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RESEARCH

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An effective ultrasound fetal palate screening software based on the "sequential sector scan through the oral fissure" and three-dimensional ultrasound

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Abstract

Background Orofacial clefts are one of the most common congenital malformations of the fetal face and ultrasound is mainly responsible for its diagnosis. It is difficult to view the fetal palate, so there is currently no unified standard for fetal palate screening, and the diagnosis of cleft palate is not included in the relevant prenatal ultrasound screening guidelines. Many prenatal diagnoses for cleft palate are missed due to the lack of effective screening methods. Therefore, it is imperative to increase the display rate of the fetal palate, which would improve the detection rate and diagnostic accuracy for cleft palate. We aim to introduce a fetal palate screening software based on the "sequential sector scan though the oral fissure", an effective method for fetal palate screening which was verified by our follow up results and three-dimensional ultrasound and to evaluate its feasibility and clinical practicability.

Methods A software was designed and programmed based on "sequential sector scan through the oral fissure" and three-dimensional ultrasound. The three-dimensional ultrasound volume data of the fetal face were imported into the software. Then, the median sagittal plane was taken as the reference interface, the anterior upper margin of the mandibular alveolar bone was selected as the fulcrum, the interval angles, and the number of layers of the sector scan were set, after which the automatic scan was performed. Thus, the sector scan sequential planes of the mandibular alveolar bone, pharynx, soft palate, hard palate, and maxillary alveolar bone were obtained in sequence to display and evaluate the palate. In addition, the feasibility and accuracy of the software in fetal palate displaying and screening was evaluated by actual clinical cases.

Results Full views of the normal fetal palates and the defective parts of the cleft palates were displayed, and relatively clear sequential tomographic images and continuous dynamic videos were formed after the three-dimensional volume data of 10 normal fetal palates and 10 cleft palates were imported into the software.

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Conclusions The software can display fetal palates more directly which might allow for a new method of fetal palate screening and cleft palate diagnosis.

Keywords Cleft palate, Three-dimensional, Software, Cleft lip, Ultrasound

Background

Orofacial clefts are one of the most common congenital malformations of the fetal face and have an adverse effect on physical and psychological development [1, 2]. The palate consists of a primary palate and a secondary palate. The primary palate is the small part of the hard palate, consisting of lips, maxilla, and nasal bones, while the secondary palate is the large part of the palate, including most of the hard palate, the alveolar bones behind fangs and the whole soft palate which is located behind the hard palate and ending in the uvula. The palate develops and merges from the globular process of the median nasal process and the palatine process of the maxillary process. The globular processes on both sides form the premaxillary processes, which fuse at the midline to form the primary palate. The palatine processes on both sides grow and fuse at the midline and then grow forward to fuse with the primary palate at the incisor hole to form the secondary palate. At the 9th week of the embryo, if one or both palatine processes fail to fuse with the upper nasal septum, unilateral or bilateral cleft palate forms. If one or both primary palates fail to fuse with secondary palates normally, a primary cleft palate or alveolar cleft may form. At the 12th week of the embryo, palatine processes on two sides fuse from front to back and if the fusion is obstructed, soft cleft palate and submucosal cleft can form.

Ultrasound is one of the most important methods to diagnose orofacial clefts [3, 4]. Fetal palate is a dome-shaped structure that is hidden by bony structures which may cause sound attenuation(The property of sound wave is weakened or reduced in energy due to the divergence, absorption, reflection, and scattering) and sound shadow(An area through which sound waves fail to propagate, presenting a dark area), as a result, the palate is easily obscured during screening, making the display of the palate and the prenatal diagnosis of cleft palate difficult [5]. And that are parts of why there is currently no unified standard for fetal palate screening, and the diagnosis of cleft palate is not included in the relevant prenatal ultrasound screening guidelines [6, 7]. Therefore, it is imperative to increase the display rate of the fetal palate, which would improve the detection rate and diagnostic accuracy for cleft palate.

Our research group designed a fetal palate screening technique based on the characteristics of the fetal oral anatomy and the directivity of the ultrasound beam—the "sequential sector scan through the oral fissure (SSSTOF)" (an ultrasound screening technique that performing sequential scans starts from the initial section of the anterior superior border of the mandibular alveolar bone-tongue-pharynx and ends up with the final section of the maxillary alveolar bone-anterior superior border of the mandibular alveolar bone after selecting the anterior superior border of the mandibular alveolar bone as the fulcrum, fissure refers to the gap between the maxillary and mandibular alveolar bones which are not covered by bony structures). This technique has been applied for routine fetal palate screening in our hospital for several years. Our cases were all compared with the follow-up results after birth or induction. Excluding the missing cases and the cases without satisfactory images, for cleft lip and palate, the sensitivity and specificity of our method were 100%, and for isolated cleft palate, the sensitivity was 100%, revealing that the "SSSTOF" is a feasible and relatively accurate technique for fetal palate screening [8]. In addition, we designed a training program, which revealed that the "SSSTOF" greatly helped to standardize fetal palate scanning and increase the display rate of the fetal palate [9]. However, repeated and targeted training which costs much time and labor must be provided to help doctors to master this method. Aiming to further simplify the process, improve the popularity and practicability of the scanning method and further help with the diagnosis of cleft palate, we designed software for screening the fetal palate according to the "SSSTOF" and three-dimensional (3D) ultrasound.

Methods

The methodological design of the "SSSTOF" and its effectiveness

The ultrasound beam was adjusted to follow the superior border of the mandibular alveolar bone, pointing to the pharynx through the oral fissure, thus obtaining the preliminary section-section A image (Fig. 1, Section A, Fig. 2, Section A), which displayed the arc-shaped strong echo of the upper edge of the mandibular alveolar bone (Fig. 2, a) and the anechoic area of the pharynx (Fig. 2, b).

Then, the superior border of the mandibular alveolar bone was selected as the fulcrum, and a sequential sector scan was performed with a tilted beam based on section A, continuously sliding from the pharynx to the fetal head side to display the following sections sequentially: the soft palate section (Fig. 1, Section B, Fig. 2, Section B), the hard palate section (Fig. 1, Section C, Fig. 2, Section C), the maxillary alveolar bone section (Fig. 1, Section C, Fig. 2, Section C), and the soft palate (Fig. 2, c),

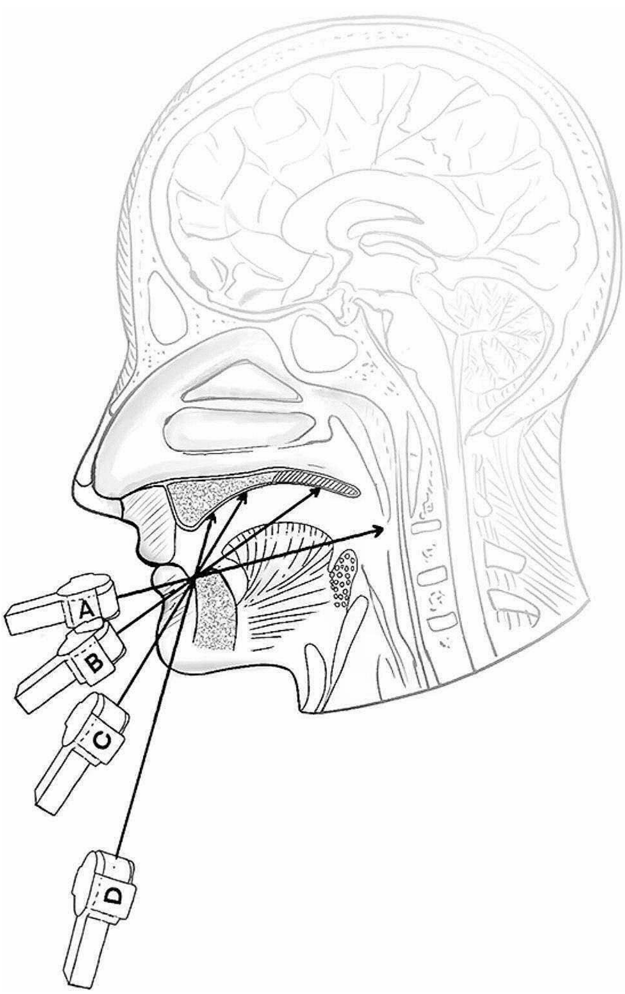

Fig. 1 Diagram illustrating sequential sector scan approaches through the oral fissure: **A**, section of the superior border of the mandibular alveolar bone, tongue, and pharynx; **B**, section of the soft palate; **C**, section of the hard palate; **D**, section of the maxillary alveolar bone

the hard palate (Fig. 2, d), and the maxillary alveolar bone (Fig. 2, e).

The dynamic scan of "SSSTOF" is shown in Additional file 1 [9].

The "SSSTOF" can make full use of the oral fissure, a physical lacuna, and the directivity of the acoustic beam, resulting in avoidance of the coverage of bony structures to the maximum extent, and thus, obtaining better reflected signals of the fetal palate. Furthermore, a dynamic scan of the "SSSTOF" could show a full view of the fetal palate, not just a single or several planes. Therefore, the "SSSTOF" overcomes two major problems: ultrasound beams cannot directly enter the fetal palate though conventional two-dimensional (2D) scans and the whole fetal palate cannot be observed by a single section.

The palates of fetuses with lethal malformations but normal palates in vitro after induction were scanned using the "SSSTOF", and the sections obtained are shown in Fig. 2 [8]. It was revealed that the "SSSTOF" could clearly and completely display the fetal palate.

We applied the "SSSTOF" for routine fetal palate screening in our hospital and screened a total of 7,154 fetuses at approximately 20–28 weeks of gestation, fifty-six of whom were lost to follow-up; thus, 7,098 fetuses were ultimately included in the analysis. Among the included fetuses, satisfactory images of the palate structure were obtained for 6,885 fetuses, and the fetal palate acquisition rate was 97% (6,885/7,098). Our diagnoses were consistent with the follow-up results. Excluding the missing cases and the cases without satisfactory images, for cases of cleft lip and palate, the sensitivity and specificity of our technique were both 100%, and for cases of isolated cleft palate, the sensitivity was 100%. Our diagnostic accuracy was 100%, and there were no missed diagnoses [8]. Thus, the "SSSTOF" has been confirmed to be a feasible method for palate screening.

The design of software base on "SSSTOF" and 3D ultrasound

To master "SSSTOF", repeated and targeted training is essential, which requires relatively high labor, material, and time costs. To further simplify the whole scan process and increase the efficiency of fetal palate scanning, we designed software for automatic screening of the fetal palate. The software was designed to simulate the manual 2D ultrasound scanning process of "SSSTOF" to realize the automatic scanning process to observe the fetal palate intuitively and completely.

The screening software was designed according to the "SSSTOF" and 3D ultrasound and was developed by Matlab, and the development environment was also Matlab. Various interpolation processes are used for the original 3D image volume data to improve the image resolution. The software was mainly composed of 3D volume data import, 3D images interpolation processing, fetal palate sector scanning, image saving and display.

Results

We successfully developed the software and has obtained the Chinese software copyright ("Software for fetal screening based on 3D ultrasound V1.0", No.2023SR0166273). The software interface is shown in Fig. 3.

We imported the 3D volume data of 10 fetuses with normal palates and 10 fetuses with cleft palates into the software and selected the fulcrum coordinates, scan angles, and number of section layers. First, we obtained 3D volume data of the fetal face through a 3D probe, then, exported the data (Vol/DICOM3D) offline and imported them into the software after they were being converted into Nrrd format files by Slicer5.2.1 software. Second, we taken the sagittal plane as the reference

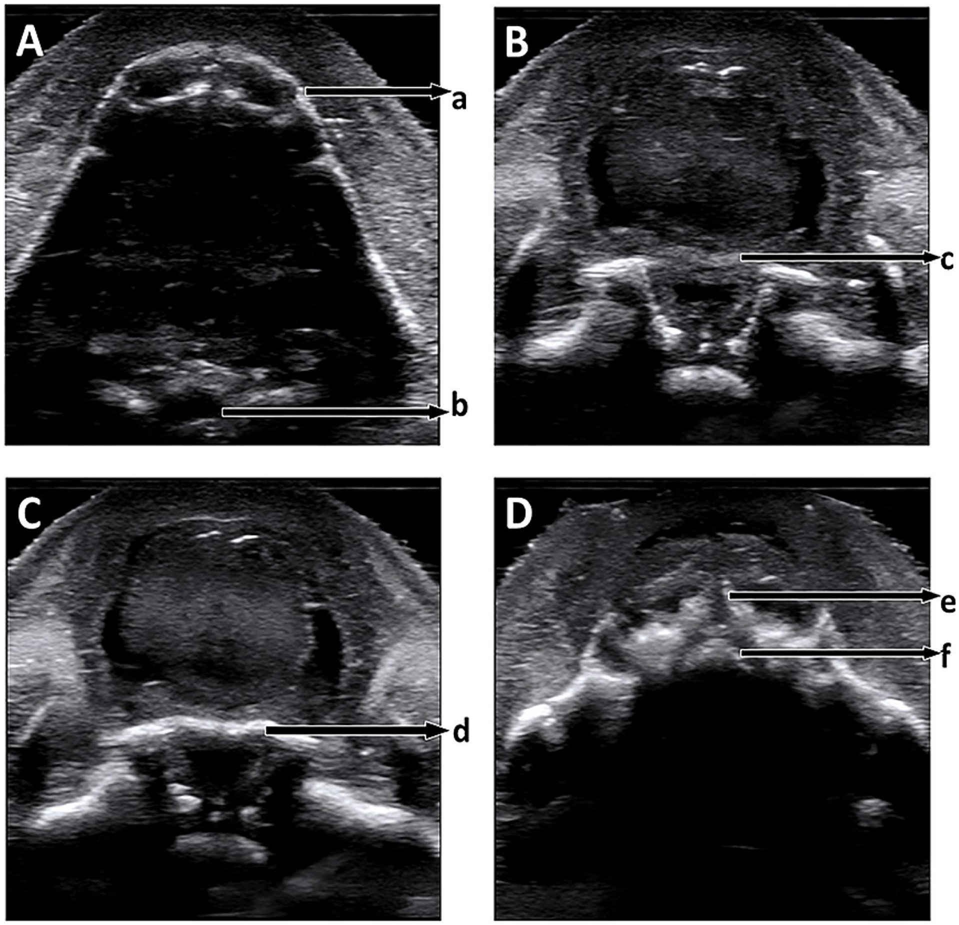

Fig. 2 Sections of the normal palates of fetuses with lethal malformations after induction using the "SSSTOF": **a**, mandibular alveolar bone; **b**, pharynx; **c**, soft palate; **d**, hard palate; **e**, maxillary alveolar bone; **f**, primary palate. We have obtained permission from the copyright holder to reproduction

interface, selected the anterior upper margin of the mandibular alveolar bone as the fulcrum after visually adjusted the coronal, transverse, and sagittal planes (Fig. 3, a), and then set the interval angles of the sector scan and the number of layers (Fig. 3, b). Third, after clicking "start", a continuous sequential sector scan was performed, which started from the anterior superior edge of the mandibular alveolar bone-tongue-pharynx section and ended at the anterior superior edge of the mandibular alveolar bone- maxillary alveolar bone section. Then, panorama and continuous scan sections of the fetal palate were obtained, and the mandibular alveolar bone, pharynx, soft palate, hard palate, and maxillary alveolar bone were displayed in sequence to evaluate the palate (Fig. 3, d). The operation progress of this software is shown in Additional file 2.

The software was able to display full views of the normal fetal palates and the defective parts of the cleft palates and form relatively clear serial tomographic images (as shown in Figs. 4 and 5) and corresponding continuous sequence dynamic scan is shown in Additional file 3 and Additional file 4, which directly and comprehensively displayed the fetal palate. In the normal cases, the palate was clearly displayed as a continuous arc sequence from the pharynx to the soft palate and to the hard palate, while the cleft palate was clearly displayed as having an interruption and loss of echo continuity from the pharynx to palate.

Discussion

Cleft lip and palate are categorized as cleft lip with or without a cleft palate and isolated cleft palate. Ultrasound is recognized as the safest and most accurate protocol for fetal palate screening. It is difficult to display the palate, resulting in a low detection rate of cleft palate [6, 10]. The main reason is that the fetal palate is hidden by the bony structures of the fetal head, and the attenuation of incident sound waves resulting from the large acoustic impedance (The complex ratio of the sound pressure of a medium over an area of a wave to the velocity of volume through that area) of the bony structures causes acoustic shadows, which obscure the fetal palate. Furthermore, the palate is a dome-shaped structure that requires multiangle ultrasonic observation. Due to the

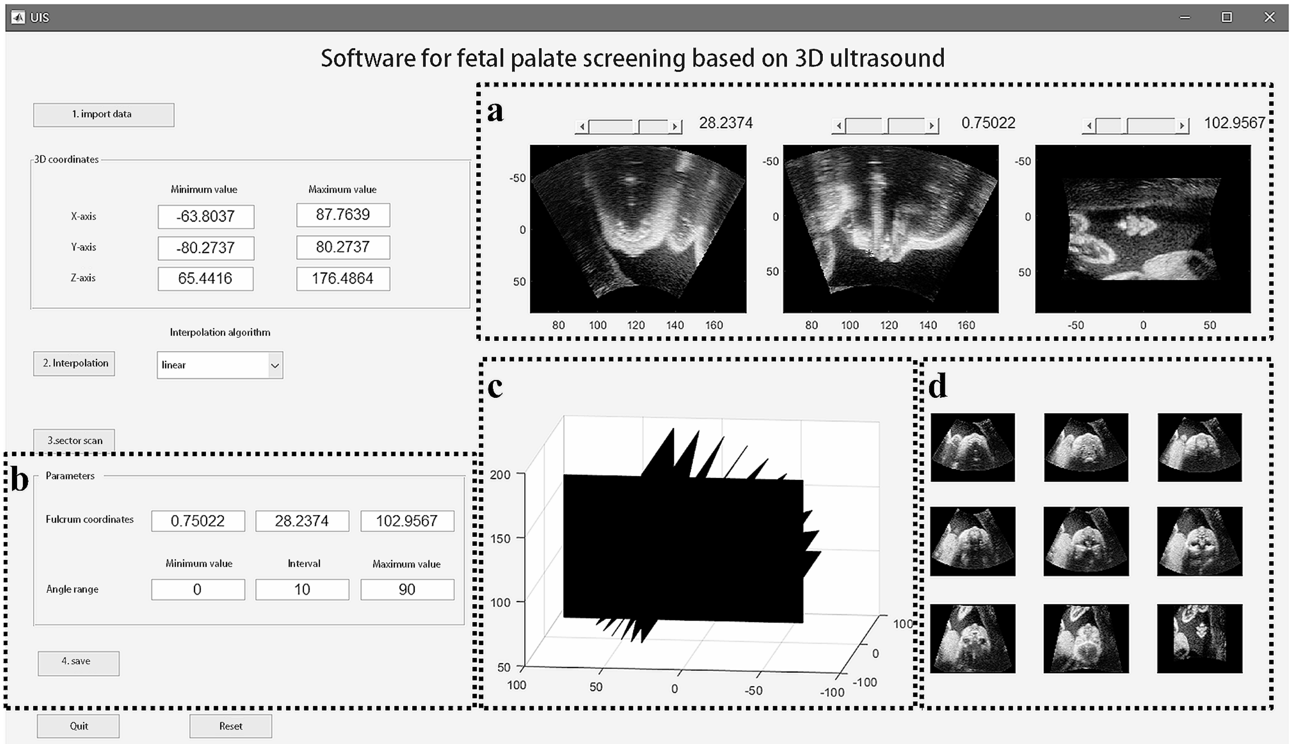

Fig. 3 The operating interface of the fetal palate analysis software based on the "SSSTOF": **a**, the transverse section, median sagittal section and coronal section and their coordinate values; **b**, the sector scan parameters (fulcrum coordinates and scanning angle range); **c**, the spatial distribution diagram of X, Y and Z coordinate axis values after the 3D volume data were imported into the software; **d**, continuous section of the fetal palate obtained from the software

low display rate, fetal palate screening has not yet been adopted into the essential aspects of prenatal ultrasound screening guidelines or consensus, and a unified standard has not yet been formed. Therefore, it is a great challenge to screening the fetal palate, which is also the purpose of this paper. Our research group designed the "SSSTOF" according to the special anatomical features of the fetal palate, which proved to be effective in screening the fetal palate, and we further designed a semi-automatic scanning software based on "SSSTOF" and 3D ultrasound. The software can display the panorama of normal fetal palates and cleft palates relatively clearly, which, may promote the ultrasonic scanning of fetal palate and detection of cleft palate, and be of innovative significance.

In recent years, many researchers have explored 2D ultrasound signs and techniques for palate screening, such as the "superimposed-line" sign and the "equal" sign in the second trimester of pregnancy and the "retronasal triangle" sign and the "maxillary gap" sign in the first trimester of pregnancy [11–18]. The "superimposed-line", as a marker for the presence of cleft palate, is mainly based on the special anatomical basis that the vomer of the normal fetus is fused with the nasal septum and forms a joint. Studies have shown that the sensitivity of diagnosing fetal cleft palate is approximately 89.5% when this sign is observed which has a high diagnostic value for the midline cleft of the secondary palate [11]. However, for the soft and primary cleft palates, this sign cannot provide diagnostic information. For the "equal" sign, the point is to identify the uvula and take the "equal" sign (high-low-high echo) of the uvula as a symbol of secondary palate integrity as the development of cleft palate always starts from the uvula and develops along the midline. The "equal" sign also has some limitations. When the fetal head is obviously flexed, the uvula cannot be displayed, and the uvula is most clearly displayed only at 13 to 17 weeks, and it is fused into a single line after 24 weeks which is not easy to identify and display. For the "retronasal triangle" sign, generally observed in the coronal section, the three echo lines of the palatal process of the maxilla on both sides and the primary palate, consist of a triangle. Its main application value is to show whether the primary palate is defective, but it cannot identify the secondary and soft cleft palates and provide diagnostic information [13–15]. For the "maxillary gap" sign, in the midsagittal section, if there is a visible gap between the maxilla- "maxillary gap" sign, it might indicate the existence of cleft palate. However, cleft palate cannot be excluded if there is no "maxillary gap". Furthermore, at 11 to 13 weeks, the maxilla may still be

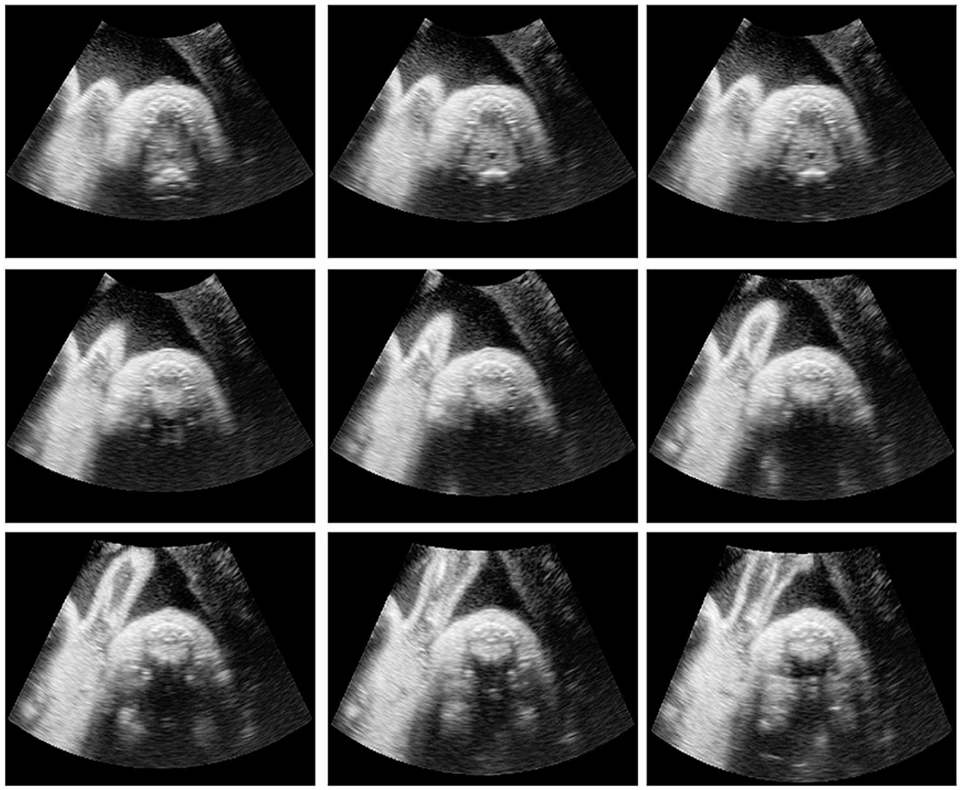

Fig. 4 Continuous sequential scan sections obtained from the software for fetuses with normal palates

incompletely ossified, and false negative and false positive cases might not be excluded. Related scholars have also explored 3D ultrasound, which revealed that 3D ultrasound helps in greatly improving the diagnosis of orofacial cleft [19–27].

The above signs only focus on single plane or several planes of the palate, which cannot provide whole information of the fetal palate. However, our research group designed a fetal palate screening method— the "SSSTOF". This technique has breaks through the scanning blind area where the palate is hidden by bony structures and cannot be completely and directly displayed. The sound beam is directly pointed at the fetal palate though the oral fissure and sector scanning is performed by selecting the anterior superior edge of the mandibular alveolar bone as the fulcrum to display the full view of the palate, reducing the influence of the bony structures to a greater extent and obtaining a better reflex signal of the palate [8]. Furthermore, the "SSSTOF" has more advantages in displaying the panorama of the palate and for judging the type of cleft palate. In addition, it has been indicated that the technique is a feasible and relatively accurate method for fetal palate screening [8].

The "SSSTOF" helps to standardize fetal palate scanning by doctors and may provide a consensus for fetal palate screening [9]. More pregnant women or fetuses benefit if an automatic screening software could be designed or if a software could even be implanted into an ultrasound machine to achieve automatic data acquisition and intelligent evaluation. To realize this idea, we designed this software. We needed to display the median sagittal plane of the fetal face, which is more easily obtained and to obtain all 3D volume data by a 3D transducer. Then, we imported the data into our software offline, set the parameters of the sequential scan, and selected the anterior superior edge of the mandibular alveolar bone as the fulcrum to perform an automatic sequential sector scan, simulating and replacing the former artificial scan, which is more intelligent in displaying the panorama and the continuous sections of the fetal palate. This improved the display rate and the efficiency in displaying the fetal palate. In our research, we imported the 3D volume data of 10 fetuses with normal palates and 10 fetuses with cleft palates into the software and obtained clear panoramas, continuous sections, and videos for each fetal palate, which revealed that the software has strong clinical feasibility and practicability for displaying the fetal palate. In addition, the software can avoid the image variation caused by scanner variation to a large extent. The image and video in the software can be saved and exported for repeated research, reducing the time of fetal ultrasonic exposure, and enhancing safety.

However, whether the software can display the fetal palate clearly depends on whether we can obtain

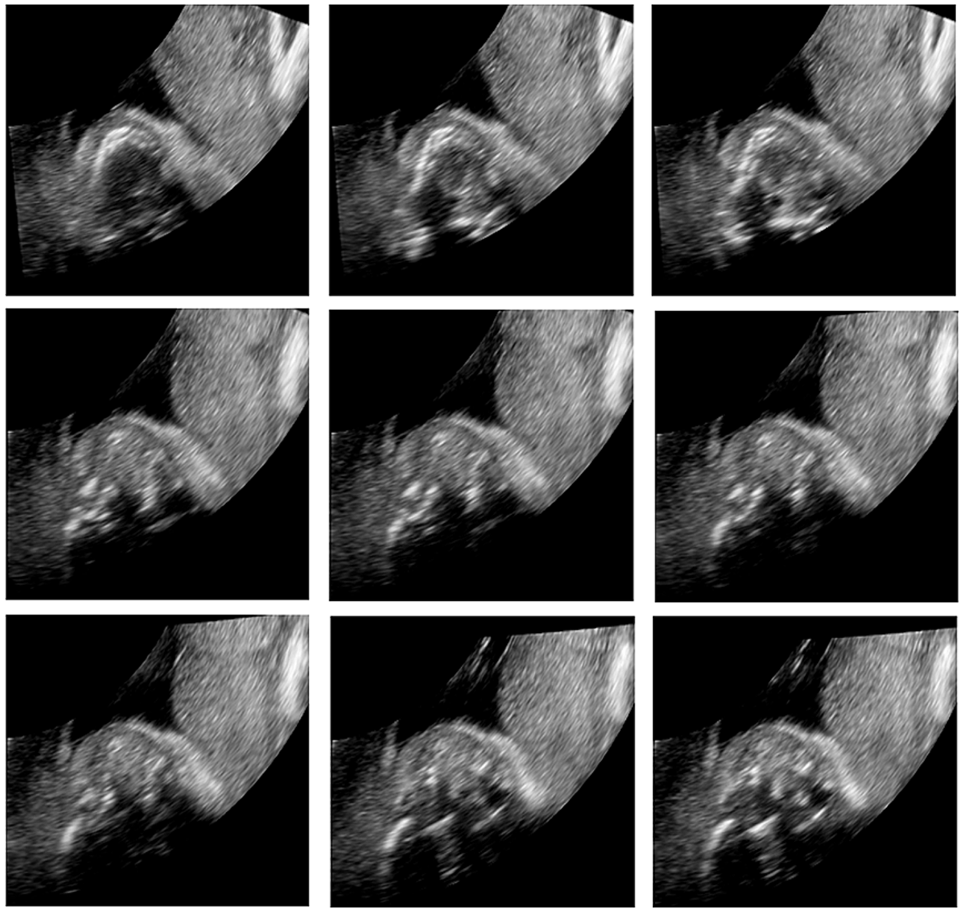

Fig. 5 Continuous sequential scan sections obtained from the software for fetuses with cleft palates

high-quality 3D volume data of the fetal face. For cases of head hyperflexion, the 3D probe cannot provide complete volume data of the fetal face, and we should try our best to obtain data when the fetal head is extended. Therefore, we should place the 3D probe as close as possible to the mandibular alveolar bone and avoid the shadow of the alveolar bones to the greatest extent possible.

Due to the limitation of the exported data file format, the size and quality of the image rendered by the software might be slightly affected. In the future development stage, if the software can be implanted into ultrasound equipment, raw data could then be used online to complete the automatic scan, and the image quality rendered by the software would be improved. This software based on imported 3D volume data could perform automatic sector scanning by manually setting the sequence scanning fulcrum, and the software might automatically identify the upper edge of the mandibular alveolar bone as a scanning fulcrum though combination with the application and progress of artificial intelligence in target recognition in the future. Then, automatic sequential sector scanning can be carried out to realize the transition from semiautomatic fetal palate screening to fully automatic screening.

In the future development stage, more additional functions of the software can be expanded, such as importing raw data directly, thus, no converting data formats resulted in loss of image resolution, automatically identifying scanning fulcrums and optimizing image resolution to display more subtle anatomical structures, measuring the defect parts according to the images of children with cleft lip and palate, and printing images to provide suggestions for surgical options.

Conclusions

The fetal palate screening software based on the "sequential sector scan though the oral fissure" has some clinical feasibility and practicability in quickly, accurately, and comprehensively displaying the fetal palate.

Availability and requirements

Project name: Software for fetal screening based on 3D ultrasound V1.0.

Project home page: Not applicable.

Operating system(s): Windows.

Programming language: Matlab.
Other requirements: Not applicable.
License: Not applicable.
Any restrictions to use by non-academics: Not applicable.

Abbreviations

SSSTOF	"Sequential sector scan through the oral fissure"
3D	Three-dimensional
2D	Two-dimensional

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12884-024-06729-z.

Additional file 1 Dynamic scan obtained from directly front of the oral fissure using "SSSTOF". We have obtained permission from the copyright holder to reproduction.

Additional file 2 The operation process of fetal palate screening software based on the "SSSTOF".

Additional file 3 Continuous sequence dynamic scan obtained from the software for fetus with normal palate.

Additional file 4 Continuous sequence dynamic scan obtained from the software for fetus with cleft palate.

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Author contributions
Y.W. drafted and revised the manuscript; Y.Z. obtained images and revised the manuscript, C.X. Z. revised the manuscript and gave suggestions in the design of software; Y.D. W. gave suggestions and helped in the development of software. X.F. L. collected and converted data. X.Y. X. created pictures of this manuscript. All authors reviewed the manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Our study was submitted to and approved by the local ethics committee of the First affiliated hospital of Anhui Medical University and the ID is PJ-2022-08-46. All participants provided written informed consent after a complete description that their ultrasound images might use to scientific or clinical research and report.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Shkoukani MA, Lawrence LA, Liebertz DJ, Svider PF. Cleft palate: a clinical review. Birth Defects Res C Embryo Today. 2014;102(4):333–42.
2. Jensen ED, Poirier BF, Oliver KJ, Roberts R, Anderson PJ, Jamieson LM. Childhood experiences and perspectives of individuals with Orofacial clefts: a qualitative systematic review. Cleft Palate Craniofac J. 2022.
3. Gai S, Wang L, Zheng W. Comparison of prenatal ultrasound with MRI in the evaluation and prediction of fetal orofacial clefts. BMC Med Imaging. 2022;22(1):213.
4. Tonni G, Peixoto AB, Werner H, Grisolia G, Ruano R, Sepulveda F, et al. Ultrasound and fetal magnetic resonance imaging: clinical performance in the prenatal diagnosis of orofacial clefts and mandibular abnormalities. J Clin Ultrasound. 2023;51(2):346–61.
5. Campbell S. Prenatal ultrasound examination of the secondary palate. Ultrasound Obstet Gynecol. 2007;29(2):124–7.
6. Offerdal K, Jebens N, Syvertsen T, Blaas HG, Johansen OJ, Eik-Nes SH. Prenatal ultrasound detection of facial clefts: a prospective study of 49,314 deliveries in a non-selected population in Norway. Ultrasound Obstet Gynecol. 2008;31(6):639–46.
7. Salomon LJ, Alfirevic Z, Berghella V, Bilardo C, Hernandez-Andrade E, Johnsen SL, et al. Practice guidelines for performance of the routine mid-trimester fetal ultrasound scan. Ultrasound Obstet Gynecol. 2011;37(1):116–26.
8. Lu XF, Zhou Y, Li WY, Li L, Gao CF, Shen JW, et al. Methodological study on the screening of fetal palate by sequential sector-scan through oral fissure. Chin J Perinat Med. 2022;25(5):339–42.
9. Wan Y, Zhou Y, Li L, Gao C, Fan M, Qin J, et al. A deliberate practice-based Ultrasound Training Program for fetal palate screening using a Sequential Sector scan through the oral fissure. J Ultrasound Med. 2023;42(5):1103–12.
10. Pilu G, Segata M. A novel technique for visualization of the normal and cleft fetal secondary palate: angled insonation and three-dimensional ultrasound. Ultrasound Obstet Gynecol. 2007;29(2):166–9.
11. Lakshmy SR, Rose N, Masilamani P, Umapathy S, Ziyaulla T. Absent 'superimposed-line' sign: novel marker in early diagnosis of cleft of fetal secondary palate. Ultrasound Obstet Gynecol. 2020;56(6):906–15.
12. Wilhelm L, Borgers H. The 'equals sign': a novel marker in the diagnosis of fetal isolated cleft palate. Ultrasound Obstet Gynecol. 2010;36(4):439–44.
13. Sepulveda W, Wong AE, Martinez-Ten P, Perez-Pedregosa J. Retronasal triangle: a sonographic landmark for the screening of cleft palate in the first trimester. Ultrasound Obstet Gynecol. 2010;35(1):7–13.
14. Li WJ, Wang XQ, Yan RL, Xiang JW. Clinical significance of first-trimester screening of the Retronasal Triangle for Identification of primary cleft palate. Fetal Diagn Ther. 2015;38(2):135–41.
15. Zheng MM, Tang HR, Zhang Y, Ru T, Li J, Xu BY, et al. Improvement in early detection of orofacial clefts using the axial view of the maxilla. Prenat Diagn. 2018;38(7):531–37.
16. Chaoui R, Orosz G, Heling KS, Sarut-Lopez A, Nicolaides KH. Maxillary gap at 11–13 weeks' gestation: marker of cleft lip and palate. Ultrasound Obstet Gynecol. 2015;46(6):665–9.
17. Lachmann R, Schilling U, Brückmann D, Weichert A, Brückmann A. Isolated cleft lip and palate: Maxillary Gap Sign and Palatino-Maxillary Diameter at 11–13 weeks. Fetal Diagn Ther. 2018;44(4):241–6.
18. Wu S, Han J, Zhen L, Ma Y, Li D, Liao C. Prospective ultrasound diagnosis of orofacial clefts in the first trimester. Ultrasound Obstet Gynecol. 2021;58(1):134–7.
19. Faure JM, Captier G, Bäumler M, Boulot P. Sonographic assessment of normal fetal palate using three-dimensional imaging: a new technique. Ultrasound Obstet Gynecol. 2007;29(2):159–65.
20. Faure JM, Bäumler M, Boulot P, Bigorre M, Captier G. Prenatal assessment of the normal fetal soft palate by three-dimensional ultrasound examination: is there an objective technique? Ultrasound Obstet Gynecol. 2008;31(6):652–6.
21. Nicot R, Rotten D, Opdenakker Y, Kverneland B, Ferri J, Couly G, et al. Fetal dental panorama on three-dimensional ultrasound imaging of cleft lip and palate and other facial anomalies. Clin Oral Investig. 2019;23(4):1561–8.

22. Schlund M, Levaillant JM, Nicot R. 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;57(8):1041–4.
23. Ji C, Yang Z, Yin L, Deng X, Pan Q, Lu B, et al. The application of three-dimensional ultrasound with reformatting technique in the diagnosis of fetal cleft lip/palate. J Clin Ultrasound. 2021;49(4):307–14.
24. Faure JM, Mousty E, Bigorre M, Wells C, Boulot P, Captier G, et al. Prenatal ultrasound diagnosis of cleft palate without cleft lip, the new ultrasound semiology. Prenat Diagn. 2020;40(11):1447–58.
25. Campbell S, Lees C, Moscoso G, Hall P. Ultrasound antenatal diagnosis of cleft palate by a new technique: the 3D reverse face view. Ultrasound Obstet Gynecol. 2005;25(1):12–8.
26. Martínez Ten P, Pérez Pedregosa J, Santacruz B, Adiego B, Barrón E, Sepúlveda W. Three-dimensional ultrasound diagnosis of cleft palate: 'reverse face', 'flipped face' or 'oblique face'-which method is best? Ultrasound Obstet Gynecol. 2009;33(4):399–406.
27. Rotten D, Levaillant JM, Benouaiche L, Nicot R, Couly G. Visualization of fetal lips and palate using a surface-rendered oropalatal (SROP) view in fetuses with normal palate or orofacial cleft lip with or without cleft palate. Ultrasound Obstet Gynecol. 2016;47(2):244–6.

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