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Frontomaxillary facial angle at 11 + 0 to 13 + 6 weeks' gestation – reproducibility of measurements

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KEYWORDS: 3D ultrasound; first-trimester screening; FMF; frontomaxillary facial angle; maxilla; trisomy 21

ABSTRACT

Objective *To assess the intra- and interobserver reproducibility in the measurement of the frontomaxillary facial (FMF) angle at 11 + 0 to 13 + 6 weeks' gestation and to investigate the effect of deviations from the exact mid-sagittal view on these measurements.*

Methods *Three-dimensional (3D) volumes of the fetal face were used by two operators to measure the FMF angle in 50 chromosomally normal and 50 trisomy 21 fetuses. The measurements were taken in the exact mid-sagittal view and repeated after lateral rotation of the head by 5°, 10° and 15° away from the vertical position of the occipitofrontal diameter axis. Mean difference and 95% limits of agreement between paired measurements of FMF angle by the same and by two different sonographers were determined.*

Results *In the mid-sagittal plane the maxillary bone was rectangularly shaped. Rotation away from this plane became easily recognizable because at a mean of 7° (range, 4–10°) the shape of the maxilla changed with the appearance of the zygomatic process of the maxilla and at a mean of 8° (range, 4–12°) the tip of the nose became invisible. In both the normal and trisomy 21 fetuses the FMF angle measured at 5–15° was not significantly different from the one measured in the mid-sagittal plane. In 95% of the cases, the difference between paired measurements of the FMF angle by the same sonographer at the mid-sagittal plane was between −2.3° and 3.0° and at 15° it was −1.0° to 6.8°. At the mid-sagittal plane, the difference in measurements between two sonographers was −3.1 to 3.0°.*

Conclusion *The landmarks that define the mid-sagittal plane of the fetal face are the tip of the nose and the rectangularly shaped maxilla. Measurement of the FMF angle is highly reproducible. Copyright © 2006 ISUOG. Published by John Wiley & Sons, Ltd.*

INTRODUCTION

In fetuses with trisomy 21 the frontomaxillary facial (FMF) angle, defined as the angle between the upper surface of the maxilla and the frontal bone in a mid-sagittal view of the fetal face, is substantially increased. A three-dimensional (3D) ultrasound study of 100 fetuses with trisomy 21 and 300 chromosomally normal fetuses at 11 to 13 + 6 weeks' gestation reported that the FMF angle was significantly bigger in the trisomy 21 than in the normal fetuses (mean 88.7°, range 75.4–104° vs. mean 78.1°, range 66.6–89.5°)[1]. The FMF angle was above 85° in 69% of the trisomy 21 fetuses and in 5% of the normal fetuses. Furthermore, there was no significant association between the FMF angle and crown–rump length (CRL) or nuchal translucency thickness. Consequently, measurement of the FMF angle is likely to be a useful marker in addition to nuchal translucency thickness in first-trimester screening for trisomy 21.

In the measurement of the FMF angle the value of 3D ultrasonography is to ensure that the exact mid-sagittal view of the fetal face is obtained. The aims of this study were firstly, to compare the FMF angle measurement agreement and bias for a single examiner and between different examiners and secondly, to investigate the effect of deviations from the exact mid-sagittal view on the measurement of the FMF angle.

METHODS

We measured the FMF angle using 3D volumes of the fetal face, which had been acquired from 50 chromosomally normal and 50 trisomy 21 fetuses before karyotyping by chorionic villus sampling (CVS) at 11 to 13 + 6 weeks' gestation. The 3D volumes had been obtained with the fetus in the mid-sagittal plane and the transducer parallel to the long axis of the nose. All 3D examinations

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were carried out transabdominally (RAB 4-8L probe, Voluson 730 Expert, GE Medical Systems, Milwaukee, WI, USA), by sonographers with extensive experience in first-trimester scanning and 3D ultrasound.

The 3D volumes were displayed in the three orthogonal planes that compose the multiplanar mode of the 3D image. In the exact mid-sagittal plane of the fetal profile, defined by the presence of the tip of the nose anteriorly, the translucent mid-brain in the middle and the nuchal membrane posteriorly, the maxillary bone had a rectangular shape (Figure 1). The FMF angle between a line along the upper surface of the maxilla and a line which traverses the upper corner of the anterior aspect of the maxilla extending to the external surface of the frontal bone at the point of its greatest anterior excursion was then measured (Figure 1)[1]. At 11 to 13 + 6 weeks of gestation what we refer to as frontal bone is an echogenic line under the skin. In a previous study we described that in early pregnancy there is a gap between the two frontal bones which starts to close from the nasal region at around 16 weeks' gestation and moves superiorly towards the anterior fontanelle by 28 weeks[2].

The transverse plane was scrolled up to obtain the standard view for measurement of the biparietal diameter (BPD). At this plane the mid-point of the BPD and occipitofrontal diameter (OFD) was determined and the head was positioned so that the midline of the OFD was at 0° (Figure 2). The head was then slowly rotated around

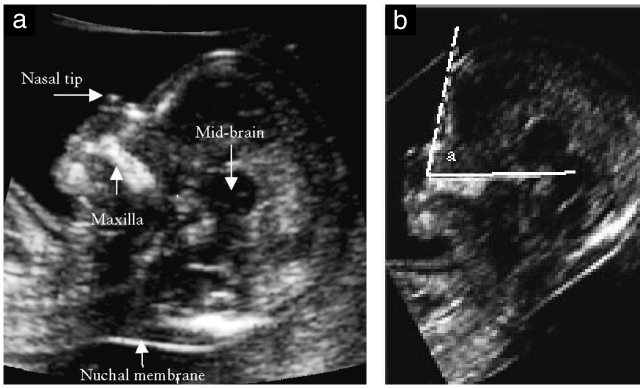

Figure 1 Ultrasound image in the mid-sagittal plane of the fetal profile, demonstrating the tip of the nose, the translucent mid-brain, the nuchal membrane and the rectangularly shaped maxillary bone (a). The frontomaxillary facial (FMF) angle is defined by a line along the upper surface of the maxilla and a line that traverses the upper corner of the anterior aspect of the maxilla and extends to the external surface of the frontal bone (b).

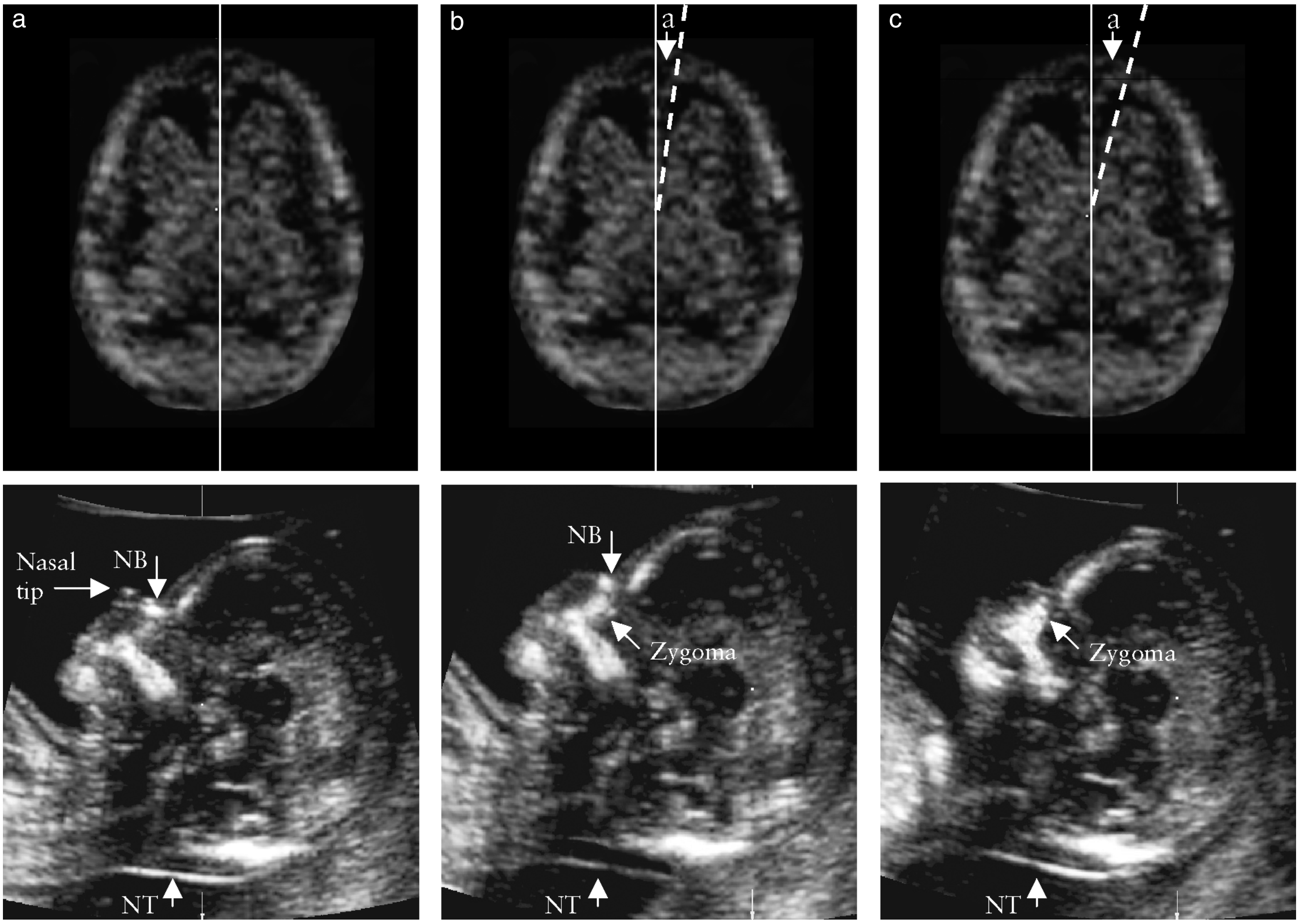

Figure 2 Ultrasound images showing simultaneous demonstration of the transverse and corresponding sagittal plane of the fetal head at the mid-sagittal plane (a), and after rotation around the mid-point of the biparietal diameter and occipitofrontal diameter until the tip of the nose was not visible and the rectangular shape of the maxilla was altered by the superimposition of the zygomatic process of the maxilla (b) and until the nasal bone was not visible (c). NB, nasal bone; NT, nuchal translucency.

the mid-point of the BPD and OFD until firstly, the tip of the nose was not visible, secondly, the rectangular shape of the maxilla was altered by the superimposition of the zygomatic process of the maxilla and thirdly, the nasal bone was not visible (Figure 2). The angle between the original vertical line and the new OFD line at each one of the above three positions was measured.

The FMF angle was measured at 0° and again after rotation of the head so that the OFD line formed an angle of 5°, 10° and 15° from the vertical axis. All four measurements of the FMF angle were made by the same operator, A, who on completion of the study of 50 cases repeated the measurement at 0°. The whole process was then repeated by Operator B. Numeric displays on the screen were covered so that the operators were blinded to the actual measurement and were unaware of the results obtained by the previous operator.

Bland–Altman analysis was used to compare the measurement agreement and bias for a single examiner and between different examiners[3]. The data were analyzed using the statistical software SPSS 12 (Chicago, Illinois, USA), and a P-value of less than 0.05 was considered statistically significant.

RESULTS

The median maternal age was 38 (range, 17–47) years, the median gestation was 13 (range, 11 to 13 + 6) weeks and the median fetal CRL was 68 (range, 45–84) mm. The nasal bone was absent or hypoplastic in 30 (60%) of the fetuses with trisomy 21 and in none of the chromosomally normal fetuses. The median FMF angle at the mid-sagittal plane was 90° (range, 77–102°) for the trisomy 21 fetuses and 78° (range, 68–88°) for the chromosomally normal fetuses, and it was 85° or more in 32 (64%) and 2 (4%) of the cases, respectively.

In the mid-sagittal plane of the fetal face the tip of the nose and the 'rectangularly' shaped maxillary bone were visible in all cases. In fetuses with normal karyotype, rotation of the head away from the vertical position (0°) of the OFD axis resulted in non-visibility of the tip of the nose at a mean angle of 8° (range, 4–12°) and of the nasal bone at 18° (range, 11–24°). At a mean of 7° (range, 4–10°) the zygomatic process of the maxilla became visible as an echogenic structure between the nasal bone above and the anterior part of the maxilla below. With further rotation of the head there was enlargement of the zygomatic process of the maxilla and coalescence with the maxillary bone.

In fetuses with trisomy 21, there were no significant differences from the normal group in the angles at which the tip of the nose became non-visible (mean 8°, range, 4–11°; $P = 0.771$), the nasal bone became non-visible (mean 18°, range, 14–21°; $P = 0.082$) and the zygomatic process became prominent, distorting the shape of the maxilla (mean 7°, range, 3–10°; $P = 0.862$). In both the chromosomally normal and the trisomy 21 fetuses there was a significant association between the angle at which the tip of the nose became non-visible and the angle at which the zygomatic process became visible ($r = 0.637$, $P < 0.0001$ and $r = 0.644$, $P < 0.0001$, respectively).

The mean difference and the 95% limits of agreement between paired measurements of FMF angle at the mid-sagittal plane and between the mid-sagittal plane and each of the three planes at 5°, 10° and 15° by the same sonographer and between paired measurements by the two different observers for fetuses with normal karyotype are shown in Table 1. The corresponding data for fetuses with trisomy 21 are shown in Table 2. There was no significant change with gestation in either the intraobserver or interobserver agreement in paired measurements ($r = -0.1216$, $P = 0.2280$ and $r = -0.0707$, $P = 0.4847$; Figure 3).

The individual results of the difference in the measurement of the FMF angle at 5°, 10° and 15° from

Table 1 Mean difference in frontomaxillary facial (FMF) angle and the 95% limits of agreement (LOA) with their 95% CI between 50 paired measurements by the same sonographer and between 50 paired measurements by two sonographers in the chromosomally normal fetuses

FMF angle at different planes	*Mean difference (95% LOA) [95% CI]*
Intraobserver A	
Mid-sagit. and mid-sagit.	0.3 (−2.3 [−2.9, −1.7], 3.0 [2.3, 3.6])
Mid-sagit. and at 5°	1.9 (−0.9 [−1.6, −0.2], 4.7 [4.0, 5.3])
Mid-sagit. and at 10°	2.7 (−0.5 [−1.3, 0.3], 5.9 [5.1, 6.7])
Mid-sagit. and at 15°	2.9 (−1.0 [−2.0, −0.1], 6.8 [5.8, 7.8])
Intraobserver B	
Mid-sagit. and mid-sagit.	0.0 (−2.5 [−3.1, −1.9], 2.4 [1.8, 3.0])
Mid-sagit. and at 5°	2.4 (−0.3 [−1.1, 0.2], 5.2 [4.5, 5.8])
Mid-sagit. and at 10°	3.2 (0.1 [−0.7, 0.9], 6.4 [5.6, 7.2])
Mid-sagit. and at 15°	3.4 (0.4 [−0.4, 1.1], 6.4 [5.6, 7.1])
Interobserver	
Mid-sagit. and mid-sagit.	−0.1 (−3.1 [−3.9, −2.4], 3.0 [2.2, 3.7])

Mid-sagit., mid-sagittal.

Table 2 Mean difference in frontomaxillary facial (FMF) angle and the 95% limits of agreement (LOA) with their 95% CI between 50 paired measurements by the same sonographer and between 50 paired measurements by two sonographers in the trisomy 21 fetuses

FMF angle at different planes	*Mean difference (95% LOA) [95% CI]*
Intraobserver A	
Mid-sagit. and mid-sagit.	0.1 (−2.8 [−3.5, −2.1], 3.0 [2.3, 3.7])
Mid-sagit. and at 5°	1.5 (−0.8 [−1.4, −0.3], 3.9 [3.3, 4.4])
Mid-sagit. and at 10°	2.4 (−0.1 [−0.7, 0.5], 4.8 [4.2, 5.4])
Mid-sagit. and at 15°	3.4 (0.4 [−0.4, 1.1], 6.4 [5.7, 7.2])
Intraobserver B	
Mid-sagit. and mid-sagit.	0.1 (−2.9 [−3.6, −2.1], 3.2 [2.4, 3.9])
Mid-sagit. and at 5°	1.7 (−0.2 [−0.7, 0.2], 3.5 [3.1, 4.0])
Mid-sagit. and at 10°	2.7 (0.6 [0.1, 1.1], 4.7 [4.2, 5.2])
Mid-sagit. and at 15°	3.3 (0.6 [−0.1, 1.3], 6.0 [5.4, 6.7])
Interobserver	
Mid-sagit. and mid-sagit.	−0.4 (−3.7 [−4.5, −2.9], 2.9 [2.1, 3.7])

Mid-sagit., mid-sagittal.

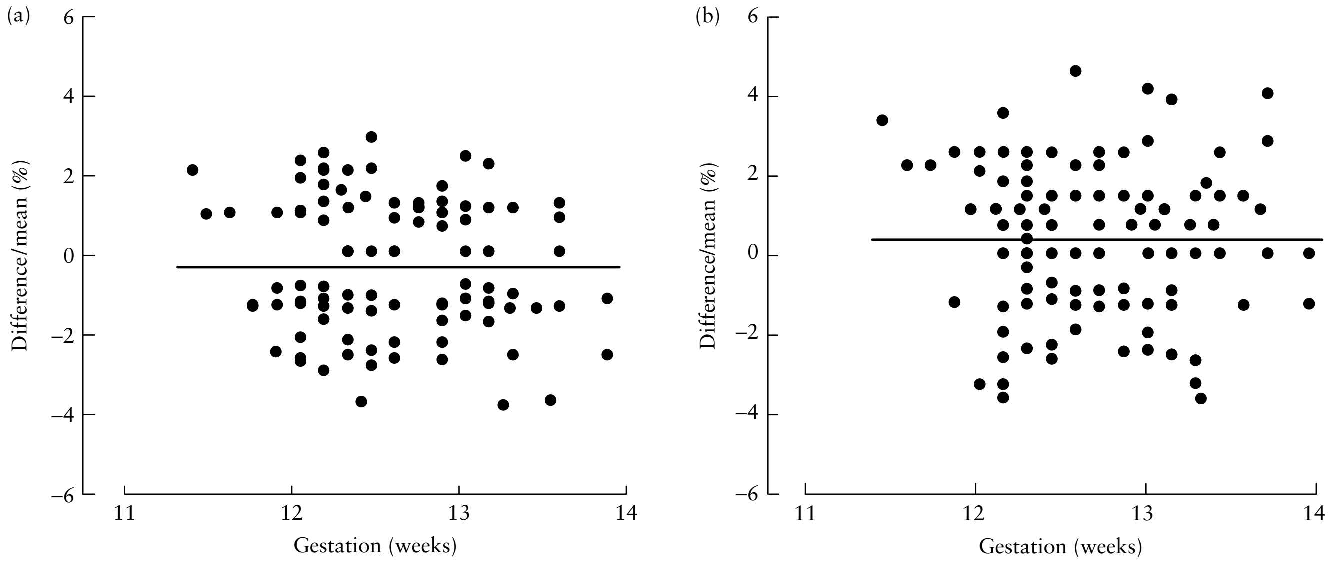

Figure 3 Relationship between intraobserver (a) and interobserver (b) agreement in paired measurements of the frontomaxillary facial angle with gestation.

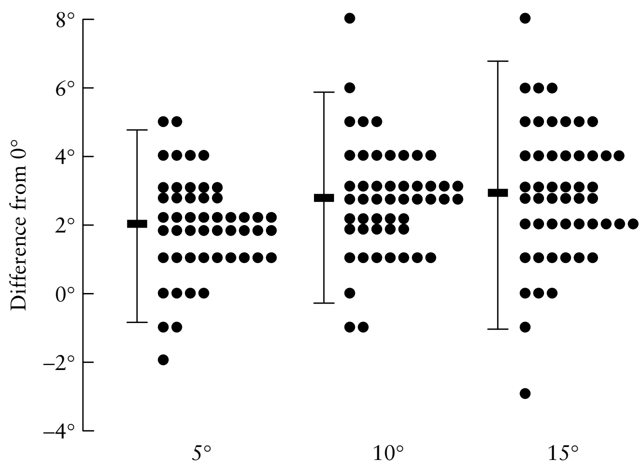

Figure 4 Difference between the measurement of the frontomaxillary facial angle at the mid-sagittal plane (0°) and the measurements at 5°, 10° and 15°.

the measurement at the mid-sagittal plane obtained by Observer A are shown in Figure 4. Compared to the FMF angle measured at the mid-sagittal plane (0°), there was a non-significant (the 95% limits of agreement contained the 0 value) tendency for overestimation of the FMF angle by about 2° when the head was rotated to 5°, and about 3° when the head was rotated to 10° or 15° (Table 1).

DISCUSSION

This study has utilized the multiplanar mode of 3D ultrasound to define that the sonographic markers of an exact mid-sagittal plane of the fetal face are the echogenic tip of the nose and the rectangular shape of the maxillary bone. Rotation of the head away from the vertical position of the OFD axis results in non-visibility of the tip of the nose and usually at the same angle of 4–12° the zygomatic process of the maxilla becomes visible at the anterior part of the maxilla.

The data demonstrate that in the mid-sagittal plane measurement of the FMF angle is highly reproducible, and in about 95% of cases the differences between two measurements by the same observer or measurements by different observers are within 3° of each other. Although with rotation away from the mid-sagittal plane, up to at least 15°, there was a tendency for higher deviations in FMF angle, this difference was not significant in either the normal or the trisomy 21 fetuses.

If the preliminary encouraging results on the difference in FMF angle between trisomy 21 and normal fetuses[1] are confirmed it is likely that this measurement will be incorporated into first-trimester sonographic screening for trisomy 21. In such cases the findings of our study suggest that measurement of the FMF angle could potentially be undertaken by two-dimensional ultrasound, provided that the sonographers are appropriately trained to recognize the necessary landmarks that define the mid-sagittal plane of the fetal face. In any case, even minor deviations from such a plane would not unduly influence the performance of the test.

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