

# Bland–Altman Plot: Agreement Between Ultrasound-measured Placenta Thickness and Other Biometric Parameters in the Determination of Gestational Age

## Abstract

**Purpose:** The aim of this article is to evaluate the agreement of placenta thickness (PT) with other foetal biometric parameters in the determination of gestational age (GA) in normal singleton foetuses. **Materials and Methods:** The study was a cross-sectional descriptive study conducted among 406 consecutively recruited pregnant women with singleton foetuses at 15–40 weeks of gestation at the National Hospital, Abuja, Nigeria from October to December 2019. Biparietal diameter (BPD), femur length (FL), head circumference (HC), abdominal circumference (AC), and PT were measured using standard measurement protocols. Bland and Altman (BA) plots were used to compare PT and other foetal biometric parameters. The significant statistical level was determined at a critical value of  $P < 0.05$ . **Results:** The mean age of study participants was  $31.8 \pm 4.8$  years. The BA plot of PT and HC demonstrated a normal distribution; the mean difference was around zero (3.968) and 95% of the measurements fell within 2SD of the mean. The BA plot of HC and AC measurements also showed that the 95% limits of agreement for differences fell within 10% of the mean of the measurements (-4.236 to 15.987 with a mean difference of 5.876), indicating good agreement between the two pairs of variables. However, BA plots between PT and BPD as well as PT and FL showed no agreement. **Conclusion:** This study indicates that there is good agreement or comparability between PT and HC measurements as well as between PT and AC measurements. Hence, either HC or AC measurements may be interchangeable with PT measurements in the ultrasound determination of GA. However, PT measurements did not agree well with BPD and FL measurements, respectively.

**Keywords:** Altman, Bland, gestational age, placenta, plot, thickness

## Introduction

Accurate dating is critically important for the management of pregnancy from the first trimester to delivery, especially in premature labour and post-dates pregnancies.<sup>[1]</sup> Although a few days of inaccuracy was acceptable in the past, recent studies have shown that inaccuracy of a few days may adversely affect pregnancy management such as the performance of maternal serum screening tests and the management of post-date pregnancies.<sup>[2,3]</sup> The current body of knowledge shows that sonographically derived dates are the most accurate method of gestational age (GA) determination for clinical use.

Different formulae including ultrasound-measured foetal biometric parameters such as biparietal diameter (BPD), head circumference (HC), abdominal

circumference (AC), and femur length (FL) are being used to estimate GA.<sup>[4]</sup> In recent times, several formulae have been developed, predicting GA using BPD, HC, AC, and FL at certain periods during pregnancy.<sup>[5,6]</sup>

Placenta thickness (PT) is often considered a good estimate of GA, comparable with other foetal biometric parameters (BPD, HC, AC, and FL).<sup>[7,8]</sup> While linear relationships between PT and other biometric parameters have been described in literature,<sup>[8]</sup> the extent to which PT can be used in place of other established parameters (BPD, HC, AC, and FL) in the determination of GA has not been fully explored in literature. Studies have shown that two quantitative measurements may be used interchangeably if both measurements agree.<sup>[9-14]</sup>

The authors often aim to determine the agreement between two parametric measures to determine whether they may

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be used interchangeably especially in situations in which the use of established measures is either not possible or not suitable. It is important that such studies are conducted with the appropriate statistical methods suitable for testing agreement between two sets of quantitative data.<sup>[15]</sup> One of the methods used to assess the relationship between the measurement of PT and other established foetal biometric parameters in the estimation of GA is the product–moment correlation coefficient.<sup>[8,16]</sup> While correlation test can determine linear association between two quantitative variables, it does not provide a useful answer to the agreement between two quantitative methods of measurement.<sup>[9]</sup> Bland and Altman (BA) analysis has been reported as a suitable method for evaluating the extent of agreement between two quantitative measurement methods.<sup>[10,11,17]</sup> While BA analysis has been used in a previous study in the determination of estimated foetal weight using foetal biometric parameters,<sup>[18]</sup> there is paucity of literature on its use in the determination of GA. Therefore, this study aims to evaluate the agreement of PT with other biometric parameters (including BPD, HC, AC, and FL) in the determination of GA.

### Materials and Methods

This cross-sectional study was conducted at the Department of Radiology, National Hospital, Abuja (NHA), Nigeria. Pregnant women with singleton pregnancy who were between 15 and 40 weeks' GA were recruited into the study. The inclusion criteria were as follows: (i) singleton pregnancies, 15–40 weeks; (ii) history of regular menstruation; (iii) pregnant women sure of the last menstrual period (LMP), confirmed by early obstetric ultrasound scan; and (iv) women who gave consent for inclusion in the study. Pregnant women excluded from the study were as follows: (a) those with gestational diabetes, hypertension in pregnancy, anaemia, uterine masses, absence of an early obstetric ultrasound scan, rhesus isoimmunization, and women who do not give consent and (b) women whose foetus had suspected intrauterine growth restriction, hydrops fetalis, congenital malformations, multiple pregnancies, amniotic fluid conditions, renal pathology, gross foetal hydronephrosis, and foetal structural abnormality. Women who have placenta previa, poor visualization of the placenta, and other placental anomalies were also excluded. Pregnant women who had these conditions were excluded from this study to ensure comparability with previous studies.<sup>[7,8]</sup>

Using the formula for calculating the sample mean,<sup>[19]</sup> a minimum sample size was determined for this study, in which  $Z$  is the standard normal variate;  $\sigma$  is the standard deviation of the mean placental thickness; and  $E$  is the desired error margin. This study used  $Z = 1.96$  (for 95% confidence interval);  $E = 0.5$ ;  $\sigma$  the standard deviation of placental thickness derived from a previous study = 4.9.<sup>[20]</sup> Entering these values into the equation,

$$n = \left[ \frac{(1.96 * 4.9)}{0.5} \right]^2,$$

$n = 369$ . The study employed a sample size of 406 after accounting for the anticipated 10% non-response.

Using a trans-abdominal Phillips Ultrasound Scanner HD II XE (The Netherlands, 2012) with a 3–5 MHz curvilinear array probe, foetal biometric parameters including the BPD, FL, HC, AC, and PT were measured using standard protocols.<sup>[21]</sup> PT (in millimetres) was measured at the mid-portion of the placenta, at the level of umbilical cord insertion [Figure 1]. All measurements were made on still images captured with the freeze facility of the US scanner with the on-screen electronic caliper of the US unit. For each foetal biometric parameter, three best measurements and the mean of the measurements were taken and recorded for each participant.

GA estimation was done in two ways: by data and by ultrasound. Estimation of GA (by date) was based on a reliable recollection of the first day of the LMP and validated by a previous first trimester US scan. With participants' LMP, Naegele's rule was used to calculate the GA by date (in weeks).<sup>[22]</sup> Estimation of GA (by ultrasound) was done through the Hadlock formula-based algorithm of the scanner.

### Statistical analysis

Pearson's correlation analysis as well as a correlation matrix was computed to determine linear relationships among BPD, AC, HC, FL, PT, and GA. To appraise the agreement between PT and other foetal biometric parameters, BA analysis, an evaluation of the difference between two quantitative measurements via a graphical method, was used. The respective differences between PT and BPD, HC, FL, and AC measurements were calculated. Similarly, the respective means of PT and BPD, HC, FL, and AC measurements were also calculated. The respective limits of



Figure 1: US image showing a placenta that is relatively homogeneous in echotexture

agreement for BPD, HC, FL, and AC were then calculated using the formula: mean of difference of two measurements  $\pm (1.96 \times \text{Standard deviation of difference})$ .<sup>[12]</sup> A scatter plot (BA Plot) was then constructed with the difference between paired quantitative measurements on the *y*-axis and the mean of the same pair of measurements on the *x*-axis.<sup>[9,11,23]</sup>

Ethical clearance for the study was obtained from the Research Ethics Committee of the National Hospital, Abuja, Nigeria. Informed consent was also obtained from the selected participants.

## Results

There were 406 participants in the study with age ranging from 22 to 49 years, and the mean ( $\pm$ SD) age was  $31.8 \pm 4.8$  years. The mean ( $\pm$ SD) values of the participants' weight and height were  $81.7 \pm 14.7$  kg and  $1.6 \pm 0.1$  m, respectively. Almost 3 out of 10 (27.3%) participants were primigravida, 29.1% primiparous, 40.6% multiparous, and 3.0% grand multiparous women.

The mean measurements of PT, BPD, HC, AC, and FL at 15 weeks were 16.8, 23.6, 8.7, 7.8, and 14.8 mm, respectively. In contrast, the mean PT, BPD, HC, AC, and FL at 40 weeks were 37.9, 91.3, 33.2, 34.0, and 75.2 mm, respectively.

A strong positive correlation between BPD and PT ( $r=0.831$ ,  $P = 0.00$ ) was observed. Comparing the BPD and PT measurements, the BA's limits of agreement was from 14.193 to 32.022. The mean difference was 23.107 (95% CI: 22.672–23.542), and a statistically significant difference in variability between the PT and BPD measurements ( $P = 0.000$ ) was found, indicating significant variance between the two measurements [Figure 2].

A strong positive correlation was found between PT and HC ( $r=0.813$ ,  $P = 0.00$ ). The BA plot conducted to test

agreement of PT and HC measurements demonstrated normal distributions; the mean difference was around zero (3.968) and 95% of the measurements fell within 2SD of the mean. Furthermore, the difference in variability between the two measurements (PT and HC) was non-significant ( $P = 0.403$ ), indicating good agreement/comparability between the PT and HC measurements [Figure 3].

A strong positive correlation exists between PT and AC ( $r=0.771$ ,  $P = 0.00$ ). The BA plots for PT and AC measurements demonstrated normal distributions, and 95% of the measurements fell within 2SD of the mean. The difference in variability between the two measurements (PT and AC) was non-significant ( $P = 0.950$ ). Furthermore, the 95% limits of agreement for differences between the PT and AC measurements fell within 10% of the mean of the measurements (-4.236 to 15.987 with a mean difference of 5.876), indicating good agreement/comparability between the two measurements [Figure 4].

The correlation between PT and FL was strongly positive ( $r=0.836$ ,  $P = 0.00$ ). BA's limits of agreement for PT and FL measurements were from 13.182 to 38.156 with a mean difference of 25.669 [Figure 5]. There was a statistically significant difference in variability between the two measurements ( $P = 0.00$ ), indicating a significant variance between PT and FL measurements.

BA discussed the interpretation of BA plots in previous studies (references). If the data points in a specific BA plot are very close to the zero line, it signifies a good level of agreement between the two methods under investigation. A weak agreement between the two measurement methods is implied if the data points are far from the zero line. Furthermore, if the constructed limits of agreement are within clinical acceptable differences, the two methods may be said to be interchangeable.

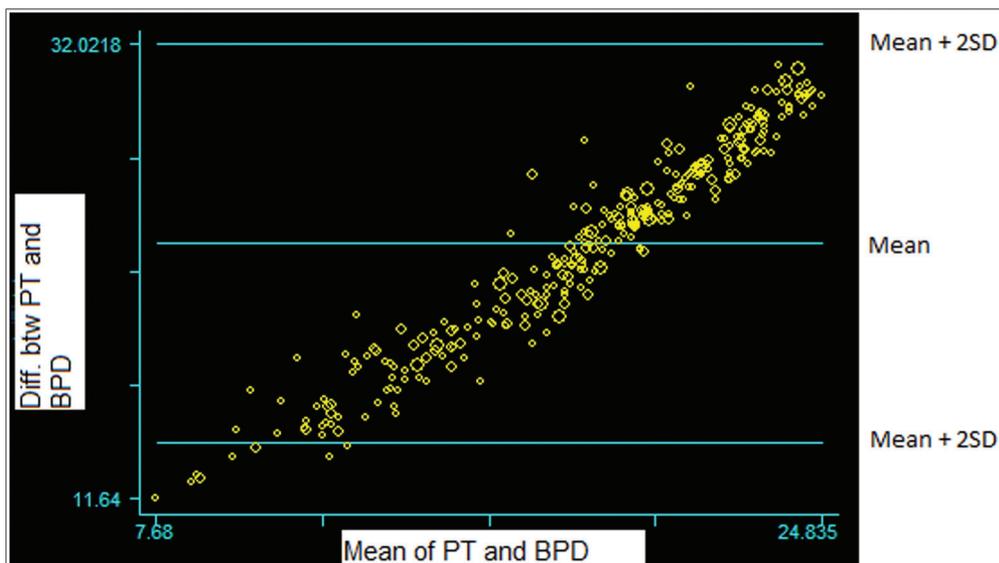


Figure 2: Bland and Altman plot for PT and BPD

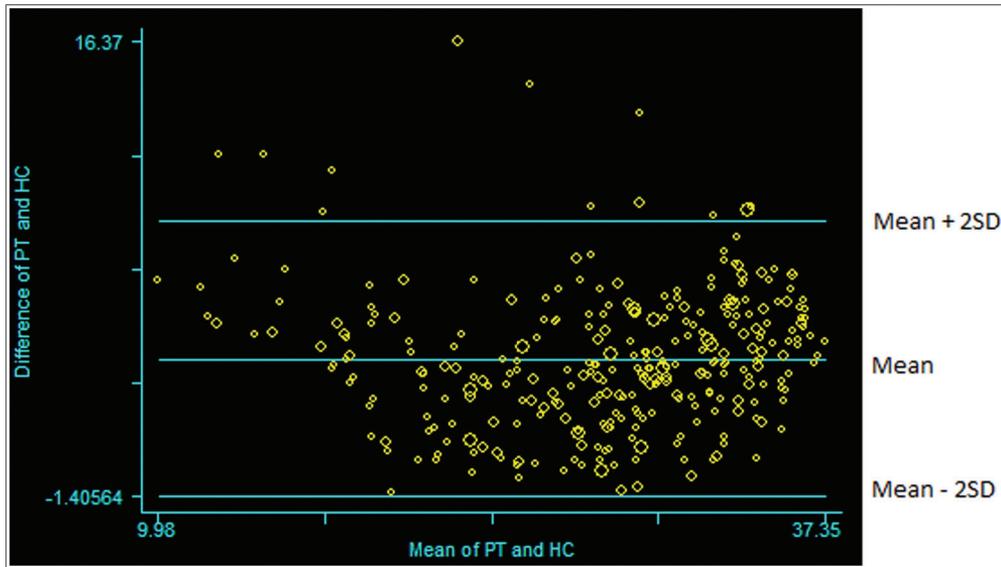


Figure 3: Bland and Altman plot for PT and HC

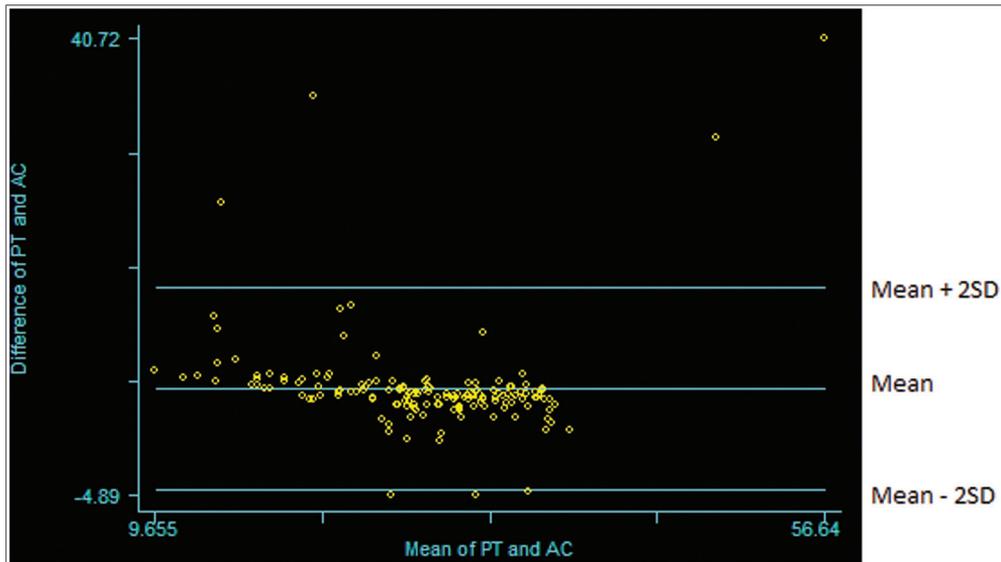


Figure 4: Bland and Altman plot for PT and AC

Of the four foetal biometric parameters compared with PT in the study, only HC and AC measurements are in agreement with PT measurements. This implies that PT measurement may be a potential biometric parameter that may be used.

### Discussion

This study evaluated the agreement of PT with other biometric parameters (BPD, HC, AC, and FL) in the determination of GA. The study found that all foetal biometric parameters had a strong positive correlation with PT. However, only HC and AC agreed with PT using the BA plots as a measure of agreement.

As the foetus grows, placenta size increases, enabling it to perform to its vital functions. It is therefore expected that

the thickness of the placenta will be linearly related to the GA. Our study showed that PT is strongly positively correlated with BPD, HC, and AC, respectively. This finding is in keeping with the study conducted by Ohagwu *et al.*,<sup>[24]</sup> which showed that there was a statistically significant positive correlation between PT and BPD, on the one hand, and between PT and AC, on the other hand.

Studies have shown that correlation depends on the range and distribution of two variables.<sup>[10,12,17]</sup> Furthermore, the correlation test usually shows that as a variable increases the second variable being compared also increases if the correlation is positive, or decreases if there is negative correlation between them. However, correlation is unable to provide a useful answer to the agreement between two quantitative methods of measurement.

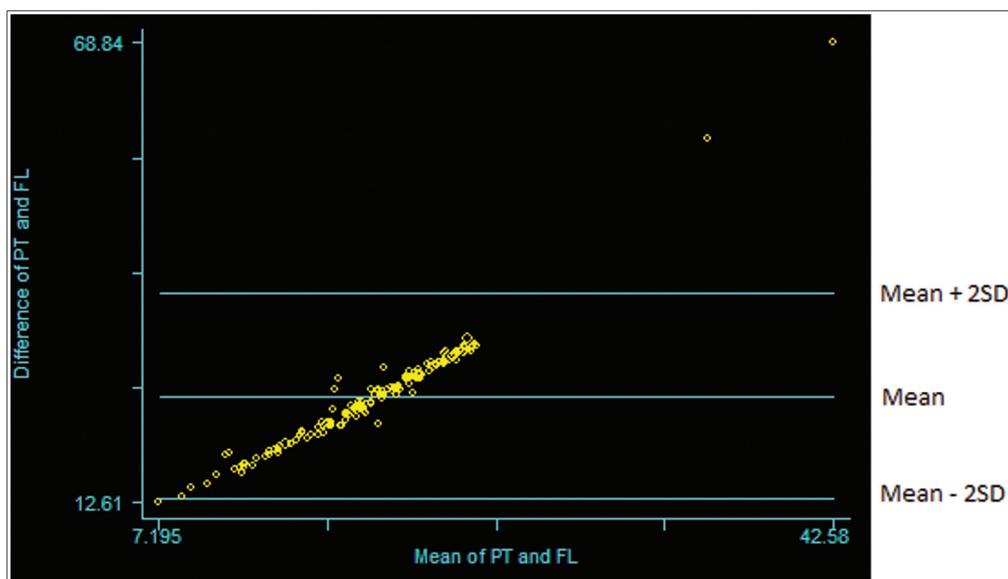


Figure 5: Bland and Altman plot for PT and FL

Majority of the studies conducted on PT and GA assessments only used correlation tests.<sup>[24,25]</sup> To the best of our knowledge, our study is the first one that considered a test of agreement in addition to correlation in the study of relationship between PT and other foetal biometric parameters.

Our study has a limited number of participants. A large (multicentre) study is recommended to enable a more rigorous evaluation of the limits of agreement of PT and other biometric parameters with a view to determining whether PT can be used in place of any of the other foetal biometric parameters (BPD, HC, AC, FL) in estimating GA in singleton pregnancies.

## Conclusion

This study showed that comparing two quantitative measurement methods using the limits of agreement approach is fundamentally simple and useful. While PT showed a strong positive linear relationship with other foetal biometric parameters, only HC and AC agree significantly with PT in the estimation of GA of singleton foetuses.

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## Ethical statements

This study was performed in keeping with the principles of the Declaration of Helsinki. Approval was granted by the Research Ethics Committee of the National Hospital, Abuja, Nigeria (NHA/EC/050/2019). Informed consent was obtained from all individual patients who participated in the study. The authors affirm that research participants provided informed consent for publication of the images in the manuscript.

## Authors' contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by OAO, OOO, KOJ, and AOO. The first draft of the manuscript was written by OAO and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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## Conflicts of interest

The authors have no relevant financial or non-financial interests to disclose.

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