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Original Article

THE INTERPLAY OF MATERNAL BMI AND GLYCEMIC CONTROL IN SHAPING PLACENTAL MORPHOLOGY IN GDM

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ABSTRACT

Gestational diabetes mellitus (GDM) and high body mass index (BMI) are significant risk factors for adverse pregnancy outcomes, impacting both maternal and fetal health. This study examines the relationship between BMI and glycemic control on placental morphology—specifically placental weight, shape, and umbilical cord attachment—in lean and obese GDM pregnancies. A total of 120 pregnant women were randomly selected from antenatal clinics at three study centers. Participants were categorized into three groups based on BMI and GDM status: Control (BMI <22.9 kg/m^2, normal OGTT), Lean GDM (BMI <22.9 kg/m^2, GDM), and Obese GDM (BMI ≥23 kg/m^2, GDM). GDM was diagnosed using a 75-g OGTT at 12 and 24–28 weeks of gestation. Management included diet alone, diet with metformin, or insulin therapy, with patients sub-classified as well-controlled or poorly controlled. All participants were monitored prospectively until delivery. Placental morphology, including weight, shape, and umbilical cord attachment, was documented and subjected to statistical analysis. Findings indicated that BMI significantly influenced placental morphology. Poorly controlled GDM pregnancies were associated with increased placental weight, irregular shape, and a higher incidence of marginal and velamentous umbilical cord insertions. Additionally, obese GDM cases showed a higher occurrence of incomplete placental expulsion, while preterm delivery was more frequent in lean GDM pregnancies. Both BMI and glycemic control were found to independently impact placental morphology in GDM pregnancies. Categories: Obstetrics/Gynecology,Anatomy

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Introduction

Gestational Diabetes Mellitus (GDM), characterised by glucose intolerance first identified during pregnancy, affects 5-7% of pregnancies worldwide, making it one of the most prevalent obstetric complications[1].GDM is associated with maternal insulin resistance, mild inflammation, and dysfunction of placental endothelial cells, which collectively contribute to adverse outcomes for both the mother and fetus[2,3,4].The rising incidence of obesity among women of reproductive age has been identified as a significant factor in the increasing prevalence of GDM globally [5,6].

The placenta,the exchange site of nutrients between the mother and the fetus, is a mirror that reflects the effects of maternal metabolic alterations[2,3].Microscopic alterations in the placenta, such as thickened vessel walls, increased immature villous arterioles, increase in syncytiotrophoblast nodules, lumen narrowing, and elevated fibrinous exudation, are commonly observed in pregnancies complicated by GDM and obesity. These changes disrupt villous development, leading to premature placental maturation[7].

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Biochemical and molecular changes associated with obesity and GDM, including oxidative stress, inflammation, dyslipidemia, and hormonal imbalances, contribute to endothelial damage and placental hypoxia [8,9]. Research indicates that effective glycemic control can mitigate early placental maturation, thereby improving perinatal outcomes [10,11].

GDM alone significantly altered placental weight [12-14], volume, and morphology [15-18].However, studies examining the impact of obesity on placental morphology have produced inconsistent results, and some reporting minimal placental morphological changes with co-existing GDM [17,19-21].

This study aims to explore the effects of maternal body mass index (BMI) and glycemic control on placental morphology, providing further insight into their independent and combined impacts on pregnancy outcomes.

Materials & Methods

Study Design: Prospective observational study

Study Setting: The study was conducted at the Department of Anatomy at the All India Institute of Medical Sciences after approval from the Institutional Ethics Committee (No. IEC/Pharma/2022/360, dated 22-02-2022).

Study population: Antenatal women who reported to the Department of Obstetrics and Gynecology at study centers, AIIMS, Nagpur; Govt. Medical College& Hospital, Nagpurand Daga Memorial Govt. Women Hospital, Nagpur ,Maharashtra, India, from April 2022 to December 2023, fulfilled the inclusion and exclusion criteria.

Screening method:

•**For BMI calculation:** The height and weight of each participant were recorded at the first antenatal visit, and the BMI was calculated [22]. A BMI of 18.5-22.9kg/m2 was considered normal, and ≥23 kg/m2 was considered obese.

•**The screening and diagnostic criterion of the GDM:** Based on guidelines given by the Ministry of Health and Family Welfare, India, adopted from WHO using an OGTT75g (Oral Glucose Tolerance Test75g) at12weeks of gestation and subsequently repeated at 24-28 weeks if the first test result was negative. The patient's glycemic control was checked at regular intervals by measuring 2-hr post-meal blood sugar (value≤ 120mg/dl considered as good glycemic control)[23].

Study criteria:

•The inclusion criteria were (i) registered pregnant women between 18 and 40 years old with a singleton pregnancy and (ii) prior booking in an antenatal care (ANC)clinic with documented glycemic status and BMI of the first trimester.

•The exclusion criteria were (i) multiple pregnancies (ii)medical disorders like pre-existing diabetes and hypertension (iii) pregnancy resulting from assisted reproduction (iv) maternal smoking, alcoholism, or other substance abuse.

Informed consent was collected from the patients in either English or local language in a designated study proform a before the start of the study. The grouping of the participants was done (Chart:1). Initially, the GDM group was managed by physical exercise and medical nutrition therapy. Later, based on their glycemic control, either Insulin or oral antidiabetics were prescribed.

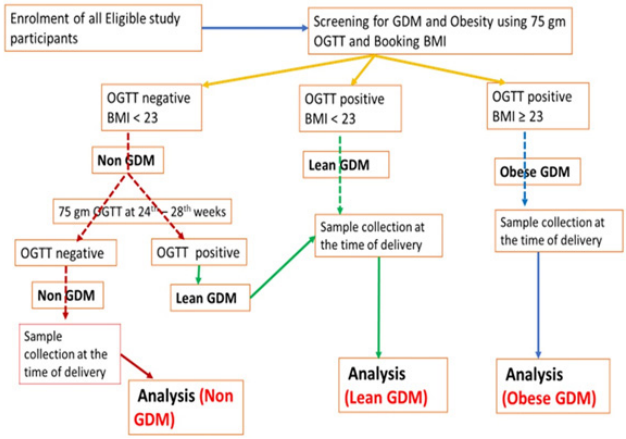


Chart :1 Patient grouping process

Sample collection:

Participant demographic and obstetric data like age, trimester at which diagnosis of GDM was made, etc, were noted. The recruited study participants were followed through their pregnancy for their glycemic control and alterations in BMI. At the time of delivery, the placenta was collected.

Morphological parameters:

•**Weight:** The membranes were trimmed. The umbilical cord was cut leaving a 2 cm stump at its attachment. Placental weight was measured in grams by weighing on an electronic scale.

•**Shape of placenta:** The Shape of the placenta was noted as normal (discoid/ovoid) or abnormal (irregular) (Figure 1,2).

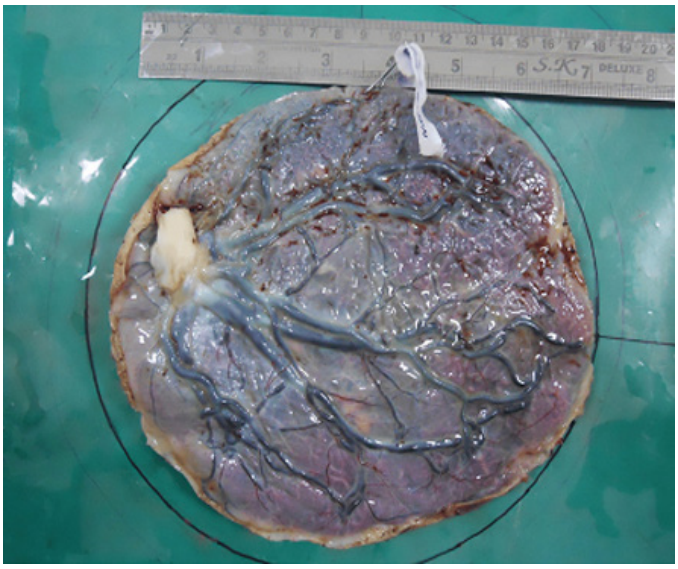


FIGURE1: Discoid Shape of placenta with marginal attachment of umbilical cord



FIGURE2: Irregular Shape of placenta with the velamentous attachment of an umbilical cord

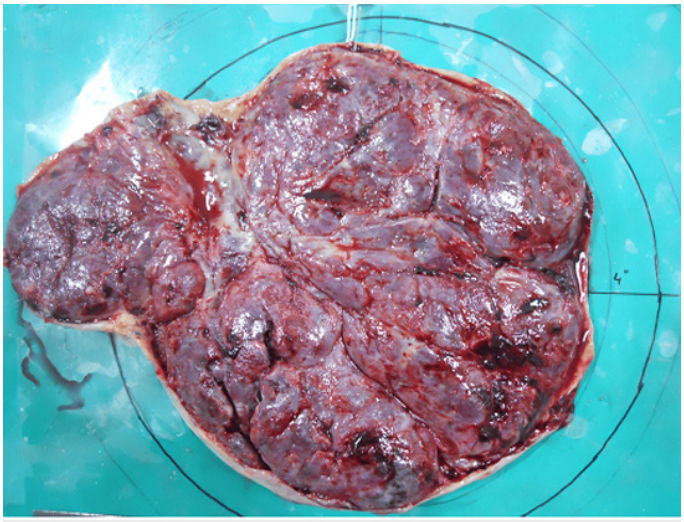


FIGURE3: Ovoid shape of placenta with Accessory lobe seen from maternal side

•**Expulsion:** Complete/ Incomplete.

•**Accessory lobes:** present /Absent (Figure 3).

•**Umbilical cord attachment:** The attachment of the umbilical cord was noted as either central, eccentric, marginal, or velamentous (Fig.1-4). The four circles were drawn on the transparency sheet with radii of 2 cm, 5 cm, 7.5 cm, and10cm (Figure4). The center of the placenta was marked as a point of intersection of the two axes perpendicular to each other. The insertion of the umbilical cord within a 2 cm area of the center of the placenta was classified as central insertion. The insertion of the umbilical cord within a region marked by a width of 3 cm from the placenta's peripheral margin was considered a marginal attachment. The cord insertion into the area between the central and the marginal regions was regarded as eccentric. The umbilical cord insertion on the membranes outside the disc margin is called velamentous insertion [7].

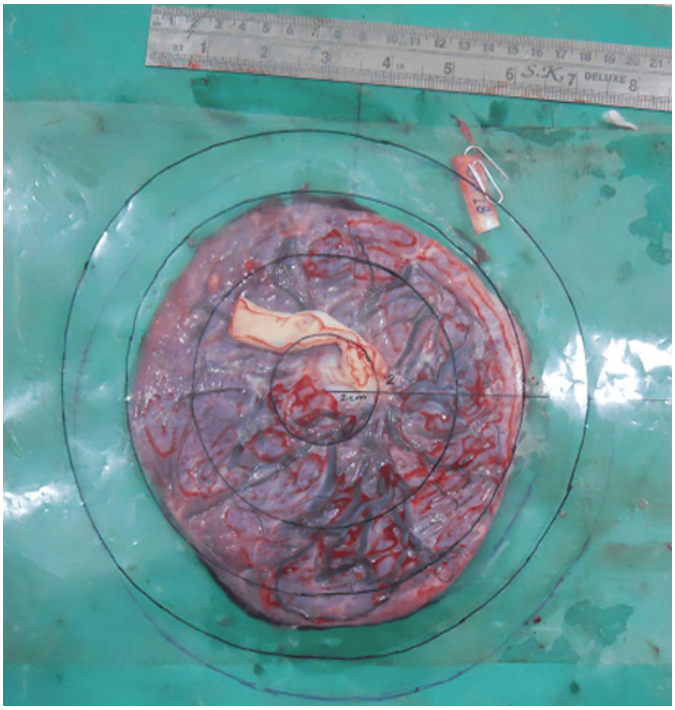


FIGURE4: Placenta (Ovoid shape) with central attachment of umbilical cord

Data analysis:

The data was entered into Microsoft Excel 2019 and checked for completeness before analysis. Statistical analysis was performed using IBM SPSS version 21. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as proportions. The student's t-test was applied to compare the means of two groups when the data followed a normal distribution; otherwise, the Mann-Whitney U test was used. The Chi-square test was employed to evaluate the association between glycemic control and placental morphology. A p-value of <0.05 was considered statistically significant.

Results

Analysis based on demographic and obstetric parameters:

Increased maternal age was observed to be associated with increased incidence of obesity but this association was not seen to be statistically significant.

The diagnosis of GDM was made for 45(56.25%), 25 (31.25%) and 10(12.5%) of the participants during the 3rd, 2nd and 1st trimesters respectively.

A statistically significant difference (p-value0.034*; chi- squarevalue4.501) in the gestation age at the time of delivery was noted between the study groups, with the lean GDM group having preterm deliveries more commonly (Table1).

Table1: The comparison of demographic characteristics among 3study groups

Characteristics	Control group	Lean GDM	Obese GDM	Statistics
	N=40 (%)	N=40 (%)	N=40 (%)	Pearson chi-square (p-value*)
Maternal age (years)				
a. 18-20	3 (42.9%)	2 (28.6%)	2 (28.6%)	0.837 (0.933)
b. 21-30	29 (33.7%)	29 (33.7%)	28 (32.6%)	
c. 31-40	8 (26.9%)	9 (34.6%)	10 (38.5%)	
GA at the time of delivery				
a. Term	38 (36.2%)	30 (28.6%)	37 (35.2%)	4.501 (0.034*)
b. Preterm	2 (13.3%)	10 (66.7%)	3 (20.0%)	

*(*The result is considered statistically significant at a p-valueof less than 0.05. GA- Gestational Age)*

Analysis based on placental morphology:

The weight of the placenta ranged from 205gm to 686.6gm. The ovoid was the commonly noted shape of the placenta in 56.7%, followed by irregular shape in 22.5% of the study groups. The accessory lobe was found only in the lean GDM group. The central and eccentric attachment of umbilical cord was seen in 30% and 45% respectively. None of these morphological findings were statistically significant among the groups **(Table 2).**

Table 2: The comparison of between placental morphology in 3study groups

Characteristics	Control Group	Lean GDM	Obese GDM	Statistics
	N=40 (%)	N=40 (%)	N=40 (%)	Pearson chi-square (p-value*)
Weight of placenta (grams)				
Min. (gm)	205	221.4	269	$F = 0.705^a$ $P = 0.496^a$
Max. (gm)	536.2	650	686.6	
Average (gm)	391.05 ± 75.725	399.17 ± 102.346	414.87 ± 93.433	
Shape of placenta				
a. Discoid	6 (40.0%)	4 (26.7%)	5 (33.3%)	6.987 (0.538)
b. Ovoid	26 (37.2%)	21 (30.0%)	23 (32.8%)	
c. Irregular	8 (29.6%)	11 (40.7%)	7 (29.6%)	
d. Incomplete	0 (0.0%)	2 (28.5%)	5 (71.5%)	
e. Accessory lobe	0 (0.0%)	2 (100%)	0 (0.0%)	
Umbilical cord insertion				
a. Central	13 (36.1%)	9 (25.0%)	14 (38.9%)	3.421 (0.754)
b. Eccentric	18 (33.3%)	19 (35.2%)	17 (31.5%)	
c. Marginal	8 (28.6%)	12 (42.9%)	8 (28.6%)	
d. Velamentous	1 (50.0%)	0 (0.0%)	1 (50.0%)	

*(*The result is considered statistically significant at a p-value of less than 0.05. Test statistics ANOVA[a])*

Analysis based on glycemic control status in GDM group:
The morphology of the GDM placentae among obese and lean was analyzed based on glycemic control during pregnancy. 41 participants had good control, while 39 had poor control. In the poor controlled group, 21 were lean GDM. A statistically significant association was found between the weight of the placenta and glycemic control (p value= 0.013), wherein the placental weight was higher in poor glycemic control participants. The irregular and incomplete types were commonly found with eccentric cord insertion in the poor glycemic participants **(Table 3).**

Table 3: Thecomparison of placental morphology in 3study groups

Characteristics	Good glycemic control	Poor glycemic control	Statistics
	(N=41) (%)	(N=39) (%)	Test Value (p-value)
Weight of placenta (grams)			
Ave. weight	389.24 ± 83.451	525.71 ± 108.67	964$(0.013*)
Shape of placenta			2.822^ (0.588)
a. Discoid	6 (60%)	4 (40%)	
b. Ovoid	24 (55.9%)	19 (44.1%)	
c. Irregular	8 (42.1%)	11 (57.9%)	
d. Incomplete	2 (28.6%)	5 (71.4%)	
e. Accessory lobe	1 (100.0%)	0 (0.0%)	
Umbilical cord insertion			1.639^ (0.651)
a. Central	12 (52.2%)	11 (47.8%)	
b. Eccentric	20 (55.6%)	16 (44.4%)	
c. Marginal	9 (45.0%)	11 (55.0%)	
d. Velamentous	0 (0.0%)	1 (100.0%)	

*(*The result is considered statistically significant at a p-value of less than 0.05. $ Mann-Whitney U test, ^ Pearson chi-square*

Discussion

Gestational diabetes mellitus (GDM) is a metabolic condition that develops during pregnancy, characterized by insulin resistance and glucose intolerance. Depending on the treatment approach, GDM can be classified into two types: diet-controlled, where management is achieved through nutrition alone without medication, and medication-managed, where glycemic control is maintained through medication [24]. The current study investigated the impact of BMI and blood sugar levels on the morphological characteristics of the placenta, including its shape and weight.

Both BMI and GDM have a combined effect on placental morphology, influencing pregnancy outcomes [25]. The findings of the study align with the previous studies which highlighted that as age and obesity increase, so does the incidence of gestational diabetes mellitus [5,21,25-26]. The preconception body mass index of pregnant women is alone a modifiable risk factor for development of GDM and is positively associated with fasting glucose levels at the time of GDM diagnosis [27].

It further affects the neonatal anthropometric parameters and perinatal pregnancy outcomes and is responsible for development of metabolic diseases in the offspring [28]. This is influenced by the changes in the socio-economic status as a result of education, rising interest in the career, use of artificial reproductive medicine, modern lifestyle leading to family planning and delayed childbirth. Moreover, the increased maternal age >32 years exerted an additive effect on the glucose challenge test in obese pregnant women [29,30]. The risk of unfavorable pregnancy outcome like preterm delivery increases three times when maternal age is more than 35 years [31-33].

Investigation of the macroscopic differences in placental characteristics between pregnant women with GDM found significantly increased placental weight in GDM pregnancies suggestive of a compensatory mechanism for impaired placental function [20]. Along with similar finding of increased placental weight, the centrally attached cord was commonly observed in GDM pregnancy followed by other types in differing frequencies. These findings were attributed to impaired placental function. These abnormalities, in turn, could contribute to less favourable perinatal outcomes, highlighting the impact of GDM on placental development and function [16].

A study conducted in 2016 found that approximately 25% of placentas in GDM-affected pregnancies showed increased weight and surface area. While significant differences in placental weight and size were observed between the control and GDM groups, it was suggested that the gross morphological changes in the placenta were only partially influenced by the patients' glycemic status [17]. Increase in diameter, weight with eccentrically attached cord in an irregular placenta as observed in obese GDM pregnancy suggested that these macroscopic changes in placental structure, especially in the context of obesity, may represent an adaptive response to enhance placental efficiency, though the degree of this response may vary [18].

Another study that noted eccentric cord attachment as the common morphological variation along with increased placental weight ascribed these effects to the likely overexpression of vascular endothelial growth factor in GDM pregnancies. This overexpression could lead to microscopic alterations in the placental structure, ultimately affecting placental function and contributing to the complications associated with GDM pregnancies (34). The GDM pregnancy showed increased BMI during pregnancy along with, placental weight, eccentric cord attachment and with an adverse perinatal outcome (35). Ehlers et al (2021) have concluded that disrupted placental structure is the outcome of GDM but have additionally queried for the other factors [36]. These study findings correlate with the present study.

In the present study, both GDM-affected obese & lean groups showed altered placental morphology compared to the control group pregnancies. These changes were pronounced in patients with poor glycaemic control showing the presence of more irregular and incomplete placentas. This emphasizes that the altered placental morphology in the poorly controlled state may be due to fetal macrosomia and to prevent hypoxemia in the fetus. Microscopically this can be attributed to overgrowth of parenchymal villous tissue, intervillous spaces and extra villous trophoblasts to increase feto-maternal exchange surface area [16,20,36].

In 2009, Salafia C, et al succeeded in proving the fetal-placental version of Kleiber's law which states that in diabetes, alteration in the development of branching pattern of placental villi/vasculature may lead to deformed placental shape. It is also evident from the abnormal attachment of the umbilical cord from where the villi/vascular tree develops. In other words, if the feto-placental ratio (measured as a ratio between fetal mass and placental weight) is low at birth, indicates poor fetal growth due to underlying placental pathology. This is because the energy generated from basal metabolism in the fetus passes through the placenta and that is reflected in the variable feto-placental ratio.

This support our study findings showing abnormal placental morphology in GDM patients, more in poorly controlled diabetes [37]. Insulin remains the preferred treatment for managing gestational diabetes, as confirmed by the present study [22,24,38]. The study results indicate that poor glycemic control adversely affects the placental morphology, potentially leading to unfavorable pregnancy outcomes [8,9].

Conclusion:

In pregnancies complicated by GDM, placental insufficiency can reduce the placenta's ability to supply nutrients and oxygen to the fetus. As a compensatory response, the placenta may increase in size to enhance its capacity to meet the metabolic demands of the growing fetus, helping to mitigate the effects of reduced efficiency. This finding aligns with other research suggesting that placental hypertrophy in GDM pregnancies may be an adaptive response to overcome the functional challenges posed by the altered maternal metabolic state.

Limitation: In the present study, the effects of poor glycaemic control on the pregnancy outcome had not been studied. We recommend investigating such GDM mothers and comparing the results with normal healthy pregnancies.

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