we have shown that low-cost printing with ABS (less than $50) provides very high satisfaction on the part of visually impaired or blind patients. Resin models could also be made easily, with a slightly higher cost (less than $100).

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

NA

Funding

This work was supported by UNADEV for 3D printing funding.

References

[1] R.R.A. Bourne, S.R. Flaxman, T. Braithwaite, M.V. Cicinelli, A. Das, J.B. Jonas, J. Keeffe, J.H. Kempen, J. Leasher, H. Limburg, K. Naidoo, K. Pesudovs, S. Resnikoff, A. Silvester, G.A. Stevens, N. Tahhan, T.Y. Wong, H.R. Taylor, Vision Loss Expert Group, Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis, Lancet Glob Health. 5 (2017) e888–e897. https://doi.org/10.1016/S2214-109X(17)30293-0.

[2] H.F. Daiber, D.M. Gnugnoli, Visual Acuity, in: StatPearls, StatPearls Publishing, Treasure Island (FL), 2020.

[3] D. Ofir, R. Kessous, N. Belfer, T. Lifshitz, E. Sheiner, The influence of visual impairment on pregnancy outcomes, Arch. Gynecol. Obstet. 291 (2015) 519–523. https://doi.org/10.1007/s00404-014-3412-4.

[4] R. Nicot, C. Druelle, E. Hurteloup, J.-M. Levaillant, Prenatal craniofacial abnormalities: from ultrasonography to 3D-printed model, Ultrasound Obstet Gynecol. (2019). https://doi.org/10.1002/uog.20242.

[5] R. Nicot, G. Couly, J. Ferri, J.-M. Levaillant, Three-dimensional printed haptic model from a prenatal surface-rendered oropalatal sonographic view: a new tool in the surgical planning of cleft lip/palate, Int J Oral Maxillofac Surg. 47 (2018) 44–47. https://doi.org/10.1016/j.ijom.2017.06.005.

[6] M. Schlund, J.-M. Levaillant, R. Nicot, Three-Dimensional Printing of Prenatal Ultrasonographic Diagnosis of Cleft Lip and Palate: Presenting the Needed “Know-How” and Discussing Its Use in Parental Education, Cleft Palate Craniofac. J. (2020) 1055665620926348. https://doi.org/10.1177/1055665620926348.

[7] J.J. Coté, A.S. Badura-Brack, R.W. Walters, N.G. Dubay, M.R. Bredehoeft, Randomized Controlled Trial of the Effects of 3D-Printed Models and 3D Ultrasonography on Maternal-Fetal Attachment, J Obstet Gynecol Neonatal Nurs. 49 (2020) 190–199. https://doi.org/10.1016/j.jogn.2020.01.003.

[8] R. Nicot, S. Joachim, J.-M. Levaillant, Prenatal tactile three-dimensional ultrasonography for visually impaired women, Acta Obstet Gynecol Scand. 99 (2020) 555–556. https://doi.org/10.1111/aogs.13755.

[9] F. Maschio, M. Pandya, R. Olszewski, Experimental Validation of Plastic Mandible Models Produced by a “Low-Cost” 3-Dimensional Fused Deposition Modeling Printer, Med. Sci. Monit. 22 (2016) 943–957. https://doi.org/10.12659/msm.895656

[10] H. Werner, J. Lopes, G. Tonni, E. Araujo Júnior, Maternal-fetal attachment in blind women using physical model from three-dimensional ultrasound and magnetic resonance scan data: six serious cases, J. Matern. Fetal. Neonatal. Med. 29 (2016) 2229–2232. https://doi.org/10.3109/14767058.2015.1085015

[11] S.J. Lederman, R.L. Klatzky, Haptic perception: a tutorial, Atten Percept Psychophys. 71 (2009) 1439–1459. https://doi.org/10.3758/APP.71.7.1439.

[12] D. Goldreich, I.M. Kanics, Tactile acuity is enhanced in blindness, J. Neurosci. 23 (2003) 3439–3445. https://doi.org/10.1523/JNEUROSCI.23-08-03439.2003

[13] J.F. Norman, A.N. Bartholomew, Blindness enhances tactile acuity and haptic 3-D shape discrimination, Atten Percept Psychophys. 73 (2011) 2323–2331. https://doi.org/10.3758/s13414-011-0160-4.

[14] M. Wong, V. Gnanakumaran, D. Goldreich, Tactile spatial acuity enhancement in blindness: evidence for experience-dependent mechanisms, J. Neurosci. 31 (2011) 7028–7037. https://doi.org/10.1523/JNEUROSCI.6461-10.2011.

[15] S.J. Lederman, A. Kilgour, R. Kitada, R.L. Klatzky, C. Hamilton, Haptic face

processing, Can J Exp Psychol. 61 (2007) 230–241.
https://doi.org/10.1037/cjep2007024.

Tables and figures

Figure 1: Tactile ABS plastic 3D models of normal entire fetus at 12 weeks printed with Up Plus 2, used as sensory vector in a blind pregnant woman to discover her unborn child.

Figure 2: Tactile ABS plastic 3D model of fetal face at 28 weeks printed with Up Plus 2.

Figure 3: Tactile ABS plastic 3D model of fetal face at 27 weeks printed with Up Plus 2.

Figure 4: Tactile ABS plastic 3D model of profile view of fetal face at 23 weeks printed with Up Plus 2.

Figure 5: Tactile photopolymer resin 3D models of normal entire fetus at 27 weeks printed with Form 2, used as sensory vector in a blind pregnant woman to discover her unborn child. Printing was performed with Form 2 3D printer (Formlabs Inc, Somerville, MA 02143, USA) using a liquid photopolymer resin, which is cured with an ultraviolet laser.

Table 1: Characteristics of patients who benefited from tactile ultrasonography

	Parent affected by the disability	Level of disability	Braille-reader	Age of fetus at printing	Type of 3D-printed model	Level of satisfaction	Number of printed models
1	Mother	Visual impaired	No	12	ABS	Very high	1
2	Mother	Visual impaired	No	19	ABS	Very high	3
3	Mother	Visual impaired	No	22	ABS	Very high	4
4	Father	Acquired Blind	No	22	ABS	Very high	3
5	Father	Acquired Blind	No	28	ABS	Very high	4
6	Mother	Acquired Blind	No	22	ABS	Very High	1
7	Mother	Congenitally blind	Yes	12	ABS	Very high	2
8	Father	Congenitally blind	Yes	12	ABS	Very high	2
9	Mother	Congenitally blind	Yes	23	ABS	Very high	2
10	Father	Congenitally blind	Yes	23	ABS	Very high	2
11	Mother	Congenitally blind	Yes	27	ABS	Very high	3
12	Father	Congenitally blind	Yes	27	ABS	Very high	3
13	Mother	Congenitally blind	Yes	12	ABS	Very high	2
14	Father	Congenitally blind	Yes	12	ABS	Very high	2
15	Mother	Acquired Blind	No	13	ABS	Very high	2
16	Mother	Acquired Blind	No	24	ABS	Very high	3
17	Mother	Acquired Blind	No	22	ABS	Very high	2
18	Mother	Acquired Blind	No	28	ABS	Very high	3
19	Mother	Acquired Blind	No	23	ABS	Very high	2
20	Father	Congenitally blind	Yes	28	ABS	Very high	2